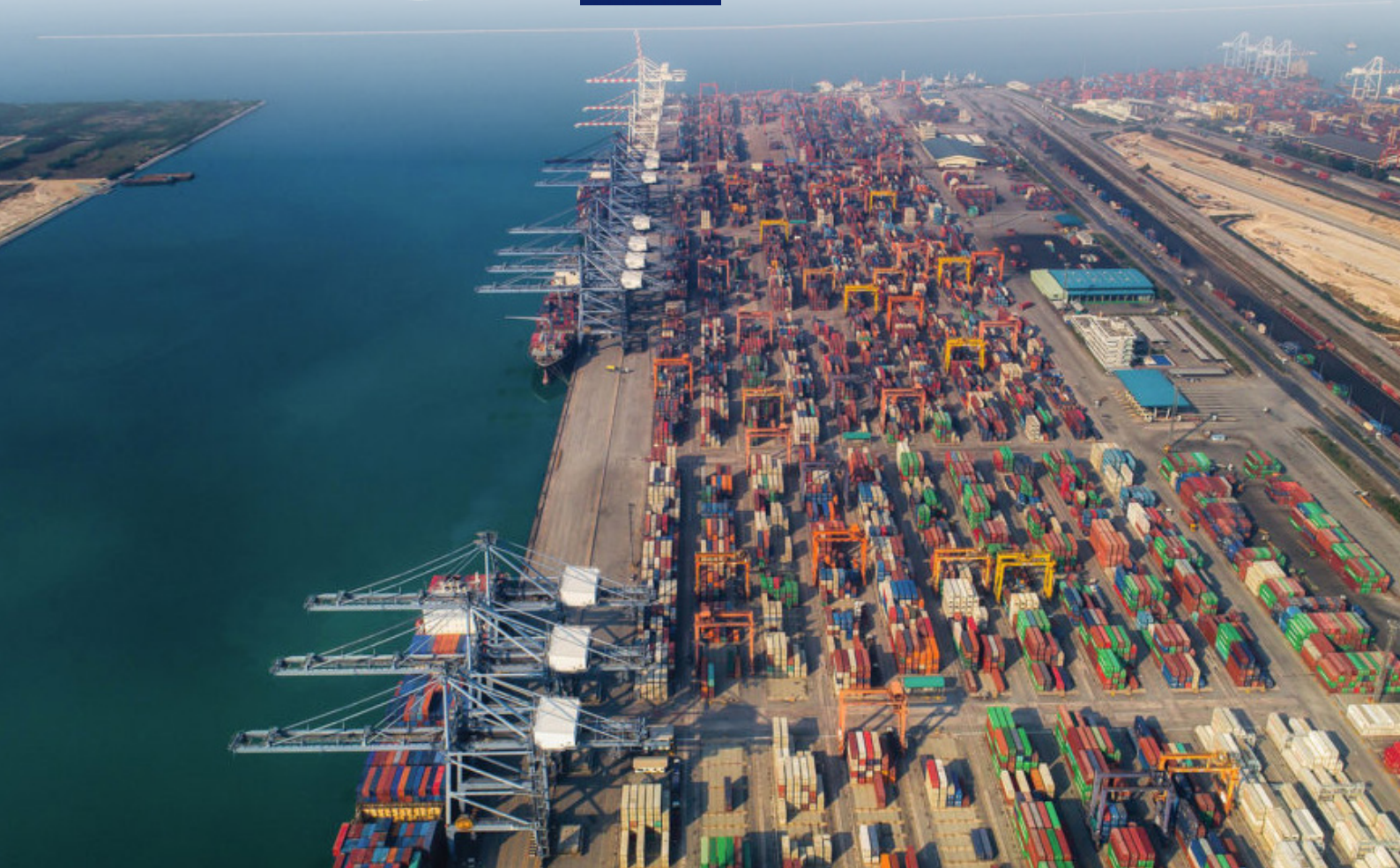


SEA OF THE RAYONG PROVINCIAL DEVELOPMENT PLAN - BASELINE ASSESSMENT

ADB TA-9204 THA: Strategic Environmental Assessment of the Rayong Provincial
Development Plan and Revision of the Draft Thai SEA Guidelines

August 2019



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Disclaimer

This document was prepared for Thailand's National Economic and Social Development Council (NESDC), the Rayong Provincial Governor's Office, and the Asian Development Bank (ADB) by an ICEM team engaged to undertake the technical assistance project TA 9204-THA Phase 2: Strategic Environmental Assessment (SEA) of the Rayong Provincial Development Plan, and Revision of the Draft SEA Guidelines. The views, conclusions and recommendations in the document are not to be taken to represent the views of NESDC and ADB.

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ABBREVIATIONS

ADB	Asian Development Bank	IUU	Illegal, unreported and unregulated
AEDP	Alternative Energy Development Plan	KMUTT	King Mongkut's University of Technology Thonburi
ALRO	Agricultural Land Reform Office	LNG	Liquid natural gas
AR5	Fifth assessment report	MCM	Million cubic meters
As	Arsenic	MCM	Water use
ASEAN	Association of Southeast Asian Nations	Mn	Manganese
BAU	Business-as-usual	MSL	Mean sea level
bcm	billion cubic metres	MSW	Municipal solid waste
Biotec	National Centre for Genetic Engineering and Biotechnology	MW	Megawatt
BOD	Biochemical oxygen demand	NPOA-IUU	National Plan of Action to Prevent, Deter and Eliminate IUU Fishing
CCMP	Climate Change Master Plan	NEB	National Environment Board
CDS	National Committee for Sustainable Development	NESDC	National Economic and Social Development Council
CHP	Combined Heat and Power	NH4+	Ammonia
DNP	Department of National Parks, Wildlife and Plant Conservation	NO ₃ -	Nitrate
DO	Dissolved oxygen	NOx	Mono-nitrogen oxides NO and NO ₂ (nitric oxide and nitrogen dioxide)
DWT	Deadweight tonnage	NOx	Nitrogen oxides
EC	Electrical conductivity	NSTDA	National Science and Technology Development Agency
EEC	Eastern Economic Corridor	O&M	Operation & Maintenance
EECO	Eastern Economic Corridor Office of Thailand	ONEP	Office of Natural Resources and Environment Policy and Planning
EEPSA	Economy and Environment Program for Southeast Asia	Pb	Lead
EFCOM	Eastern Forest Complex	PCD	Pollution Control Department
ESB	Eastern seaboard	PDP	Power Development Plan
ESDP	Eastern Seaboard Development Plan	PEA	Provincial electricity authority
EU	European Union	PES	Payment for ecosystem services
FCB	Faecal coliform bacteria	PM	Particulate matter
Fe	Iron	PM ₁₀	Particulate matter 10
FMP	Fisheries Management Plan	PM _{2.5}	Particulate matter 2.5
GCMs	Global Climate Models	PO ₄ ³⁻	Phosphate
GDP	Gross domestic product	POPs	Persistent organic pollutants
GHG	Greenhouse gas	PTT	Petroleum Authority of Thailand Public Company Limited
GIS	Geographic information system	PTTGC	Petroleum Authority of Thailand, Global Chemical
GPP	Gross provincial production	PWA	Provincial Waterworks Authority
GPSC	Global Power Synergy Public Company Limited	RBCs	River Basin Committees
ha	Hectare	RCPs	Representative Concentration Pathways
HA	Hospital Accreditation	R&D	Research and Development
HAII	Hydro and Agro Informatics Institute	REO	Regional Environmental Office
Hg	Mercury	RID	Royal Irrigation Department
ICEM	International Centre for Environmental Management	RPDP	Rayong Provincial Development Plan
IE	Industrial estate	RPAO	Rayong Provincial Administration Office
IEAT	Industrial Estate Authority of Thailand		
IPCC	Intergovernmental Panel on Climate Change		
ITOPF	International Tanker Owners Pollution Federation		

RTG	Royal Thai Government
SEA	Strategic Environmental Assessment
SEARCH	Suphattraland Excellent Agriculture Research Centre Hub
SEP	Sufficiency economy philosophy
SO ₂	Sulphur Dioxide
SO _x	Sulfur oxides
SPP	Small power producer
TAO	Tambon administrative organization
TAT	Tourism Authority of Thailand
TCB	Total coliform bacteria
TDS	Total dissolved solid
TEU	Twenty-foot equivalent unit
THB	Thai Baht
UNIDO	United Nations Industrial Development Organization
USD	United States Dollar
VOCs	Volatile Organic Compounds
WHO	World Health Organization
3Rs	Reduce, reuse and recycle

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SUMMARY

1. Background

The Asian Development Bank (ADB) funded *TA-9204 THA Phase 2: Strategic Environmental Assessment (SEA) of Rayong Provincial Development Plan and Revision of the Thai Draft SEA Guidelines* demonstrates the use of SEA as a key strategic planning tool in provincial development planning. The pilot SEA informs review and completion of the draft SEA guidelines prepared by the Thai National Subcommittee on SEA convened under the National Committee for Sustainable Development (CDS) with technical support from the National Economic and Social Development Council (NESDC).

Under the first of these goals, a pilot SEA is being conducted into the Rayong Provincial Development Plan to demonstrate good practice for sector, area wide and provincial SEAs. The experience in implementing the pilot SEA, carried out with NESDC and the Rayong Provincial Governor's Office, provides the basis for proposing improvements to the draft SEA guidelines.

The pilot SEA addresses environmental and socio-economic issues within Rayong Province and the contiguous coastal and marine environment as well as upstream influences of development in Rayong's two river basins – the Klong Yai

and Pra Sae. The SEA recognises the challenges in provincial, river basin and coastal development, including rapid industrial expansion and population growth, constraints in water resources, and concerns over environmental quality and pollution.

The pilot SEA focuses specifically on the current four year Rayong Provincial Development Plan (RPDP) which will be revised for the next five year development planning period 2022-2026. Rayong Province is within the Eastern Economic Corridor (EEC), an area encompassing the three eastern provinces of Chachoengsao, Chonburi, and Rayong which since the mid-1980s have been promoted as strategic areas for industrial growth and production. Under the EEC Development Plan, approved by the Thai National Legislative Assembly in February 2018, these provinces will be the focus of accelerated economic growth, including new industrial areas, new urban centres, expansion of ports and airports and new railway lines toward the goal of developing the region as an arterial hub for trade, investment and regional transportation (Figure 1-1). The Rayong Provincial Development Plan and its associated spatial plan is evolving to integrate EEC plan infrastructure priorities and development zoning objectives. The SEA – a cross-sector integrated spatial and economic planning initiative, seeks to enhance the ecological sustainability and social equity of the RPDP.

Figure 1-1: The Eastern Economic Corridor and Rayong province in relation to Bangkok

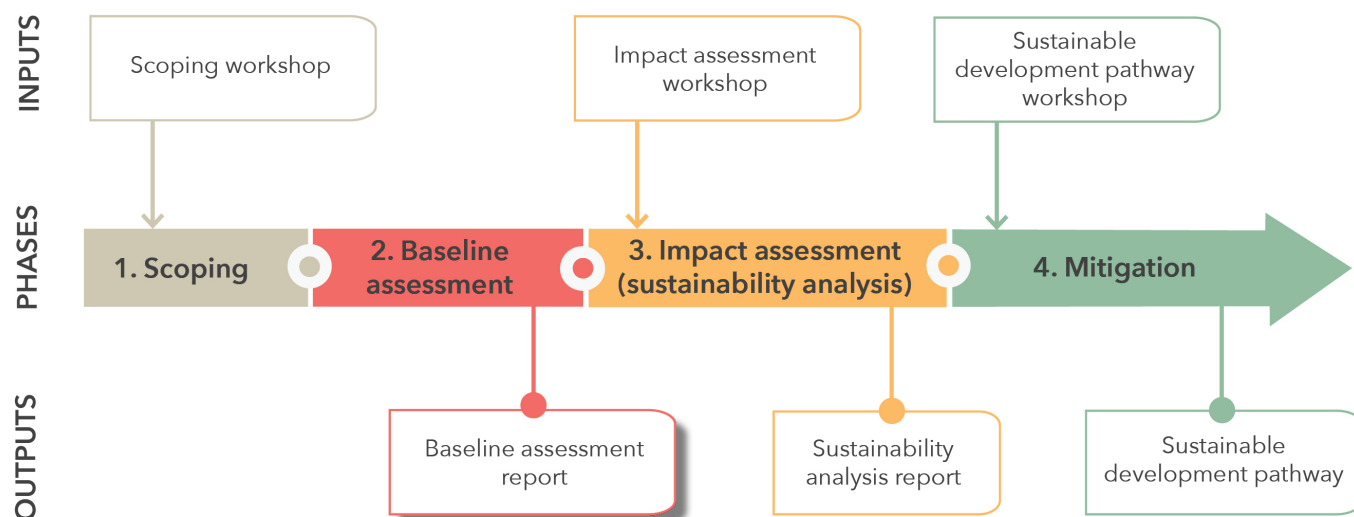


Source: <https://www.straitstimes.com/asia/se-asia/thai-junta-aims-to-make-eastern-economic-hub-its-legacy>

2. The SEA process

This Baseline assessment establishes the foundation and evidence base of the SEA. The phases of the pilot SEA are described in Figure 1-2.

Figure 1-2: Phases of the pilot SEA



Source: ICEM 2019

This pilot SEA addresses socio-economic and environmental implications of existing and planned development within the province, the linked river basins, as well as the adjacent coastal and marine environment.

The SEA:

- ✓ Considers the variety of national, regional and sector plans that influence and shape development in Rayong Province, but with a focus on the Rayong Provincial Development Plan;
- ✓ Takes an integrated approach to assessing the sustainability of development, by examining relationships between key economic sectors including industry, transport, energy, water, tourism, agriculture, and fisheries;
- ✓ Applies spatial planning tools and processes to analyze natural resource availability and usage. Natural resources analyzed included water and land resources, forests and the marine environment, as well as petroleum resources. The spatial analysis integrated climate change impacts;
- ✓ Takes an ecosystems-based approach to assess development implications for natural systems and environmental quality; and,
- ✓ Analyses demographic and socio-economic trends and impacts, which are both influencing and being shaped by, development plans and population increases.

1. Scoping

The scoping phase sets the spatial, temporal, and substantive boundaries of the SEA. The spatial focus of the project determines the geographical boundaries of the SEA – in this case Rayong Province. In determining geographical scope it is also important to recognize areas outside the province which have significant influence within it. This includes the consideration of development activities in the entire Khlong Yai and Prasae River Basins, as well as in the provincial cluster of Rayong, Chonburi, and Chachoengsao provinces. The temporal scope of the SEA incorporates both historical trends and future perspectives, for example to 2050 for climate change.

The scoping process also identifies strategic issues of most concern to sustainable development in Rayong Province. Those issues are grouped in strategic themes which are linked with sustainable development objectives and indicators. The involvement of stakeholders in defining the SEA scope is especially important for the credibility and authority of the process. The scoping phase included the scoping workshop held in Rayong on the 10th and 11th of June, 2019 (Figure 1-2), as well as several round table meetings held at national and provincial levels.

Through these round table meetings, the project team worked closely with NESDC and representatives from Rayong Provincial Government to confirm work plans including the SEA methodology and tools to be used. During the scoping

phase the nature and extent of stakeholder involvement for the remainder of the project was defined, through development of a **Consultation and Communications Plan**.

This plan:

- outlines the stakeholder consultation and communication activities for each step of the SEA,
- identifies key stakeholder groups, and
- identifies necessary resources and length of time needed to achieve effective participation in each stage of the process.

2. Baseline assessment

The baseline assessment describes past trends and status of the strategic themes and issues identified during the scoping phase. They include economic activities, demographics and social issues, and environmental and natural resource issues of concern to development in Rayong Province. The baseline assessment also includes projected climate change and documentation of past extreme natural events such as flooding, droughts, landslides, coastal erosion and subsidence, and the impacts of these events on communities, infrastructure, and natural resources.

The baseline assessment phase is concerned with the collection and analysis of data related to the strategic themes and issues. It establishes the evidence base for the entire SEA. It can be the most demanding and time consuming of phases in the assessment because information may not be readily accessible, is widely dispersed and often inaccurate and inconsistent. Data is derived from national and provincial agencies and international organizations and needs to be cross checked and validated with stakeholders.

Stakeholder consultations form a critical part of the baseline assessment. Consultation meetings have been held with key stakeholders in Rayong Province, including from the Governor's Office, Provincial Office of Natural Resources and Environment, Rayong Provincial Energy Authority, Rayong Royal Irrigation Department, East Water, Provincial Office of Industry, and the Provincial Office of Town and Country Planning, among others. These stakeholder meetings are key to developing an understanding of the strategic issues, as well as their trends and drivers of change. A core output of the stakeholder consultations was the identification of the 13 strategic themes and associated issues for this SEA. The 13 strategic themes provide the focus of the baseline assessment. The thirteen themes are:

1. Macro-economics
2. Social issues and demographics
3. Energy
4. Industry
5. Transport
6. Urban development
7. Water resources
8. Agriculture
9. Tourism
10. Coastal and marine environment
11. Terrestrial biodiversity
12. Environmental quality
13. Climate change

Within each theme, stakeholders identified strategic issues of particular concern to development and well being in Rayong Province. The baseline assessment describes each strategic theme, and the strategic issues through **trend analysis**. The trend analysis covers (i) historic trends as well as the drivers of those trends; (ii) current status; and (iii) expected future trends based on historic and projected drivers.

To use a trend analysis approach, the SEA team first worked with stakeholders to distill two or three issues of strategic importance for each of the thirteen themes. Once the strategically important issues were identified, historical data was collected and analyzed to determine the trends in the issues and the factors which have shaped those trends.

For example, one of the strategic issues identified for the energy sector is decentralized power generation in the province, because this has had a large impact on how industrial development has evolved in Rayong. Analysis of historical data shows that the first decentralized power plants in Rayong were commissioned in the 1980s, and that now there are more than twenty decentralized plants supplying power to provincial industrial estates. The factors driving this growth in decentralized power were government policies aimed at ensuring power security in an environment where consumers were plagued with power cuts. Today, decentralized power continues to be promoted by government because it offers advantages such as cogeneration of hot and cold water for industry, relationships with power suppliers, and lower requirement for public investment.

Following the analysis of historical trends in the strategic issues, and the drivers for these trends, the trends are projected into the future, and likely changes in the drivers assessed.

This baseline report includes full chapters on each of the thirteen themes. A summary of the baseline assessments for each of the thirteen themes is provided in this introductory section.

Summary of baseline assessments

1. Macroeconomic development in Rayong

Strategic issues of critical concern:

- Rapid economic growth and structural change
- Distribution of benefits of Rayong's economic growth

Sustainable Development Objectives

- Ensuring the sustainable development of the economy
- Ensuring equitable distribution of economic benefits including long term support to vulnerable effected groups and areas

Since the late 1980s, Rayong has experienced extensive structural changes and rapid economic growth. Over that time, Rayong's economy has shifted strongly away from the agricultural sector to capital intensive heavy industry. This shift was driven by government policies to move manufacturing and industry out of Bangkok, as well as by the natural gas fields discovered in the Gulf of Thailand.

Compared with the country as a whole, Rayong has a

proportionally heavy reliance on the gas sector as well as power generation, petrochemicals and oil refining. There has been growth in tourism since Rayong's structural shifts began, however the percentage of the economy tied up in the services sector as a whole has declined. Services in Rayong form a much smaller share of the value-added economy than they do nationally.

The move away from agriculture has led to some resource conflicts. For example, industry is a heavy user of water, which is impacting on the agricultural sector. The economic growth in the province has also attracted large numbers of migrants, including many unregistered migrants. Unregistered migrants pose a problem for the province because funding for services such as municipal amenities, health and education facilities are allocated from the center based on official population statistics.

2. Social Issues and Demographics

Strategic issues of critical concern:

- Registered and unregistered population growth
- Availability of infrastructure and services
- Growing socio-economic inequality

Sustainable Development Objective:

- Strengthen community resilience and inclusive development based on the sufficiency economy philosophy and environmental sustainability

One of the most striking trends in Rayong is that since 1993 the population in municipal areas has grown from 20% to 49% of the province's population. While the urban population has grown significantly over this period, the rural population has remained static. This links to work related immigration into the province and moves of younger members of farming families to live and work in urban areas.

Rayong is an attractive destination for those looking for work, and has a high migrant population. Most registered migrants come from other countries, including low-skilled workers from Cambodia, Laos and Myanmar, who provide agricultural and other labour, and high skilled workers from countries like Japan, the Philippines and Germany. Unregistered migrants come mainly from other Thai provinces. That means that Rayong is not receiving the full per capita budget allocations from national government to provide the needed services and infrastructure for the growing population. This may explain issues like the low rate of physicians and the worsening rate of hospital beds per capita in Rayong. These issues underpin a provincial society that is becoming more disparate over time, heightening the potential for unrest in the province.

In addition to issues associated with unregistered migration, keeping up with rapid socio-economic changes is challenging in Rayong because of a growing centralization in financial allocations. For example, Rayong's budget allocations doubled between 2015 and 2018, however the provincial administration budget over the same period grew by only 20%. The remainder was allocated to nationally administered agencies operating in Rayong. Centralized governance makes it difficult for local government to respond to issues on the ground.

3. Energy

Strategic issues of critical concern:

- Continued growth of decentralized power generation
- Rayong as a strategic energy hub for Thailand
- Environmental consequences of energy sector development

Sustainable development objectives:

- Promotion of renewables and energy efficient generation technologies
- Affordability of energy supply to residents and businesses in the province
- Reduce pollution emissions from energy supply to meet ambient and point source air quality standards and GHG emissions reductions targets

The energy sector sustainable development objectives focus on distributed power generation, ensuring affordable energy supply and reduction in pollution emissions. Rayong is now Thailand's main energy hub, mainly due to the natural gas discovered in the Gulf of Thailand. All of Thailand's liquid national gas receiving capacity is in Rayong. Most of Thailand's natural gas comes ashore in the province, and there are significant coal and oil receiving capabilities at Map Ta Phut port. The province hosts over half of Thailand's oil refining capacity, and a quarter of Thailand's electricity is produced there.

The easy access to natural gas in Rayong was consolidated through national government policies and strategies designed to: (i) decentralise development efforts out of Bangkok, and reduce pollution in the capital; and (ii) ensure security of energy supply by promoting decentralized power generation.

There is now significant momentum in Rayong to continue as an energy hub for the country, despite the likelihood of natural gas resources in the Gulf of Thailand being depleted before 2030. For example, Map Ta Phut port area is currently being extended by 160 hectares in order to increase its ability to receive LNG imports. Thus, Rayong's energy sector will continue to grow into the foreseeable future.

4. Industry

Strategic issues of critical concern:

- Rapid industrial growth
- Increased generation of industrial pollution
- Resource use in industry

Sustainable development objectives:

- Environmentally sustainable development through the promotion of green industries using cleaner production technologies and resource efficient production
- Use of best international practice in environmental technologies and management to prevent and moderate the discharge of industrial pollutants to water, air and land
- Structural transformation increasing the capacity of local industry for value-addition, diversification, job creation and production in high-tech sectors

The industrial sector sustainable development objectives focus on promotion of green industry, use of up to date technology and structural transformations within the sector. While the land area of Rayong is still predominantly rural, industry now constitutes the bulk of Rayong's economy. The growth of industry in Rayong over the last two decades was driven by government policies and incentives that came on the back of natural gas discoveries as well as proximity to growing markets nearby.

While industrial growth has resulted in Rayong having the highest per capita gross provincial product in the country, it has been accompanied by significant environmental costs. Air quality is poor, particularly near industrial zones where municipal authorities receive complaints on a daily basis about odors and health issues. Industrial solid waste is a large problem, with the province producing over 1 million tons of industrial waste per annum, of which a third is hazardous waste produced at Map Ta Phut and in plants within and outside other industrial estates. Water pollution is also a significant issue, with volatile organic compounds found in ground water and surface water around the monitored pollution control zone at Map Ta Phut. Pollution around other industrial areas is concerning, but figures are hard to come by as they have not been declared pollution control zones and so are not monitored.

Finally, industrial resource usage is growing. The sector is using increasing quantities of water, which puts pressure on other areas including agriculture. Industrial estates in Rayong cover around 8,000 hectares of land, with a further 2,000 industrial enterprises operating outside of these estates, including the IRPC oil refinery located a few kilometers east of Rayong City.

5. Transport

Strategic issues of critical concern:

- Expansion of transport infrastructure
- Increasing air pollution due to increased transportation

Sustainable development objectives:

- Promote an equitable and safe transportation system, offering a choice of transport modes, and a geographical balance of development
- Reduce transportation related emissions and resource use

The transport related sustainable development objectives are focused on affordable and efficient transport systems, reductions in transport related emissions and safety issues. The main transport corridors in Rayong are in the west of the province, connecting it to Pattaya, Laem Chabang, Bangkok and Sattahip. In addition to these road corridors, Map Ta Phut port has the capacity to receive around 15,000 tankers and cargo ships annually, and U-tapao airport is receiving a growing number of airplanes each year. With increasing industry and population, it is not surprising that transport infrastructure and stock in Rayong and between Rayong and neighbouring areas is expanding. The transport sector has also increased as a result of over 7 million tourists (mostly domestic) who come to Rayong each year. U-tapao airport is scheduled for significant upgrades under the EEC development plan, which will see capacity of the terminal grow in coming years.

Despite there being efforts to stem the growth in road traffic by upgrading existing rail networks and adding a high speed rail link, transport impacts on the environment will continue to increase in Rayong. Air pollution will come from road transport, shipping and aircraft. Car and truck maintenance means significant quantities of oil and other waste products are produced, and much of this will not be disposed of correctly if current practice continues.

6. Urban development

Strategic issues of critical concern:

- Urban expansion
- Waste management (solid and liquid)

Sustainable development objectives:

- Urban areas are planned for energy and water conservation, transit oriented design and equity, emphasizing green infrastructure and nature based approaches
- Pollution and waste streams in urban areas are effectively managed, creating a pollution free environment

The urban sustainable development objectives focus on attractive, livable urban areas that have effective waste management systems. Urban population growth in Rayong between 1980 and 2019 was rapid. This was driven largely by migrant population growth as job-seekers moved to the province. Job-seekers were predominantly looking for work in the industrial sector, although there are many low-skilled international migrants working in the agriculture sector, for example, in rubber tapping. In addition to registered migrants, many workers in Rayong have never registered their move from other provinces, indicating that urban population growth is significantly higher than official figures would suggest.

Accompanying the population growth, urban areas of Rayong have expanded by 40% in the past 12 years, from 26,000 hectares in 2006 to 36,000 hectares in 2018. The urban population has more than doubled in the same period, increasing density, and reducing green space, public health and amenity. Those issues are of particular concern in light of the poor record of domestic waste-water treatment in the province.

Rayong is producing more solid municipal waste, despite national programs aimed at encouraging re-use, recycling and reduction in production of waste (the 3Rs program). There have been attempts at source separation of waste in Rayong, but so far these have met with limited success. And with reported inadequate management of the central waste-transfer facilities, separation of waste is too slow, and is accumulating, while landfill sites are nearing capacity.

7. Water resources

Strategic issues of critical concern:

- Water demand and supply
- Water quality (surface and ground water)

Sustainable development objective:

- Rehabilitate and manage river basins and water resources for ecological sustainability and

environmental quality

- Provide a secure supply of clean water that meets demand in each sector within ecological limits without causing conflict between different user groups or with neighbouring provinces.
- Use water efficiently and equitably to eliminate wastage and reduce demand

Rayong has two main river systems - Khlong Yai and Prasae rivers - and including canals has 170 waterways. The province has 2 large reservoirs, 3 medium size reservoirs and 10 small reservoirs with a combined storage capacity of 600 million cubic metres. There is a total inflow of 652 million cubic metres of water into Rayong's reservoirs each year. East Water, the company that supplies most water to industry is projecting that, over the next 20 years, industrial water demand will increase by 38% from the current 350 million cubic metres to around 560 million cubic metres in 2036.

In addition to industrial demand for water, there is significant demand from agriculture, as well as for commercial and domestic consumption. Water supply disruptions in the province are not unknown, and some residents having spent days at a time with no water.

There are growing concerns about increasing waste-water volume from industrial and domestic sources passing direct to the environment without treatment in Rayong. Together the three domestic waste-water treatment plants in Rayong are operating at 5% capacity, and provincial administrations are wary of taking ownership of them because of concerns about design, maintenance and operating costs. There is a lack of connectivity of houses to the sewer systems, and where houses do have septic systems they often do not function correctly. As a result most waste-water goes untreated directly into Rayong's waterways. In addition to organic pollutants from domestic waste-water, water quality in Rayong is impacted by industrial effluent which is becoming increasingly hazardous. For example, groundwater in some areas shows elevated concentrations of heavy metals and volatile organic compounds that are typically associated with industrial activities.

8. Agriculture

Strategic issues of critical concern:

- Transformation of the agriculture sector, including land-use change and shortage of agricultural labour
- Securing water supply for crop production

Sustainable development objectives:

- Modernize the sector to international standards through sustainable production models for small-holders and commercial agriculture
- Farmers reduce environmental pollution, adopt sustainable land management practices and enhance biodiversity
- Farmers build resilience to climate change through diversity in production and nature based solutions

Farmland area in Rayong is steadily decreasing, with more land being converted into residential and industrial use. Consequently, demand for and the price of agricultural land is increasing.

The demographics of farming is changing as well, with younger members of farming families looking for work in urban areas, and the agricultural sector becoming increasingly reliant on migrants, such as rubber tappers from Cambodia. There is growing conflict between those that view Rayong as an "industrial" province and those who wish to retain a flourishing agricultural sector and heritage.

Water conflicts are increasing between farmers and users from other sectors, with those representing the agriculture sector arguing they are receiving an inadequate proportion of a decreasing resource. Expanding industry and urban services is impacting on water availability both directly and because of a growing population of migrant workers in industry.

9. Tourism

Strategic issues of critical concern:

- Growth in tourist numbers and facilities
- Environmental impact of tourism facilities
- Marine and coastal debris and pollution, especially plastics and petroleum products, threaten tourism

Sustainable development objectives:

- Promote ecological, community and agricultural tourism
- Ensure that tourism related solid waste and waste-water is treated properly

The tourism sustainable development objectives focus on sustainable tourism including ecological, community-based and agricultural tourism. Rayong is the seventh most popular tourist destination in Thailand by number of visitors, over 80% of whom are domestic tourists. The major tourism related concerns are waste management as well as air and water quality. Tourism contributes to the broader domestic waste-water problems, because smaller hotels in Rayong are not required to treat their own waste-water. Some hotels have opted to have multiple receptions so each block falls below the size threshold for full treatment facilities. In a province where municipal treatment of waste-water is already very poor, this adds to the negative impact on water quality.

The tourism sector also uses significant water. Tourists tend to be less conscious of water usage than they would be at home. Over 7 million visitors each year, each staying for an average of 2 days, leads to about 2.5 million cubic metres of water usage annually, and about 2 million cubic metres of waste-water generated.

There are other factors that may affect Rayong's development as a major tourist destination. Rayong's beaches often suffer from plastic and other marine debris. Similarly, Rayong's air has elevated levels of volatile organic compounds, particulate matter and other air pollutants which discourage tourists seeking relief from Bangkok conditions as do incidents of industrial pollution accidents and illegal dumping of hazardous wastes.

10. Coastal and marine environment

Strategic issues of critical concern:

- Unsustainable fishing practices

- Poor management of solid wastes and effluent discharges
- Limited environmental monitoring and reporting to support effective evidence-based management

Sustainable development objectives:

- Sustainably use marine and coastal resources
- Restoration, enhancement and protection of marine and coastal ecosystems and resources

The coastal and marine environment sustainable development objectives focus on conservation of marine and terrestrial natural resources as well as hazardous waste management.

The coastline of Rayong province extends for approximately 100 km, including a variety of important ecosystems, such as mangrove wetlands, coral reefs, seagrasses, as well as endangered species such as turtles and dolphins. Fisheries in Rayong are mainly marine capture fisheries and experiencing a steady decline in yield because of over-fishing.

Coastal pollution is a problem, with oil slicks recorded regularly, high nutrient levels associated with algal blooms along the coast, as well as discarded fishing gear and garbage. These pollution problems impact on the sensitive marine ecosystems, threatened species and the fishing industry. Despite this, monitoring of coastal waters is only undertaken twice a year, which makes it difficult to track pollution levels by season or to establish long-term trends.

11. Terrestrial biodiversity

Strategic issues of critical concern:

- Fragmentation of forests
- Very low forest cover

Sustainable development objective:

- Conserve, restore and enhance biodiversity in Rayong
- Increased forest cover throughout the province with a target to contribute to the national goal of 40% forest cover.

Forest cover in Rayong is very low and declining slowly, despite commercial logging being banned in Thailand's forests from 1989 onwards. The National Forest Reserve land is larger than the forested area of Rayong, and may provide opportunities for re-forestation. Most of the remaining forest is in Khao Chamao District and the islands off Meuang and Klaeng Districts. Small patches of National Reserve Forest scattered in other parts of the province are being managed as community forest.

Known endangered and endemic species of Rayong Province are found in these protected areas, where they have the best chances of survival. Wildlife poaching and illegal logging do not appear to be major issues, and forest encroachment is negligible. Despite their small area, Rayong forests are connected to large areas of Thailand's forests, extending into Cambodia's Cardamom mountain areas. This connectivity makes Rayong's forests part of an important national and international network of biodiversity corridors.

Human-elephant conflict is a growing issue, especially in the

area of mixed patches of forest and agricultural land in the landscape connecting Khao Chamao with Khao Ang Rue Nai. In these places, communities spend nights guarding their croplands to prevent raiding by elephants. Traffic accidents involving elephants are also increasing.

12. Environmental quality

Strategic issues of critical concern:

- Hazardous waste
- Solid waste
- Water quality
- Air Quality (emissions from transport and industry)

Sustainable development objectives:

- Establish effective measures for the prevention, control and abatement of water pollution
- Hazardous wastes from industry, domestic and agricultural sources are identified, minimized and disposed without negative environmental impacts
- Replace open dumping sites and improper treatments with sanitary landfills, incineration and waste to energy and recycling schemes
- Establish and enforce point source air pollution standards, especially relating to the industry, energy and transport sectors.

The environmental quality sustainable development objectives focus on improving water quality, enhancing waste-management and controlling point source pollutants. Rayong's is a major and growing energy and industrial hub, supported by a large and growing transport network. Rayong also maintains extensive agricultural activity.

The industry, energy and transport sectors all emit pollution to air, water and land. Domestic, industry and agricultural activities all consume and contaminate water. Poorly planned and managed development of the coastal zone has resulted in multiple point source pollution and localised water quality problems. Pollution in the Rayong River has reached critical levels due to inflows from domestic sources, from agriculture and aquaculture, as well as from localised industrial sources. Reservoirs supply water to industry, to urban centres and to agriculture. Some of these suffer serious algal blooms as well as problems with upstream pollution from factories and sedimentation.

In terms of solid and hazardous waste, landfill sites have reached capacity and an increasing accumulation of hazardous wastes remain untreated. Some sources of pollution remain largely unrecognised and unmanaged such as expanding shipping, thermal discharges and decommissioned factories.

13. Climate change

Strategic issues of critical concern:

- Increased temperature and reduced rainfall in dry season leading to increased drought conditions
- Increased flooding in wet season due to (i) increased intensity of rainfall and storm surge, and (ii) sea level rise
- Increased number of hot days
- Increased intensity of storms and winds

Sustainable development objective

- Enhance capacities to adapt to climate change
- Rayong Province, the EEC and sector agencies operating in Rayong prepare climate change adaptation plans and allocate budget for their implementation

Over the past 70 years, Rayong province has experienced increases in average temperatures and reductions in average rainfall, but with a higher incidence of extreme rainfall events leading to a more frequent floods and longer drought periods. Over the past 25 years the rates of sea level rise in Thailand (4-6mm/yr) have been higher than the global average which when combined with localized subsidence has created extensive areas at risk of erosion and flooding.

Climate changes projections to 2050 indicated that Rayong province will experience less rainfall during both the dry and wet seasons and increased temperatures in both seasons. The more extreme RCP 8.5 has rainfall increasing in the wet season and as the time slice moves closer to 2070. Those changes will bring increased likelihood of more intense droughts but with rainfall coming in more intense events. With higher average temperatures and warmer air that can hold more water, a pattern might emerge of lengthy dry spells interspersed with brief but heavy rainfall and possible flooding.

3. Impact assessment (sustainability analysis)

Following this baseline assessment, the next stage of the SEA is the impact assessment (or sustainability analysis), in which BAU scenarios for the different themes are compared with scenarios that include the full implementation of the current Rayong Provincial Development Plan. This comparison will facilitate analysis of where the RPDP is contributing to enhanced sustainability outcomes in Rayong, where it may be undermining sustainability outcomes, where there are sustainability gaps, and where the RPDP has unrealized potential to address environmental and sustainability issues. In order for the SEA to be comprehensive, the impact analysis of the RPDP also considers other factors that influence sustainability issues, but over which Rayong provincial authorities have little control such as major sector and EEC development plans.

4. Mitigation

The impact assessment is followed by the definition of sustainability pathways, which provide a framework and recommendations for changes to be considered during the upcoming mid-term review of the RPDP (2018 – 2022), as well as important sustainability inputs to the next RPDP (2022-2025).

3. Conclusion

This baseline report is the initial substantive output of the SEA of the Rayong Provincial Development Plan (RPDP). The baseline report is the foundation for the later stages of the SEA – impact assessment and the definition of the sustainable development pathway. It includes detailed background information as well as trend analyses for each of the 13 themes included in the SEA analysis.

Key points that have come from the baseline assessment include:

- ✓ Over the last 25 years Rayong has experienced a profound structural shift from an agrarian based society and economy to an industrialized economy with half the population now living in urban areas.
- ✓ Rayong's structural changes have been driven by access to natural resources, combined with government strategies to decentralise the industrial and economic sectors and establish the province as an energy and industrial hub.
- ✓ Those structural changes have lifted Rayong's average per capita income to the highest level of any of Thailand's provinces.
- ✓ Yet, many community members feel that economic growth has come at the cost of quality of life and of local culture and heritage. The development sectors have brought with them (i) increasing air pollution and solid waste and waste-water management challenges, (ii) friction between the agricultural, industrial and residential sectors regarding water allocations and land use, (iii) declining surface and sub-surface water quality, and (iv) a socio-economically divided resident population.



RAYONG PROVINCIAL DEVELOPMENT PLAN (2018 – 2022)

1. Background to the Plan

Economically, Rayong rates well above Thailand's national average, with a gross provincial product of around 850 Billion Thai Baht and with a percentage of poor people below the national average. Despite this, there are gaps between the agriculture and industry sectors, health and education services need improvement, and there is a need for better systems to support Rayong's youth, elderly and disabled populations. Additionally, Rayong has to cope with a large number of immigrant workers. Environmentally, forest area in Rayong is low and is decreasing, pollution remains problematic and only one in three factories are classed as green industry.

2. Planning principles for the Plan

The Rayong Provincial Development Plan recognises that work needs to be done to improve development indicators such as household income, employment rates, electricity access, and allocation of government budgets. To address areas of weakness in the province, the Rayong Provincial Development Plan has been developed based on the following four principles:

1. Balanced development

The first priority for Rayong province is that economic growth continues. Economic growth will be driven by balanced development in the industrial, agricultural, tourism and commercial sectors.

2. The "Sufficiency Economy Philosophy" (SEP)

Development in Rayong will be underpinned by Thailand's SEP. The SEP espouses a balanced and moderate development pathway so as to ensure that Thailand is not overly adversely affected by volatility of global markets and financial systems.

3. Innovation

Infrastructure will support economic growth with a focus on innovation in the industrial sector. Innovation forms a key part of Thailand's push to escape the middle income trap and develop into a knowledge based economy.

4. Good health, welfare and environment

While the economy grows, the people of Rayong Province will enjoy social stability, security and good quality livelihoods. Rayong will take advantage of its natural resources, but in doing so all sectors will work in harmony with the environment and include stakeholder participation.

3. Sector based goals

The Rayong Provincial Development Plan has broad development goals that fit under five primary categories: 1) Agriculture, 2) Tourism and Services, 3) Industry, 4) Natural Resources and the Environment, and 5) Social and Public

Sector Development. These broad goals are outlined below:

1. Agriculture

Value adding in agriculture, fisheries and livestock, including through agro-tourism and targeting international as well as domestic markets.

- Build sales networks for agricultural produce
- Seek to add value to agricultural products through post-harvest processing and packaging
- Strengthen farmers groups and cooperatives
- Improve agricultural related infrastructure
- Synergise with tourism and industrial sectors (agro-tourism, agro-industry)
- Enhance natural resource base through rehabilitation (with public participation as a key element)

2. Tourism & service sectors

Make use of Rayong's natural assets, and including agro-tourism focus the tourism sector on restoring and conserving sustainability

- Enhance quality of tourism products
- Promote nature conservation tourism
- Ensure tourism infrastructure is of good quality

3. Industry

Focus on developing modern eco-industries, and that industrial development is done in a way that balances social and environmental factors.

- Develop facilities and personnel in preparation for Thailand 4.0 and for the EEC development plan
- Build competitive capacities of small and medium sized enterprises
- Enhance innovative capacities in industry and community
- Invest in transport infrastructure to support the EEC development plan

4. Natural resources and the environment

Natural resource use is managed sustainably, with all sectors undertaking their activities in environmentally friendly ways.

- Increase green areas in the province as well as conserving and rehabilitating marine and coastal resources
- Manage water resources to ensure water supply is sufficient and of adequate standard
- Manage solid and hazardous waste, including ensuring proper waste treatment/disposal, including through recycling and community garbage collection and disposal.
- Reduce greenhouse gas emissions and adapt to impacts of climate change
- Monitor and evaluate natural resource usage across all sectors.

5. Social and public sector development

Ensure that the people of Rayong have increasing resilience and quality of life, and the ability to publicly participate in decision making processes.

- Enhance social safety nets and strengthen social

institutions

- In view of the SEP, support opportunities for community based economic activities
- Maintain local culture, religion and traditional knowledge
- Ensure the health of Rayong people through public health and environmental health programs, as well as through accessibility of health services.
- Ensure good quality education based on a firm moral foundation

4. Plan investment

The total investment under the plan is approximately THB 18.2 billion. This excludes two railway stations associated with the development of a high-speed railway line terminating in U-Tapao airport, which are not costed in the plan. This figure also includes Map Ta Phut by-pass, with a total investment capital of THB 6 billion or a third of the plan budget. Figure 2-1 provides an overview of the allocation of funding, illustrating how investment is shared between different sectors (or themes as defined in the SEA)¹. The top graph illustrates the share of investment capital including the bypass project, and the bottom graph excludes this project. The allocation of funding is further broken down in Tables 2-1 to 2-7 to show how funding is being spent within each category.

Table 2-1: Transport

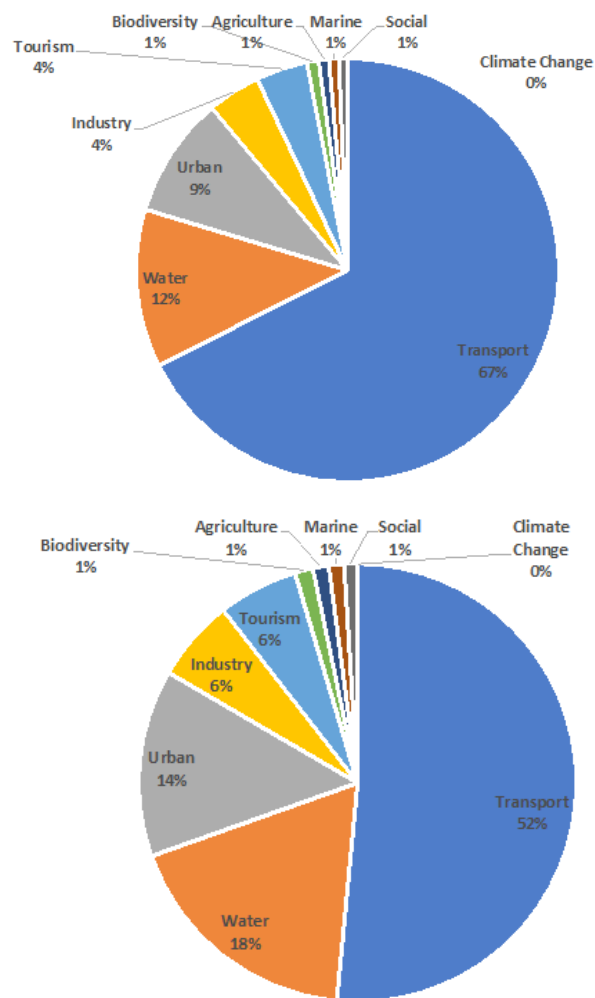
Sub-sector	Number	Amount (million THB)
EEC Related transport infrastructure	4	2,310.0
Road renovation	14	2,033
Stations related to high-speed rail	2	-
Map Ta Phut by-pass	1	6,000.0
Road infrastructure upgrading	10	1,838.0
Traffic management	2	66.0
Total	33	12,247.0

Source: RPDP, 2018

Table 2-1 highlights the emphasis on transport related projects within the RPDP. Almost 12.3 Billion THB is being allocated to transport out of a total RPDP budget of 18.2 Billion THB. Even excluding the single biggest project in the plan, the 6 Billion THB Map Ta Phut By-pass, the transport sector still accounts for more than half of the plans investment.

Water sector projects mainly irrigation and drainage related are the next biggest sector in the funding allocations from the RPDP, accounting for nearly 12% of investment capital. Primarily, irrigation and drainage funding is allocated for distribution and storage projects, as well as water pumping stations. Following this there is smaller investment in drainage, and then some investment in water treatment, which may be related to declining water quality issues in the 3 western reservoirs (interviews, East Water, May, 2019)

Figure 2-1: RPDP share of investment by theme/sector all projects (top) excluding Map Ta Phut by-pass (bottom)



Source: RPDP, 2018

Table 2-2: Water sector

Sub-sector	Number	Amount (million THB)
Canal dredging	6	69.1
Drainage projects	5	338.4
Water quality monitoring	1	7.9
Water distribution and storage	31	939.3
Water pumping stations	5	608.0
Water resources management	2	14.2
Water storage and transport	2	132.4
Water treatment plants	3	80.0
Total	55	2,189.5

Source: RPDP, 2018

¹ It should be noted that under the plan most water related projects are included as investments in the agricultural sector, much of the infrastructure investment in this sector supports agricultural development.

Table 2-3: Urban development

Sub-sector	Number	Amount (million THB)
Community education	3	32.5
EEC related	5	344.5
Public health facilities	4	645.5
Public safety	3	146.7
Waste management	3	137.8
Water supply/management	5	368.3
Total	23	1,675.3

Source: RPDP, 2018

Urban development related projects are the next largest category, accounting for around 9% of planned investment. This includes commercial and domestic water supply projects, the development of several hospitals and other public health facilities, waste management projects and a number of other smaller projects in community education and public safety.

Table 2-4: Industry

Sub-sector	Number	Amount (million THB)
Cleaner production	6	238.8
Sustainability related	1	21.6
Training and human resources development	6	153.1
Pollution monitoring/management	7	279.6
Waste management	3	43.8
Total	23	736.9

Source: RPDP, 2018

Investment relating to the industrial sector are focused mainly on pollution control and management (THB 280 million) and promoting cleaner production (THB 239 million). Developing human resources is also an investment priority with six projects costing THB 153 million. The remaining projects address solid and hazardous waste management and the promotion of sustainability in the sector.

Table 2-5: Tourism

Sub-sector	Number	Amount (million THB)
Human resources	1	6.6
Tourism related infrastructure	4	247.0
Tourism management and planning	8	452.7
Waste water treatment	1	10.0
Total	14	716.4

Source: RPDP, 2018

Tourism attracts almost the same investment as industry, at around 4% of the investment budget for the plan. Most of this is earmarked for projects to better manage tourism development in the province and on projects related to the design and planning of tourist facilities.

Table 2-6: Agriculture

Sub-sector	Number	Amount (million THB)
Promotion of organic agriculture	1	7.7
Agro-tourism related	1	4.8
Building value-added	6	129.9
Total	8	142.3

Source: RPDP, 2018

Table 2-7: Biodiversity, climate change, marine and fisheries and social development

Sub-sector	Number	Amount (million THB)
Biodiversity		
Conservation related	5	142.0
Restoration related	2	20.4
Total	7	162.4
Climate change		
--	1	7.0
Total	1	7.0
Marine and fisheries		
Conservation	1	105.7
Monitoring	1	2.3
Restoration	5	28.6
Total	7	136.6
Social development		
Public health	1	23.0
Socio-cultural projects	3	89.7
Total	4	112.7

Source: RPDP, 2018

The remaining sectors, including agriculture, biodiversity, climate change, marine and fisheries and social development get less than 1% of the total investment budget each. Agriculture, biodiversity, marine and fisheries and social development all receive a budget of THB 120 – 160 million. Agricultural projects, excluding water related projects outlined above, focus on promoting organic agriculture, promoting agro-tourism and seeking to improve the quality and marketing of produce to increase value-added. As regards biodiversity, marine and fisheries and social development projects include mangrove restoration, coral restoration, a project to manage the conservation of wild elephants as well as a project related to the conservation of genetic resources.

This distribution of capital reflects the investment remit of the Rayong provincial authorities. Provincial roads, water infrastructure and the construction of public medial facilities are capital intensive and all fall under the remit of the province, explaining to a large extent the concentration of investment in these sectors. Most of the other investments in private sector development (tourism, industry and agriculture), social issues and environmental protection do not include the provision of infrastructure or other physical assets, but focus on capacity development, research and education.

The aspirational goal of industrial development in Rayong is to move away from relatively low value-added, heavy industries like oil refining and petro-chemicals to high value-added, knowledge-based industries, like robotics and avionics, which are less polluting. The Rayong provincial government seems to be relying on national and regional strategies to effect this change, through investment programs such as the Eastern Economic Corridor Development Plan² and the Thailand 4.0 strategy³. Moreover, not all development which is planned for Rayong by national government sectors is reflected in the plan – i.e. it is not a comprehensive development plan for the

province. The extent to which sector development projects are included – for example many of the EEC transport sector projects – appears to be ad hoc and lacking in systematic or strategic planning. It reflects the realities at local government level and challenges facing the provincial authorities in their negotiations with sector and regional agencies. Yet, that lack of comprehensive coverage of all development within the Province undermines the authority and influence of the plan. It reduces its credibility as the sustainable development framework for all development activities within Rayong.

The strategic framework for the province is expressed in the plan's ambitious environmental and sustainability goals, but these are not well reflected in the project breakdown and budget. For example, the sector-based goals for the plan include ensuring proper waste treatment/disposal. Despite waste treatment being a major area of concern for the province, the RPDP proposes only 8 projects, totaling 1.6% of the budget, or 287 Million Baht of investment. One hundred Million of this targets hazardous waste and is an education program rather than a direct hazardous waste management activity.

² <https://www.eeco.or.th/en/content/development-goals>

³ <https://thaiembdc.org/thailand-4-0-2/>





STRATEGIC THEME: MACRO-ECONOMICS

1. Introduction

Since the late 1980s, Rayong has developed rapidly from a largely agricultural province to become a national hub for heavy industry. This development was driven by the Eastern Seaboard Development Program which sought to develop a secondary industrial and manufacturing hub to geographically diversify production away from Bangkok.

At the same time, Rayong was a strategic landing point for gas pipelines in the development of considerable off-shore oil and gas reserves in the Gulf of Thailand, and the potential for deep-water ports in Chonburi and Rayong (Map Ta Phut). These geographical advantages coupled with the development of extensive infrastructure to support industrial development (transport, water supply, power supply and industrial estates) spurred the rapid transformation of the provincial economy. The industrial and services sectors expanded rapidly and primary sectors (agriculture and fisheries) saw a relative decline in their importance.

2. Scope

This analysis considers the rapid growth of the economy in the province, the structural changes this has implied as well as the distributional consequences of these changes for different economic sectors.

3. Links to other sectors and themes

The economics theme is cross cutting and is linked to all other productive and infrastructure sectors. Energy, water, industry, agriculture, tourism and transport themes are linked as component parts of economic growth, as well as offering critical intermediate goods and various services to other sectors.



The provision of infrastructure itself represents economic activity but urban development and social and demographic issues are also closely linked as economic performance has created employment and

STRATEGIC ISSUES OF CRITICAL CONCERN FOR SUSTAINABLE DEVELOPMENT IN RAYONG

- ✓ Rapid economic growth and structural change
- ✓ Distribution of benefits of Rayong's economic growth

SUSTAINABLE DEVELOPMENT OBJECTIVES

- ✓ Ensuring the sustainable development of the economy
- ✓ Ensuring equitable distribution of economic benefits including long term support to vulnerable effected groups and areas

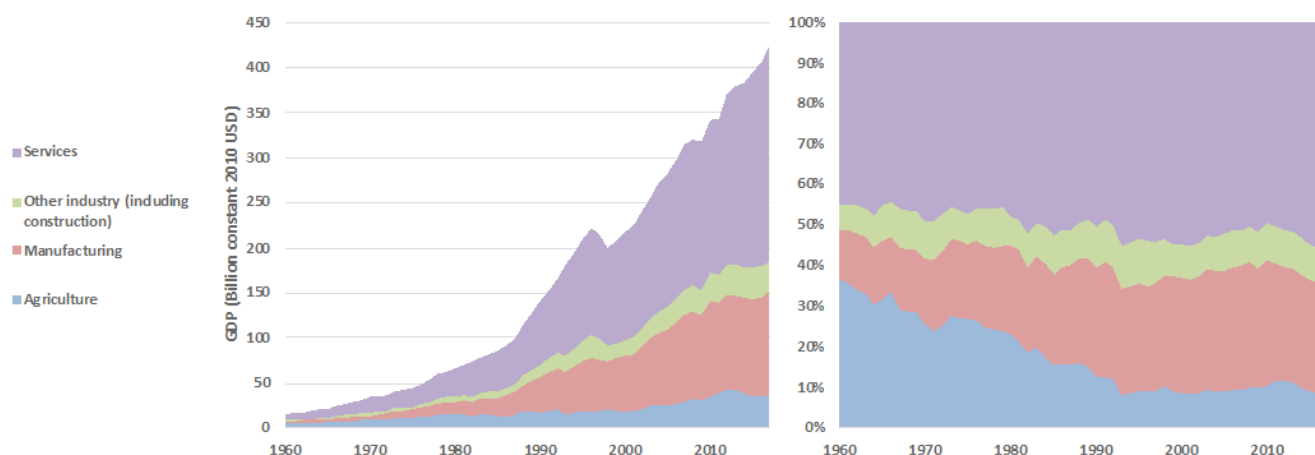
consequently been an important driver of in-migration and population growth. Similarly, the structural shift from primary sector production to secondary and tertiary sectors, has led to productivity, income growth and poverty reduction.

4. Overall context

Rayong's rapid economic growth and structural change should be put into the context of national economic performance. Thailand in general has seen remarkable levels of economic growth since the 1960s (Figure 3-1). This has been accompanied by radical structural change as growth in the more productive industrial and service sectors outstripped growth in the agricultural and related sectors. This change has been driven in particular through a focus on export-oriented manufacturing, encouragement of foreign direct investment in the manufacturing sector, as well as growth in tourism and related sectors (such as construction and services).

Rapid growth in value added, exceeding declining population growth rates has led to increases in per capita value-added, higher incomes and lower levels of poverty (Figure 3-2). It should be noted that since the Asian Financial Crisis starting in 1997-98, Thailand has been on a lower growth trajectory. Economic performance has also suffered in recent years due to external shocks such as the Global Financial Crisis 2008-2009, extensive flooding in 2011 and domestic political

Figure 3-1: National GDP growth by major sector (left) and structural change (right) 1960 - 2017



Source: World Bank, 2019, World Development Indicators database

instability that has plagued the country in recent years.

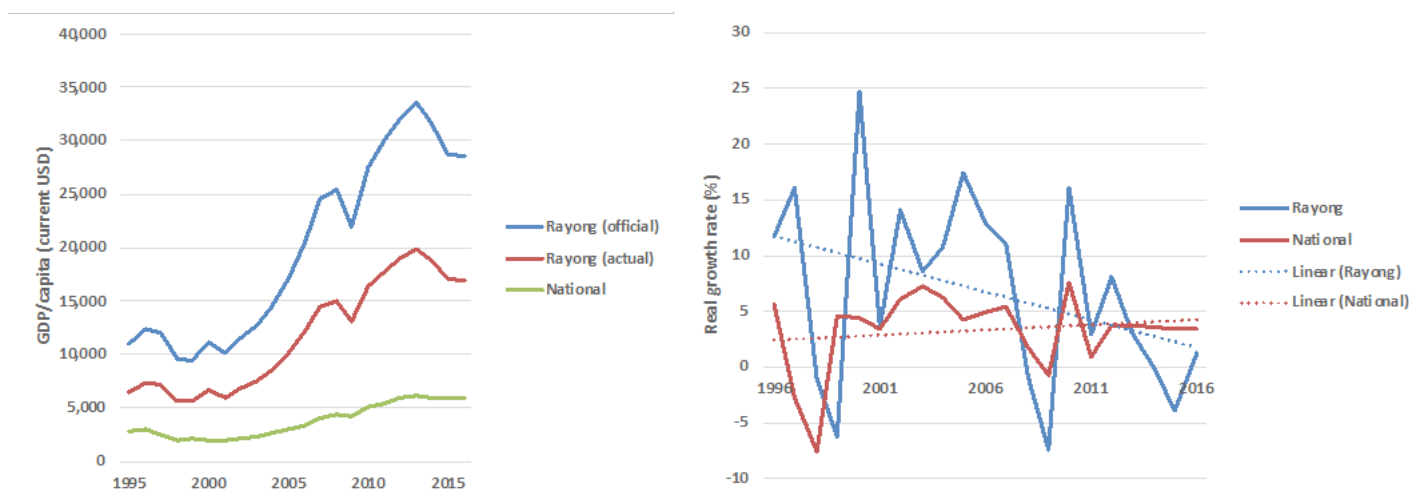
Rayong and the ESBP has played an integral part in the growth of the national economy. In terms of value-added, the province seems to have benefited significantly from ESB developments. Figure 3-2 compares value-added growth in Rayong with the national picture. Between 1996 and 2016, value-added growth in the province at 6.8% was more than double the national average of 3.3%. This was largely driven by expansion of heavy industry, the energy sector and tourism. The relative volatility of the growth rate likely reflects the less diversified nature of the economy and the lumpiness of large-scale capital investments/projects in the province relative to the size of the provincial economy. The simple linear trend-lines that have been added (Figure 3-2 right), however, suggest that economic performance in Rayong may be stalling relative to the country as a whole. This may reflect a decline in the productivity of off-shore fields as well as a decline in investment in exploration, greater regional competition in heavy industry and petrochemicals sectors in particular. Also, it may also reflect the fall-off of the economic fillip given to the regional economy by the large scale ESB investments. In this context, the economic imperative of the

program of investments under the EEC becomes clear.

Rayong's rapid economic growth is echoed in rapid growth in GDP per capita, from around 3.8 times the national average in 1995 to 4.7 times the national average in 2016. However, an important caveat to these figures is the failure to include unenumerated migrants in the calculation of these figures. Currently, the best estimates assume that migrants constitute over a third of the population, if this is taken into account GDP per capita in the province may be as low as US\$ 16,900 as opposed to the official figure of US\$ 28,600.¹

The result of this rapid growth in Rayong has been a significant structural shift in the economy, away from agricultural and service sectors towards industrial sectors (including manufacturing, oil and gas production and energy services (power, heat, cooling etc) (Figure 3-3). While the national and international context including national macro-economic policies and a global context of decreasing barriers to international trade² have been important in understanding Rayong's economic performance, more immediate, proximate drivers of Rayong's growth have broadly fallen into three.

Figure 3-2: Per capita GDP 1995-2016 (left) and real GDP growth rates (right) 1996-2016

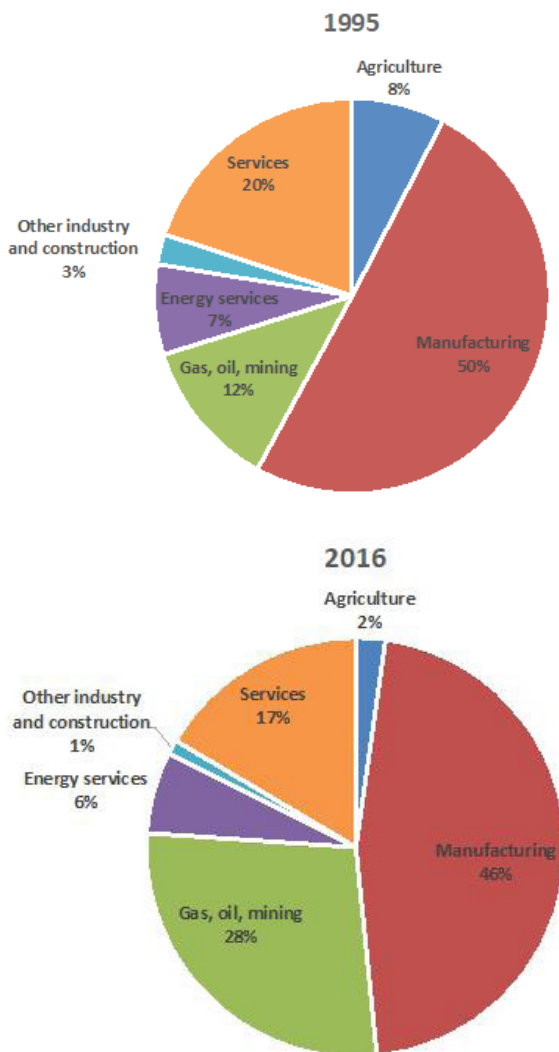


Source: NESDC 2018, World Bank, 2019, World Development Indicators. ICEM estimates.

¹ Note, to arrive at the estimate given in Figure 2, it was assumed that unregistered migrants numbered around 500,000 in 2016 and that historically they composed a similar proportion of the provincial population over the period.

First, investment in infrastructure mainly through the ESB program, with the development of transportation infrastructure (including road infrastructure and Map Ta Phut port) and infrastructure services to support the development of heavy industry being the most significant. Second, the discovery and exploitation of Thailand's off-shore fossil fuel reserves and their landing in Rayong. Third, inward investment from domestic and FDI sources (particularly from Japan).

Figure 3-3: Structural change in Rayong economy – value-added by major sector 1995 and 2016



5. Policy and projects

Key policy and projects relevant to Rayong's economy include:

Thailand 4.0: To create a value-based economy that is driven by innovation, technology and creativity, through increase R&D, resulting in higher economic growth. At the same time the strategy targets climate change resilience and a low carbon society. In particular, to reinvigorate the

development of the country and avoid the middle-income trap by spurring growth in 10 emerging technology sectors including, the 'first S-curve industries':

- Next - Generation Automotive;
- Smart Electronics;
- Affluent, Medical and Wellness Tourism;
- Agriculture and Biotechnology; and,
- Food for the Future;

and the 'New S-Curve industries':

- Robotics;
- Aviation and Logistics;
- Biofuels and Biochemicals;
- Digital and
- Medical Hub.

Eastern Economic Corridor (EEC) Development: The EEC Act was promulgated in 2018. With an increase in private sector investment in the second half of 2018. Significant investment in infrastructure are planned including the development and upgrading of an international airport at U-Tapao to function as the Eastern air transport hub and aircraft maintenance centre, a high-speed rail line linking U-Tapao airport to Donmuang and Suwannaphoum airports, further upgrades to highways and connecting roads in the region, further upgrades to ports (including Map Ta Phut), and development of industrial areas to serve the development of new industrial sectors.

Government fiscal budget stimulus: Government economic stimulus policy included in the amended government Fiscal Act (2018).

Tourism promotion: EEC tourism enhancement and promotion seeks to link Rayong's tourism assets including coastal areas, ecotourism, community tourism, health tourism, and conference and exhibition tourism. It also seeks to promote Rayong as a centre for business tourism, study, training and as a hub for modern technology and environmentally friendly activities.

Government economic measure for low-income citizens: The Government initiated a bundle of measures to promote the welfare of low-income groups and promote the grass-roots economy, including measures on utility bills, access to health care amongst other things. citizen welfare measure via state welfare card to support low-income citizens on subsistence and household expenses.

6. Key stakeholders

- Industry and business;
- Nearby communities;
- Farmers, fishermen and growers;
- Tourism service providers;
- Industrial Estate Authority of Thailand;
- Management Authorities for the 12 Industrial
- Estates in Rayong;
- Industrial Parks and their owners;
- Eastern Economic Corridor Office

² Thailand joined the WTO in 1995.

7. Past trends and current situation

- ✓ Rapid economic growth and structural change;
- ✓ Distribution of benefits of Rayong's economic growth

Rapid economic growth and structural change

Over the last 20- 30 years, Rayong has undergone a period of rapid economic growth and structural change. The provincial economy more than trebled in size between 1995 and 2016, with value-added growing from around THB 200 billion (constant 2002 prices) in 1995 to THB 713 billion by 2016. Structural change in the composition of economic production has been an integral part of this growth as the economy has moved into more capital intensive, higher-value added heavy industries.

Rayong's growth has largely been driven by the development of heavy industry based upon the ESB development and the development of the off-shore gas industry. As such, relative to the national economy as a whole, the province relies much more heavily on the gas and oil sectors, the power sector (with around 25% of the countries installed generation capacity in the province) and refining (with over 50% of refining capacity), and the petrochemicals sector (Figure 3-4). Despite growth in tourism the services sector has declined relative to the rest of the provincial economy, and represents a much smaller share of value-added than for the country as a whole. Similarly, the agricultural sector has seen significant

relative decline over the period and also represents a smaller share of production in Rayong than nationally.

Although the province has seen average economic growth of 6.8% per year over the last two decades, (more than double the national average of 3.3%), growth rates have been declining, and in recent years have fallen below the national average (Figure 3-2, left).

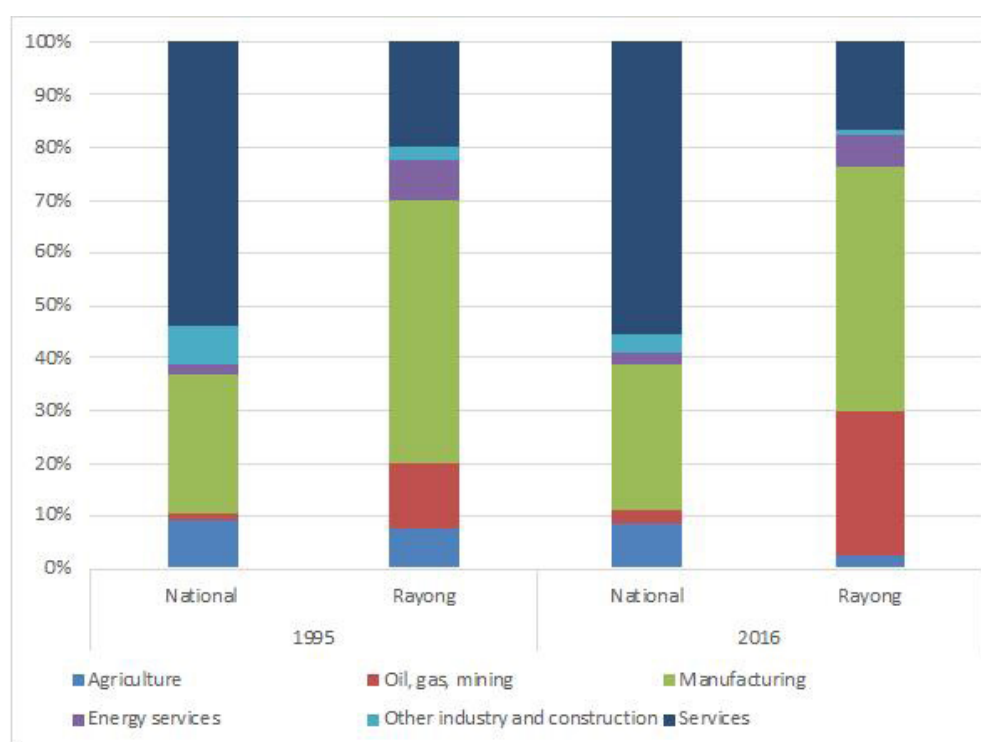
Distribution of benefits of Rayong's economic growth: Rayong's growth has focussed largely on heavy industry. Sectors such as tourism and agriculture have also grown but at a lower rate than industry. The rapid growth of the industrial sector in the province has led to the emergence of a series of trade-offs between sectors:

Water use: Industry in Rayong makes intensive use of provincial water resources, with some estimates putting industrial water use at over 50% of the total (SEA industry and water baselines). Given limitations to water supply, this implies a trade-off between agricultural and industrial water uses. Water productivity in agriculture tends to be lower than that in industry. Nevertheless, agriculture remains an important employer in the province, particularly amongst indigenous communities and lower income groups.

Industrial water pollution: Regular and accidental pollution of inland and marine water resources is of increasing concern. Inadequate treatment of industrial wastewater, dumping of solid and hazardous waste, and accidental chemical and oil spills have all affected water quality in the province, compromising supplies for other sectors and resulting in deleterious impacts on aquatic ecosystems (both inland and marine) and the sectors which rely on them (such as fisheries).

Air pollution: Industrial and transportation related activities,

Figure 3-4: Structure of value-added by major economic sector Rayong and national 1995 and 2016



Source: NESDC 2018

generated by the economic dynamism of the province, are also associated with high levels of air pollution, particularly problematic in urban areas and in areas surrounding Map Ta Phut industrial estate. This has negative health impacts on communities and on real estate prices in affected locations.

Municipal pollution: An indirect consequence of industrial expansion in the province has been significant population growth (SEA social and demographic baseline). This has increased the generation of municipal wastewater (SEA urban baseline) and resulted in declining water quality, impacting water dependant down-stream sectors.

Demand for services: More generally, the high levels of in migration drawn by the economic opportunities related to the development of heavy industry, have led to the presence of a large number of unregistered migrants. This “hidden” population leads to a greater demand for amenities and services from the province than would otherwise be the case.

Generally speaking, Rayong province has been the focus for the development of heavy industry in Thailand, but as a consequence, some other sectors, such as agriculture and fisheries, have experienced negative impacts and recession. Moreover, most heavy industry is located in 12 industrial estates throughout the west of the province (although there are also a large number of industrial establishments outside industrial estates), which are centrally administered by the Industrial Estate Authority of Thailand and largely outside the administrative remit of Rayong provincial authorities. It leaves the province with a limited role in shaping and managing industrial development. Finally, as most migrants maintain their official registration in their province of origin, they do not appear in official population figures for Rayong. This means the associated need for expanded amenities and services is not reflected in provincial budgets, thus further disadvantaging the province.

8. Future trends

- ✓ Rapid economic growth and structural change;
- ✓ Distribution of benefits of Rayong's economic growth

Rapid economic growth and structural change

Despite the downward trend in provincial value-added growth, economic growth in Rayong province is expected to return to at least national levels, driven in part by Thailand 4.0 policies. Growth is expected to come from the industrial and service sectors, although there may be some decline in petrochemicals sectors as domestic fossil fuel resources are depleted. Structural change is likely to continue as tourism and industry continue to out-strip growth in other sectors.

Distribution of benefits of Rayong's economic growth

Trade-offs between sectors are likely to continue. Trade-offs surrounding water use and availability are likely to become acute as increasing demand is accompanied by constraints in supply. While some increase in pollution issues and associated negative externalities is likely to persist in the short term, a move away from more polluting industries and better pollution control is likely to reduce concerns relating to environmental quality for all sectors in the medium to long term. Finally, with continued economic growth population growth is likely to continue unabated. This will increase the demands on provincial government for provision of adequate amenities and services, and add to mounting pressure for effective municipal wastewater treatment and reduced impacts on economic sectors and quality of life.



STRATEGIC THEME: SOCIAL ISSUES AND DEMOGRAPHICS

1. Introduction

Rayong province consists of 8 districts, 54 sub districts, 439 villages¹ and 303 communities² (Interviews, Rayong Provincial Statistical Office) (Table 4-1). Rayong has been one of the three core provinces in Eastern Seaboard Development Program (ESDP), which was initiated in 1981, and which evolved into the Eastern Economic Corridor (EEC) program in 2016 (Secretariat, Thailand's House of Representatives, 2016).

Since the ESDP began, Rayong province has been transformed from a fundamentally agricultural society into a predominantly industrial led economy. Despite this, agriculture still plays an important role in terms of 1) land area, 2) the traditional occupation for multi-generations of residents, 3) a provincial reputation for good quality agricultural produce, and 4) the many fruit orchards being promoted as attractive for agro-tourism (Interviews, Rayong Governor's Office).

The importance of agriculture in Rayong is further underscored by Thailand's sufficiency economy philosophy (SEP), which promotes balanced and moderated development that benefit individuals, communities and

STRATEGIC ISSUES OF CRITICAL CONCERN FOR SUSTAINABLE DEVELOPMENT IN RAYONG

- ✓ Registered and unregistered population growth
- ✓ Availability of infrastructure and services
- ✓ Growing socio-economic inequality

SUSTAINABLE DEVELOPMENT OBJECTIVE:

- ✓ Strengthen community resilience and inclusive development based on the sufficiency economy philosophy and environmental sustainability

society as a whole by focussing on coping capacities in the face of rapid environmental, material and social changes.³ The current backdrop for Rayong's development from a socio-economic perspective is the integration of rural agricultural lifestyles with new industrial and urban areas and the influx of a growing migrant population.

Table 4-1: Area size, number of subdistrict administration, sub districts and villages

District	Area (km ²)	Distance to Muang district	Rayong provincial administrative district						
			Number of City Municipalities	Number of Town Municipalities	Number of Sub district Municipalities	Number of Sub district Administrative Organizations	Number of Sub districts	Number of Villages	Number of Communities
Total	3,552		1	2	27	37	54	439	303
Muang	515	-	1	1	6	7	15	84	102
Banchang	238	27	-	1	3	1	3	20	50
Klaeng	788	47	-	-	8	9	15	147	91
Wangchan	359	70	-	-	1	4	4	29	5
Bankai	489	11	-	-	3	5	7	66	22
Pluagdaeng	618	46	-	-	2	6	6	34	4
Kao Chamao	270	74	-	-	1	3	4	29	9
Nikhom Pattana	238	20	-	-	3	2	4	30	20

Source: Rayong Statistical Office, 2019

* ICEM calculated figures based on data from Rayong's Provincial Statistical Office

¹ Village refers to the lowest administrative level in a rural area of Thailand

² Community refers to the lowest administrative level in a municipal area in Thailand

³ <http://tica.thaigov.net/main/en/information/7107>

2. Scope

This chapter of the SEA baseline uses three strategic socio-economic issues identified by stakeholders to examine development in Rayong. Past trends, current situations and likely future trends in the issues are all briefly presented. The three issues are 1) population growth, both registered and unregistered, 2) availability of infrastructure and services, and 3) growing socio-economic inequality, including lack of long term transition support for poorer residents. These strategic issues are also identified in the Rayong Provincial Development Plan (RPDP, 2018) as being crucial to sustainable development for the province. With accelerating industrialization and urbanization, it is even more important to address these strategic issues so that quality of life can be improved and maintained, so that social equity is achieved, and so that conflicts over environmental and resource sharing issues can be resolved and avoided.

3. Links to other sectors and themes

Industry: Population growth in Rayong is largely being driven by migrants moving to the area for work in the expanding industrial and trading sectors (RPG, 2018).

Environmental quality: Environmental quality (for example air quality, water quality, eco-system services) all play a large role in people's well-being. People also impact on environmental quality. For example, untreated domestic waste-water is largely responsible for the poor quality of river water in Rayong.

Energy: The energy sector is important to people's quality of life and livelihoods, for example, through the provision of transport, heating and cooling, light and communications, as well as cooking and storage of food.

Water: Access to adequate and safe water is a fundamental human need. Insufficient or contaminated water jeopardizes both the physical and social health of Rayong's population. Communities need water for drinking and domestic uses, to grow food especially for irrigated crops, and increasingly to run industries, tourism facilities and power plants.

Climate change: Rising numbers of hot days, less dry season rain, and more intense wet season rain will all have impacts on people living in Rayong, with these impacts disproportionately affected poorer and more vulnerable populations. Vulnerable groups include women and children, the elderly, and people with disabilities. Also, in Rayong they include artisanal fishermen, fruit orchard owners in rain-fed areas as well as informal labour and the urban poor.

Agriculture: While the industrial sector in Rayong is growing rapidly, agriculture remains a cultural identity for Rayong people. Additionally, in the event of financial crises, which may impact on industry and other economic sectors, the agricultural sector provides a sufficiency economy buffer

(stakeholder workshop on impact assessment 10-11 June, 2019). SEP became a fundamental concept underpinning Thailand's development following the Asian financial crisis in 1997, when the agricultural sector absorbed many employees from industry and tourism who had lost their jobs.

Urban development: With the growth of industry and the large numbers of migrants moving to Rayong, urban/town planning and development plays a key role in ensuring socio-economic trends are positive and support the environmental sustainability.

3. Overall context

The socio-economic aspects of Rayong's development plans are incorporated in a number of provincial and national policy and strategy documents. Specifically:

✓ The 2018 – 2022 Rayong Provincial Development Plan (RPDP, 2018). While this plan does not have specific social and demographic objectives, it does include a number of tasks and indicators that relate to social health and well-being. For example, the plan makes ten references to "good quality of life". In addition, the plan includes targets to:

- Reduce the proportion of poor people from the 2018 level of 0.32% down to 0.00%
- Achieve level 5 success in preventing and solving the drug problem⁴
- Ensure people are satisfied with provincial infrastructure (electricity, roads, water)

✓ The 2019 – 2022 Provincial Cluster Plan (Revised version) (MOAC, 2019). This plan includes tasks to ensure good quality of life through standardized public health services and lifelong support for learning with indicators targeted to:

- Ensure more hospitals get Hospital Accreditation (HA) to support EEC development
- Develop human resource capacity among Rayong youth and labourers to a level suitable for EEC labour market demand

✓ The Eastern Economic Corridor Development (EEC) Plan (Kiatpatraporn, 2018). The EEC Plan has the socio-economic objective of enhancing income in the region in order to improve people's quality of life. The EEC Plan includes 5 livability indicators that focus on the development of Rayong as a "Smart City". These are:

1. Safety
2. Education
3. Infrastructure
4. Culture and environment
5. Public health

Similar to the Rayong Provincial Development Plan, 'quality of life' is included as a strategic theme embedded at every level of the EEC Plan.

⁴ There are 5 levels of achievement and 5 is the highest, meaning that all the required indicators have been achieved. (e.g. prevention, law enforcement, rehabilitation). For example, for drug addicts a level 5 includes that the proportion of addicts is less than 3 addicts per 1,000 people.

4. Socio-economic projects

Development item 5: Strengthen living standards and community participation as per the SEP: - The project aims to improve service provision potential among Rayong hospitals (in support of EECI and EEC): Pluagdaeng Hospital, Wangchan Hospital and Princess Sirindhorn Hospital - Flood solution for economic area of Rayong province (Klong Thabma phase 4 project)	Rayong Provincial Public Health Office Rayong Irrigation Project
Development item 6: Strengthen capability of commercial and service sector into world class competition: - Measure No. 3: Promote human development in local establishments: - The project to establish Klaeng International School and Rayong Technological and Vocational College	Rayong Provincial Administrative Organization

Source: Rayong Provincial Development Plan (2018-2022)

5. Key stakeholders

Stakeholder engagement is an essential element of sustainable development. Key stakeholders related to the social development issues for Rayong are as follows:

- Provincial and provincial cluster governmental agencies:** policy and planning organizations and implementing agencies (health and social service providers, EEC and industrial estates, research and academic institutes)
- Practitioners and professions:** artisanal fishermen, fruit orchard farmers, cash crop farmers (e.g. pineapple, cassava, para rubber), labourers, vendors
- Vulnerable groups** who are likely to be affected by industrialization and urbanization, including artisanal fishermen, owners of rainfed orchards, the urban poor and informal labourers
- Private business:** industries, trade, tourism, real estate
- NGOs / civil society organizations:** Environmental health associations, local communities, and volunteer organizations

Limitation of this assessment:

- There is a lack of available information on land expropriation and its impacts on vulnerable groups.
- Representatives of the Rayong Employment office noted that with increasing use of social media by employers to connect with job seekers, that their statistics on employment may not show the complete employment picture in the province.

Targets / indicator per task	Indicator detail	2018	2019	2020	2021	2022
Quality of life of people, safety in life and property, and social security as per the SEP	Reduce the proportion of people living under the poverty line to 0.00% ⁵	0.32	0.15	0.10	0.05	0.00
	Achievement in prevention and solving drug problems level 5	5	5	5	5	5
	People are satisfied with basic infrastructure: roads, electricity, domestic water supply	n/a	82	84	86	88

Source: Rayong Provincial Development Plan (2018-2020)

6. Past trends and current situation

- ✓ Registered and unregistered population growth
- ✓ Availability of infrastructure and services
- ✓ Growing socio-economic inequality

Population Growth

One of the most striking trends in Rayong in terms of demographics is that, since 1993, the urban population has grown from 20% to 49% of the province's population (Figure 4-1). This trend is driven by industrial growth. Those figures hide unregistered migrants (for example, those who have moved from other provinces but not registered their move with relevant authorities and unregistered international migrants), and workers in Rayong's industries who live outside the provincial boundaries. Unregistered migrants and commuting workers together number around 450-500,000 people (NESDC, 2009; Rayong Excise Office 2019). In 2018, Rayong's registered population was 723,316 (Figure 4-1).

Muang city has experienced the highest population growth, and is home to around 40% of Rayong's registered population, with 281,000 people living in the municipality.

⁵ Poverty lines are adjusted annually, however in 2017, the poverty line in Rayong was THB 2,980 per person per month (see: http://social.nesdc.go.th/SocialStat/StatReport_Final.aspx?reportid=671&template=2R1C&yeartype=M&subcatid=60)

In addition, there has been significant population growth in other districts where industry and trading enterprises are concentrated, such as Pluak Daeng, Nikhom Phattana and Ban Chang. Over the period 1993 – 2018 Rayong's rural population has remained more or less unchanged.

The average number of people per household in Rayong has declined from 3.5 in 1993 to 1.5 in 2018. The average number of people per municipal household is less than that in rural areas (1.4 and 1.7 persons per household, respectively). Tied to the immigrant driven population growth in urban areas, the average age of farming households is higher than municipal households.

Infrastructure and Basic Services

In terms of availability of infrastructure and basic services, there are two budgeting related issues that are currently causing problems in Rayong Province.

The first of these relates to the large population in Rayong who are not registered as living in the province. This is a significant issue for the Rayong Government because central transfers to the province are based on official population statistics, meaning that the actual per capita funding supplied to Rayong does not reflect the real situation and need. (Rayong Excise Office, 2019). As around 35-40% of the provinces actual population is unregistered, the province is only receiving around 60-65% of the transfers that it would be entitled to if everyone in Rayong was registered as living there. This constrains the options available to provincial authorities for provision of basic infrastructure and services. For example, the number of physicians per capita is significantly lower than the national average – ie. at one physician per 4,100 people compared to one physician per 1,800 people nationally. Similarly there is one hospital bed

per 1,600 people compared to one hospital bed per 400 people nationally (Public Health Center 6, 2018). The lack of good quality basic health services is an indicator that poorer segments of society, who do not have the means to pay for medical services, will be further disadvantaged.

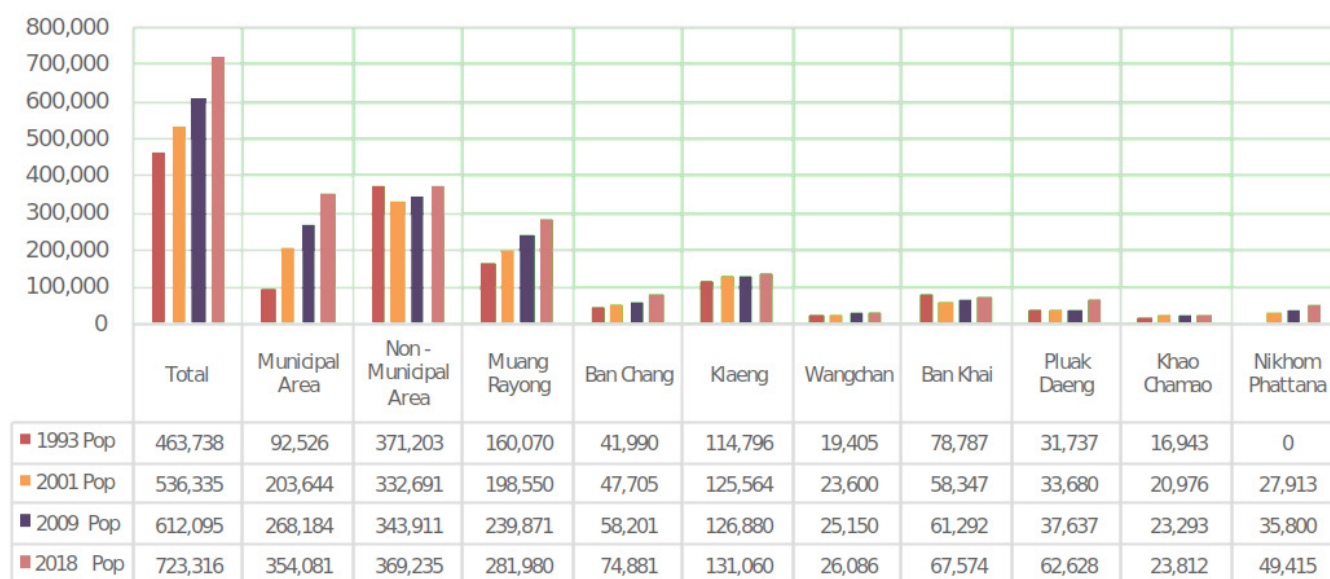
In terms of support to local livelihoods, the second budgeting issue is more about the level at which decisions are made concerning Rayong's development. Between 2015 and 2018, the total budget for Rayong province more than doubled. Yet, most of the new funding has been allocated to national implementing agencies operating in the province. Funding available for provincial and provincial cluster authorities has grown by only 20% over the same period (247 Million Baht (2014) to 298 Million Baht (2018)) (Budget Bureau, 2018). The disproportionate increase in funding between centralized implementing agencies and provincial authorities could aggravate the observed health and development disparities between socio-economic groups in the province.

Growing socio-economic inequality

In 2018 around 70% of employees were unskilled labourers (meaning their highest level of education was grade 6 or lower) whereas the number of semi-skilled workers and skilled labourers (with high school or bachelors degree qualifications) formed 14% and 13% of the labour market respectively (EECP, 2018). Past employment rates highlight a labour shortage of local professional workers and skilled labour force, and thus organisations have relied on immigrant labour (Rayong Employment Office 2019). For example, at the end of March 2019 there were 105,000 registered migrant workers living and working in Rayong. This included around 11,000 highly skilled workers and employers from Japan, China, Korea, the Philippines, India and Germany, as well as 94,000 unskilled workers from Cambodia, Myanmar, Lao PDR,

Figure 4-1

Rayong's Changing Population (1993 - 2018)



Source: RPAO (2018)

and Thailand (from ethnic minority groups) (interviews and first quarterly statistical report of 2019, Rayong Employment Office). Notably, apart from a small number of people from ethnic minority groups, there are no Thai nationals registered as having migrated to Rayong. Moreover, this number does not include those labourers who used their social networks or social media to access employment opportunities.

Because of anticipated growth in labour demand under the planned EEC investments, and current low rates of high school and bachelor degree completion among the Rayong community, a tertiary vocational education and training centre has been established by the government (Rayong EEC Coordination Center, 2019). Even so, stakeholder engagement studies have highlighted resident dissatisfaction with the EEC transition as well as raising concerns about local participation in decision-making processes and land expropriation rates. A particular concern is that vulnerable groups, such as artisanal fishermen and local residents who have been affected by the construction and expansion of new industries and deep sea ports, have not been consulted (THPF, 2018).

In terms of the percentage of the population living under the poverty line, Rayong has the second best ranking among the Eastern Region provinces.⁶ Yet, there is a large disparity in living environments and environmental health, and this negatively impacts on quality of life of the poor (SEA consultations; see also Surichai, Preecha, & Prasit, 2000). For example, some workers' residential areas near the factories and at the outskirts of big cities are overcrowded. Some are located in low land subject to potential flooding and storms and some workers' residential areas have impinged on public lands (i.e. greenbelt zones that have been demarcated by the Town Planning Department) as well as obstructing water ways. In some communities close to industrial complexes, there are problems of air pollution (for example, benzene, toluene, xylene and particulate matter from industries, traffic and construction), as well as poor water quality in rivers and canals, and rain water that is not fit for consumption. The impacts of poor air and water quality impact disproportionately poorer segments of society. There are also reports of increasing food-borne disease outbreaks, which have been linked to crowded living environments where communal eating is the norm (Public Health Center 6, 2018).

With the increasing numbers of workers employed in the industrial sector, environmental and equipment related work safety issues is a growing area of concern. For example, Rayong's 2018 statistics show that half of work related accidents/health problems relate to exposure to toxic chemicals, and a fifth relate to use of machines and other equipment (Rayong Statistical Office, 2018). Rayong also has a high road toll, related to many drivers who are not used to local traffic conditions and rules (e.g. tourists and unregistered immigrants).⁷

7. Future trends and drivers without the Rayong Provincial Development Plan

- ✓ Registered and unregistered population growth
- ✓ Availability of infrastructure and services
- ✓ Growing socio-economic inequality

Population Growth

According to NESDC's population projections (NESDC, 2013), it is projected that the population in Rayong will continue increase, though the growth rate will decline. The registered population of Rayong is anticipated to grow to around 990,000 by 2035. Despite anticipated immigration (primarily younger, working age people), Rayong's population is projected to continue aging, and it is expected that 20% of the population will be above 60 years of age by 2024. The average age in farming households is already higher than the provincial average, and there will continue to be a faster ageing trend in rural areas (Public Health Center 6, 2018).

The EEC has estimated that from 2017 to 2027, there will be around 100,000 employment opportunities in industrial and business sectors in the three EEC target provinces (Kiatpattraporn, T. 2018). Rayong has an aging population with a lack of suitable skills and training for many of the proposed high-tech work opportunities. For example, a study on the structure of manpower in EEC in 2017 found that 49% were laborers who may or may not have finished high school, 34% had vocational certificates, and only 17% of those surveyed had bachelor degrees or higher (TDRI, 2018). Because of a lack of required qualifications, many unemployed laborers in the EEC region will not be able to access available jobs. The same study recommends improvements to education curriculums, including special intensive training courses focussing on developing a skilled workforce for digital industries such as those linked to artificial intelligence and robotics, as well as targeting information and communication technologies (TDRI, 2018).

To address these issues, the Eastern Economic Corridor Policy Committee recently approved a three-pronged approach to capacity development: 1) Developing new skills for digital program students, 2) Re-skilling for graduates and other workers from non-digital backgrounds, and 3) Up-skilling for laborers and other personnel already working in digital industries (GoT, 2019). These programs will focus on the industrial and trade sectors rather than the agriculture

⁶ The Eastern Region of Thailand includes the following nine provinces: Chachoengsao, Chanthaburi, Chonburi, Nakhonayok, Prachinburi, Rayong, Sakaeo, Samutprakan and Trat (NESDC, <https://th.m.wikipedia.org>).

⁷ <https://www.isra.or.th>

or biotechnology sectors. Despite existing efforts to develop capacity, it will take time to train a local cohort of competent technicians to meet industry and business demands.

For those reasons, Rayong will continue to see large influxes of migrant workers who are likely to be better educated and better paid than local people. These divisions in education, employment opportunities and income are likely to exacerbate tensions that arise when numerous migrants move to an area. These concerns are further driven by a lack of transition support for poorer and vulnerable groups in the face of the rapid developmental changes taking place in Rayong (interviews and stakeholder workshops, 2019).

Infrastructure and Basic Services:

Over the last three decades, industry and heavy industry in Rayong has concentrated in particular areas, such as Map Ta Phut industrial zone (interviews, Town and Country Planning 18 April, 2019)). While not problematic in itself, adjacent residential areas have become overcrowded, as have residential areas on the outskirts of nearby municipalities. Further increases in the density of industrial areas is likely to have negative impacts from air, odor, noise, dust, and water pollution). These development trends could bring with them social problems as the population grows such as drug abuse, cultural conflicts and increase incidence of crime (see, e.g. Kaosa- Ad et al., 2012).

From a socio- economic perspective, the main issues facing Rayong are (i) environmental health and new diseases, (ii) occupational health and safety, and (iii) traffic accidents (SEA scoping workshop; Klangkorn, 2017). Spatial planning to enhance quality of life also becomes a critical concern. For example, in line with global standards of at least 9m² of green space per urban resident (Russo & Cirella, 2018), the EEC Environmental Management Plan (MONRE, 2019), identifies a need for 10m² of green space per resident in urban areas, a target which would require a reversal of the current trend in Rayong's expanding urban areas of diminishing green space.

Other major social concerns include a lack of treatment of domestic waste-water and the generation and disposal of urban waste. The three municipal waste-water are functioning at 5% of their capacity, and less than 3% of the province's domestic waste-water is being treated. Some residences have septic systems, but environmental officials in the area report that many do not function correctly, if at all (REO, May 2019). Similarly, municipal waste-services in the province deal with over 1,000 tons of waste each day,

including both hazardous and non- hazardous waste. Less than half of this waste is disposed of correctly, and only a small percentage is recycled (interviews, PCD, May 2019).

Waste-water and solid waste are major issues that have to be dealt with in order to secure public health, quality of life and local livelihoods. While dealing with basic services issues such as waste management is conceptually simple, long-term strategies need to be adopted to improve the situation, particularly because of anticipated population growth.

Growing socio-economic inequality

The ratio of physicians to population is a key provincial indicator for adequate health services. Between 2010 and 2018, the ratio of registered Rayong residents per physician has dropped from one physician per 3,128 people to one physician per 3,748 people. If the number of unregistered people in the province is included, this takes the ratio to one physician for 7,000 people. With anticipated high population growth under the EEC (both in numbers of registered and unregistered people), the ratio of people per physician is likely to get worse. This will be of particular concern in districts where industrial growth attracts high numbers of immigrants.

The high number of people per physician in Rayong is indicative of a public health service and social security system that is under-funded. Under-funding in public health services means that health related costs for local residents will increase. New migrants will tend to be in higher socio-economic categories and will be in a better position to pay for medical and other social services they require. Also, many immigrants are likely to have health care costs included as part of their employment packages. Registered local residents will be eligible for free health care, but facilities and health care staff will need to greatly expand if demand is to be met.

Thus, for the short to medium term, socio-economic disparity between local and immigrant populations is likely to increase and quality of life of poorer people will tend to decline.

Centralized budgeting and allocation through line departments limits the capacity of provincial government to address the growing social equity challenges. An adequate response requires on-the-ground information, knowledge and experience not available to planners in Bangkok. There are insufficient in-depth studies into social disparity in Rayong, and how it relates to infrastructure provision, equity and quality of life.

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STRATEGIC THEME: ENERGY

1. Introduction

Rayong has developed into Thailand's main energy hub. It is the main on-shore hub for Thailand's off-shore natural gas and oil fields, as well as the destination point for gas from the Malaysia–Thailand Joint Development Area. It is an important energy import location with Map Ta Phut LNG Terminal handling Thailand's LNG imports, as well as substantial coal and oil imports. Rayong is also Thailand's main refining hub with four refineries in operation representing around 55% of Thailand's national refining capacity. Access to fuels means Rayong is also the site of a substantial share of Thailand's electricity production, with almost 11 GW of installed capacity or 25% of 25% of the national total.¹

2. Scope

The three strategic issues for the energy sector have been identified during the SEA consultation process as:

- Continued growth of decentralized power generation
- Rayong as a strategic energy hub for Thailand
- Environmental consequences of energy sector development¹

For each of these three major issues, past trends and the current situation are examined, with a brief analysis of how these trends are likely to project into the future. This theme deals with environmental issues pertaining to energy development, production and transformation. Issues resulting more directly from energy consumption, such as air pollution from transport, and energy efficiency at industrial plants, are addressed under those themes. To be more specific, this section covers the issues from oil and gas production in Rayong, issues related to the transport of coal, oil and natural gas, and issues related to the transformation of energy in the generation of electrical power. The impact of oil refining is addressed in the industry theme as it is not feasible to separate out the impacts of the refining sector from the broader petrochemicals sector.



STRATEGIC ISSUES OF CRITICAL CONCERN FOR SUSTAINABLE DEVELOPMENT IN RAYONG

- ✓ Continued growth of decentralized power generation
- ✓ Rayong as a strategic energy hub for Thailand
- ✓ Environmental consequences of energy sector development

SUSTAINABLE DEVELOPMENT OBJECTIVES:

- ✓ Promotion of renewables and energy efficient generation technologies
- ✓ Affordability of energy supply to residents and businesses in the province
- ✓ Reduce pollution emissions from energy supply to meet ambient and point source air quality standards and GHG emissions reductions targets.

3. Links to other sectors and themes

Industry: Rayong's status as an energy hub has been an important determinant of location in major industries such as gas separation, electricity generation, fertilizer manufacturing, petro-chemical industries and oil refineries. A combination of access to natural gas, and government policies and strategies promoting distributed electricity generation close to industry (e.g. Energy Industries Act 2007; EPPO 2015) has also resulted in more general industrial development in Rayong Province.

Energy-related transport: In addition to natural gas pipelines from the Gulf of Thailand, Rayong's Map Ta Phut Port has more than 25 shipping berths that cater for both energy and petro-chemical supplies. Energy related port capacity accounts for over 40% (around 490,000 DWT) of shipping berths (Shipping Guides Ltd., 2011).

¹ Issue iii was changed from industrial development identified in the consultation process as this issue is addressed in the industrial theme.

Environmental quality (including coastal and marine):

There have been numerous concerns raised about air quality around Map Ta Phut, including high profile court cases about the issue. The World Resources Institute has described Map Ta Phut industrial area as, “one of Thailand’s most toxic hot spots with a well-documented history of air and water pollution, industrial accidents, illegal hazardous waste dumping, and pollution-related health impacts” (Excell & Moses, 2017). That reputation is well earned, despite the area being declared a pollution control zone in 2009 (Poboon, Jongjaiphakdee, & Singkham, 2012). Most pollutants studied in the literature are associated with petrochemical industries rather than energy (e.g. Poboon et al., 2012). There is a scarcity of literature about particulate matter, which is often associated with sulfur and nitrous oxides, including those emitted during thermal power generation (USEPA, 2018), and which have significant health impacts (WHO, 2018). There is also a risk of degraded water quality from energy sector accidents such as ruptured pipelines or tanker spills. For example, on July 29, 2013, an oil leak from a ship to shore pipeline 20 km from the Map Ta Phut port impacted on the tourist resort island Koh Samet (Bangkok Post and DPA, 2013).

Social and Livelihoods: While energy in Rayong is primarily used for industry, it also plays an important role in residential areas and in commerce in the region.

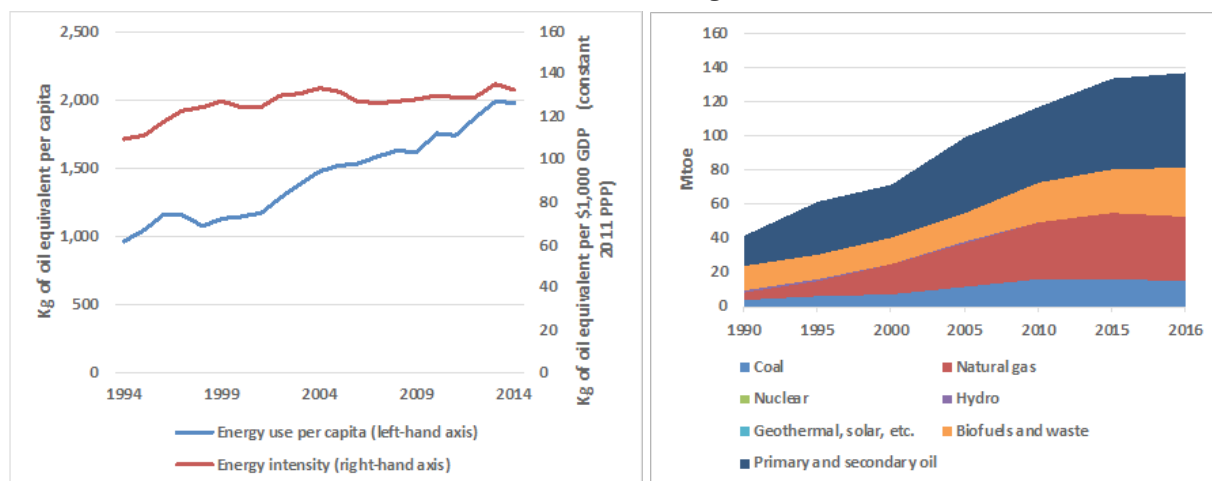
Transport: Increased freight and vehicular traffic on Rayong’s roads will add additional demand for fuel, whether that is gas, diesel or petrol. Around five percent of Thailand’s natural gas is consumed in natural gas powered vehicles (EPPO, 2018).

4. Overall context

As is typical with a country undergoing rapid development, Thailand’s energy demands have grown significantly over the last decades (Figure 5-1, right). With the growth of industrial and service sectors, the energy intensity² of Thailand’s economy has increased significantly over recent decades and overall energy consumption per capita has approximately doubled since 1994³. As the country’s energy demands have grown relative to limited domestic supplies it has been forced to rely increasingly on imports of oil, natural gas from Malaysia and Myanmar, LNG from Qatar and coal from Australia and Indonesia.⁴ Import reliance is expected to increase as domestic supply will be limited by production capacity and declining reserves.⁵ According to the IEA, Thailand’s TPES continues to rely heavily upon oil (41%), although natural gas accounts for a large share of energy supply (27%) and coal (11%) in 2016.

Thailand’s electricity demand has also increased rapidly (Figure 5-2), rising from around 125 TWh in 2005 to 198 TWh in 2016, at the same time per capita consumption has increased from 2,000 KWh/capita to 2,500 KWh/capita.⁶ Despite a moderation in consumption growth over recent years, at 4.2% the average annual growth rate between 2005 and 2016 still exceeded average growth in value added over the same period.⁷ In 2016 the electricity generation mix was dominated by natural gas (65%), with coal (19%) and biomass (10%) making up the next largest shares. Hydropower, waste to energy and renewables made up a little under 6% of the generation mix.⁹ This does not include substantial imports from coal-fired power and hydroelectricity from Malaysia and Lao PDR, amounting to around 20 TWh in 2016, or 10% of power supply.¹⁰

Figure 5-1. Thailand energy use and energy intensity 1994-2014 (left) and Total primary energy supply by source 1990-2016 (right)



Source: World Bank, 2019, World Development Indicators Database and IEA, 2019, Statistics Data Browser.

² Typically indicated by unit energy consumed per unit value added (e.g. KgoeUS\$⁻¹).

³ As a comparator, average OECD energy intensity was 110 Kgoe/capita and energy use per capita 4,142 Kgoe/capita in 2014 (World Bank 2019 WDI)

⁴ IEA Clean Coal Centre, 2013, BCLP Power Plant, Rayong Province Thailand. Website retrieved from <https://www.iea-coal.org/blcp-power-plant-rayong-province-thailand/>

⁵ Thailand’s reserve-to-production ratios are 2.3 years for oil, 5.5 years for natural gas and 81.8 years for coal (which is mainly lignite) BP Statistical Review of World Energy, June 2016

⁶ IEA, 2019, Statistics Data Browser

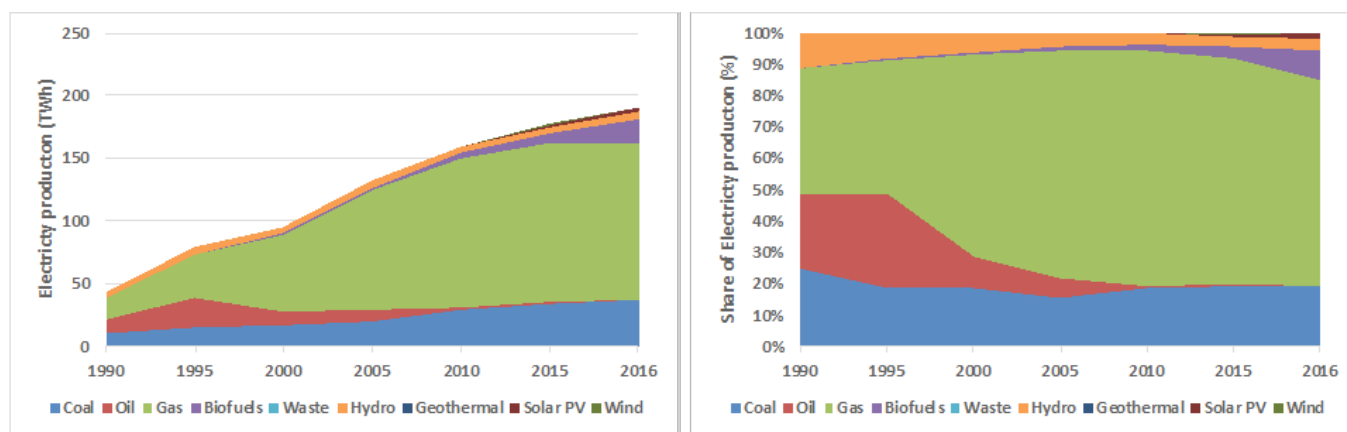
⁷ The GDP growth elasticity of consumption demand between 2005 and 2016 was approximately 1.2.

⁸ World Bank, 2019, World Development Indicators Database and IEA, 2019, Statistics Data Browser.

⁹ IEA, 2019, Statistics Data Browser

¹⁰ EIA, 2019, Thailand overview. Retrieved from <https://www.eia.gov/beta/international/analysis.php?iso=THA>

Figure 5-2. Electricity generation by technology (excluding imports) 1990 – 2016 value (left) and share of total (right)



Source: World Bank, 2019, World Development Indicators Database and IEA, 2019, Statistics Data Browser.

Thailand is heavily reliant upon its natural gas as the mainstay of energy supply and as a feedstock into Thailand's large petrochemicals sector. Thailand obtains around 70% of its natural gas from fields in the Gulf of Thailand (Figure 5-3). Most of the remainder is either imported from Myanmar by pipeline or imported from Qatar in the form of LNG.¹¹ Most of those pipelines terminate at Rayong where gas is processed and distributed by Thailand's extensive gas distribution network.

Rayong's Map Ta Phut port facilities and adjacent industrial area are central to this sector. Map Ta Phut industrial area includes four oil refineries constituting around 55% of Thailand's total refining capacity, the country's only gasification terminal for the import of LNG, a coal import terminal and BLCP's 1.4 GW coal fired power plant, as well as numerous smaller power generation and cogeneration facilities (typically natural gas fired). There are other power generation facilities located in and around the province. LNG facilities in particular have been rapidly developed. By 2017 PTT had doubled the size of LNG capacity to 13.6 billion m³year⁻¹, and has signed long term supply contracts with BP and Shell.¹²

5. Energy projects

Rayong is a national energy hub, with extensive gas pipelines and gas separation terminals, LNG import infrastructure, oil refineries and power plants, not to mention an extensive range of energy intensive heavy industry, particularly in the petrochemicals and related sub-sectors. Table 5-1 gives current capacity for oil refining, LNG terminals and gas separation units. This currently constitutes around 55% of Thailand oil refining capacity, around 84% of its gas separation capacity and all of the country's LNG import capacity.

Table 5-2 breaks down power generation facilities in Rayong province by type. There are 57 power plants with almost 11 GW of total capacity. Most of these are gas fired CHP plants. There are two large coal fired power plants, and a number of smaller renewables plants.

Figure 5-3. Thailand's natural gas transmission lines, showing Rayong's strategic importance



Source: PTT, 2019, PTT website. Retrieved from <http://www.pttplc.com/en/About/Business/PTT-Owned-Business/Gas-Unit/Pages/transmission-pipeline.aspx>

Source: MONRE EEC Pollution Control Centre, 2019

¹¹ Enerdata, 2014; Thailand Oil and Gas, 2018

¹² EIA, 2019, Thailand overview. Retrieved from <https://www.eia.gov/beta/international/analysis.php?iso=THA>

Table 5-1. Gas and oil processing infrastructure

Project name/type	Capacity
Map Ta Phut Thailand LNG Terminal	15.6 billion m ³ year ⁻¹
PTT gas separation plant (Units 1-3, 5 and 6 in Map Ta Phut)	71.1 billion m ³ year ⁻¹
IPRC Rayong Refinery	215,000 bbl/day
Rayong Purifier Refinery (Rayong Purifier Company)	17,000 bbl/day
SPRC Map Ta Phut Refinery	165,000 bbl/day
PTT Global Chemical Refinery	280,000 bbl/day

Source: Rayong Provincial Development Plan, A Barrel Full, 2019, website. Retrieved from <http://abarrelfull.wikidot.com/thai-oil-refinery>

Table 5-2. Power generation facilities in Rayong province 2019

Type	Number	Installed capacity (MW)	Notes
CHP	33	7,527	Largest Gulf PD plant with 2,500 MW under construction COD date 2023, others below 180 MW
Thermal power plant (coal)	7	2,589	Only two plants exceeding 160 MW, Gulf NLL2 (660MW) and BLCP Power Company Limited (1,436MW)
Thermal power plant (natural gas)	4	590	Between 70 MW and 300 MW
Waste to energy (biogas and solid waste)	10	58	All below 10 MW but 14.5 MW PTT
Solar PV	3	14	All plants 6MW or below
Total	57	10,777	

Source: Rayong Department of Energy

Known future developments in the energy sector include:

- ✓ A **2.65GW gas-fired power plant** developed by Gulf PD to be constructed in Pluang Daek with a COD date of 2023 for phase one and 2024 for phase two¹³;
- ✓ Additional **1 GW unit at BLCP coal fired power plant**, unclear how far this project has progressed, although the EIA for it is complete;
- ✓ **Map Ta Phut Port Phase 3** - port facilities will be expanded from the current 160 hectares to 320 hectares which will include 56 hectares for gas terminals and gas-related warehousing and businesses including additional LNG terminal, able to support 264,000 DWT vessels.

6. Key stakeholders

- Industrial estates and the businesses within them;
- Small power producers, (and maybe Very Small Power Providers) in Rayong;

- Rayong Provincial Energy Office;
- Provincial Electricity Authority / Electricity Generating Authority of Thailand;
- Ministry of Energy and Energy Policy and Planning Office;
- Map Ta Phut port; and,
- Petroleum Authority of Thailand.

7. Government targets that influence the energy sector

There are important national targets for energy efficiency improvement, which are properly dealt with in the themes that address end-use sectors (such as industry, transport and urban development). Here, the discussion is limited to important national and sub-national plans and policies that are likely to affect the development of the energy supply and transformation sectors in Rayong province.

Power development plan 2018-2037: Envisages a 40% expansion of generation capacity from 46.1 GW in 2017 to 77.2 GW in 2037, including a greater role for private

¹³ (EPPO, 2015), See also <https://gulf.listedcompany.com/misc/presentation/20180820-gulf-presentation-2q2018.pdf> (slide 12); also MHPS, 2018, MHPS Receives Order to Construct 5,300MW Power Plant Project in Thailand Incorporating Eight M701JAC Gas Turbines. Website retrieved from <https://www.mhps.com/news/20180209.html>

power provision (and a concomitant decline in the share of EGAT-owned generation) as well as a greater diversification of the energy mix. This includes expansion of imports (from Myanmar, Lao PDR and Cambodia), coal and renewables.¹⁴ At the same time a shift away from domestic natural gas towards imported LNG is planned. This reflects the decline in proven domestic gas reserves¹⁵, which are expected to be exhausted by the early 2020s. Thailand is undertaking exploration to extend the life of Gulf of Thailand reserves, but is expected to be heavily reliant on imported liquid natural gas (LNG) by 2030.¹⁶

The Eastern Economic Corridor (EEC) development plan for Chonburi, Chachoengsao and Rayong provinces:

The plan envisages the expansion of the Map Ta Phut port facilities from 160 hectares to 320 hectares which will include 56 hectares for gas terminals and gas-related warehousing and businesses.¹⁷

Small power producer (SPP) programme: First adopted in 1992 to encourage the development of private small fossil fuel (up to 90 MW) and renewables plants. Fossil fuel plants were restricted to those meeting conditions on cogeneration (at least 10% of waste steam energy used) and efficiency (greater than 45%), which were later relaxed. Legislation developed in 2007 to support smaller scale has further promoted cogeneration plants.¹⁸

Very Small Power Producer Programme: Regulations adopted in 2002 to allow renewables generators to export up to 1 MW to the grid and to offset their consumption at retail rates.¹⁹

8. Past trends and current situation

- ✓ Rayong as a strategic energy hub for Thailand
- ✓ Continued growth of decentralized power generation
- ✓ Environmental consequences of energy sector development

Rayong has developed as Thailand's main energy hub. Including the terminus and processing facilities for most of Thailand's off-shore gas and oil production, the port also

provides facilities for oil, coal and LNG imports (predominantly from the Persian Gulf). Rayong is also the main hub for Thailand's extensive gas transmission and distribution network. Finally, the province also accounts for a large share of electricity generation capacity.

Electrical generation capacity has climbed steadily over the last two decades. Rayong's share of national generation capacity between 2000 and 2017 has fluctuated between around 13% and 25% of national capacity, with a growth trend. Similar to the overall generation figures, around 22% of Thailand's SPPs (by number) are located in Rayong Province. The energy generation trends are shown in Figure 5-4.

Distributed generation and, associated with this, cogeneration have played an important part in the development of the energy sector in Rayong. Currently, the province hosts nearly half of Thailand's SPP capacity.²⁰ SPP power production has grown steadily in Rayong since distributed energy generation legislation was introduced in Thailand in the early 1990s and again updated in 2007²¹. Of the current 4,886 MW of SPP and VSPP capacity in Rayong, around 29% was installed between 2010 and 2015, with a further 37% installed between 2016 and 2019 (Figures 5-5 and 5-6). While the legislative environment promoted privately financed, small scale gas cogeneration plants, Rayong proved the ideal location for the development of such facilities. The concentration of energy intensive heavy industry in the province generates significant demands for electricity and other energy services (steam, hot water, cooling). At the same time the extensive gas supply infrastructure provided opportunity for relatively easy connection to gas supplies.

Distributed electricity generation poses some monitoring challenges for electricity and energy authorities. This is because the provincial electricity authority (PEA), which is responsible for distribution of electricity, does not have mechanisms for gathering information about power supplied directly to industrial customers by SPPs. For example, the U-Tapao airport upgrade has no direct impact on PEA forecasting of distribution requirements because all of the airport's power requirements are supplied by SPPs.²²

A key issue for Thailand and Rayong as the country's energy hub is the increased reliance on energy imports. Reliance on energy imports as a share of energy consumption has not shown any increasing trend (Figure 5-7 left), and in fact has decreased in recent years. However, the absolute levels of imports have increased significantly over the last three decades (Figure 5-7 right). Imports mainly consist of crude

¹⁴ Bangkok Post, 25 January 2019, National power plan expands private output. Website retrieved from <https://www.bangkokpost.com/business/news/1617382/national-power-plan-expands-private-output>

¹⁵ (e.g. Enerdata, 2014; Janssen, 2015)

¹⁶ (Wiwattanadate, 2016)

¹⁷ (EECO, 2018)

¹⁸ Greacen, C., 2007, An emerging light - Thailand gives the go-ahead to distributed energy. Power Engineering International website. Retrieved from <https://www.powerengineeringint.com/articles/decentralized-energy/print/volume-8/issue-2/features/an-emerging-light-thailand-gives-the-go-ahead-to-distributed-energy.html>

¹⁹ ibid.

²⁰ ICEM calculated from EPPO (2015), supplemented with data from individual producers.

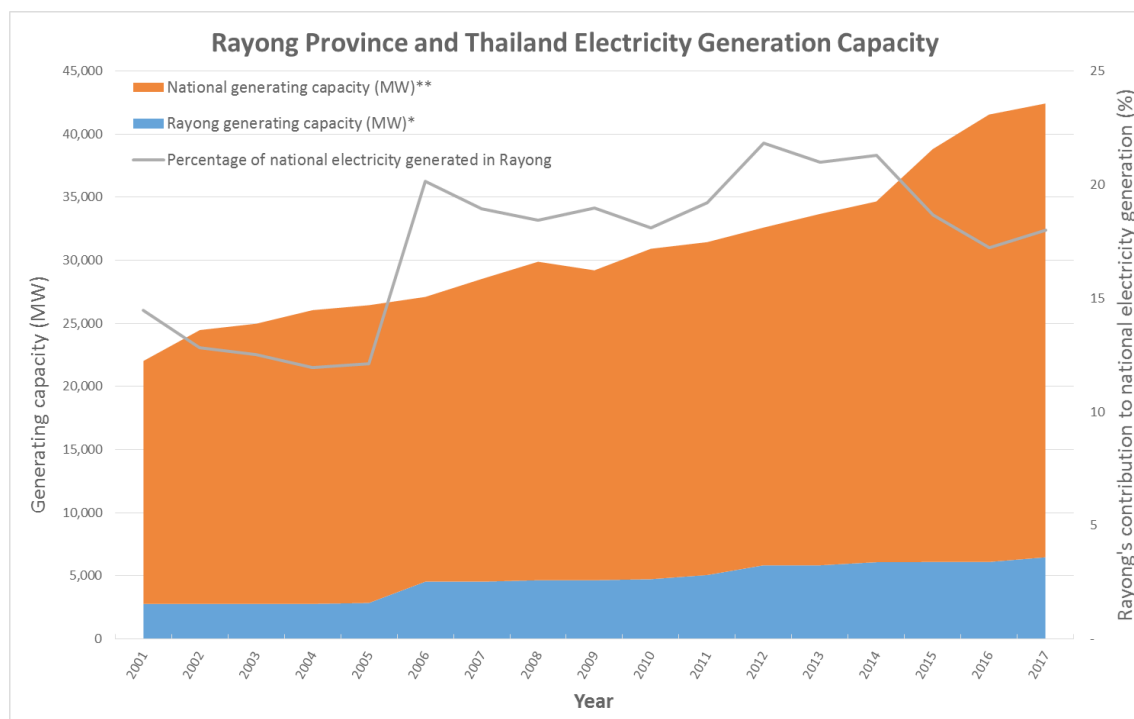
²¹ Williams & Ghanadan, 2006; Greacen, C., 2007, An emerging light - Thailand gives the go-ahead to distributed energy. Power Engineering International website. Retrieved from <https://www.powerengineeringint.com/articles/decentralized-energy/print/volume-8/issue-2/features/an-emerging-light-thailand-gives-the-go-ahead-to-distributed-energy.html>

²² PEA Chonburi – interviews.

oil, since the late 1990s natural gas imports via pipelines from Myanmar came on line and since 2011 LNG imports have gradually increased. Imports of electricity have also increased over the same period, in particular from hydropower and lignite plants in Lao PDR.²³

At the same time, proven gas reserves in the Gulf of Thailand are becoming depleted. This decline has been compounded by limited investment in exploration and new field development over recent years.²⁴ The increased reliance on imports is of particular importance for Rayong province as this is a key import hub, for oil, LNG and coal.

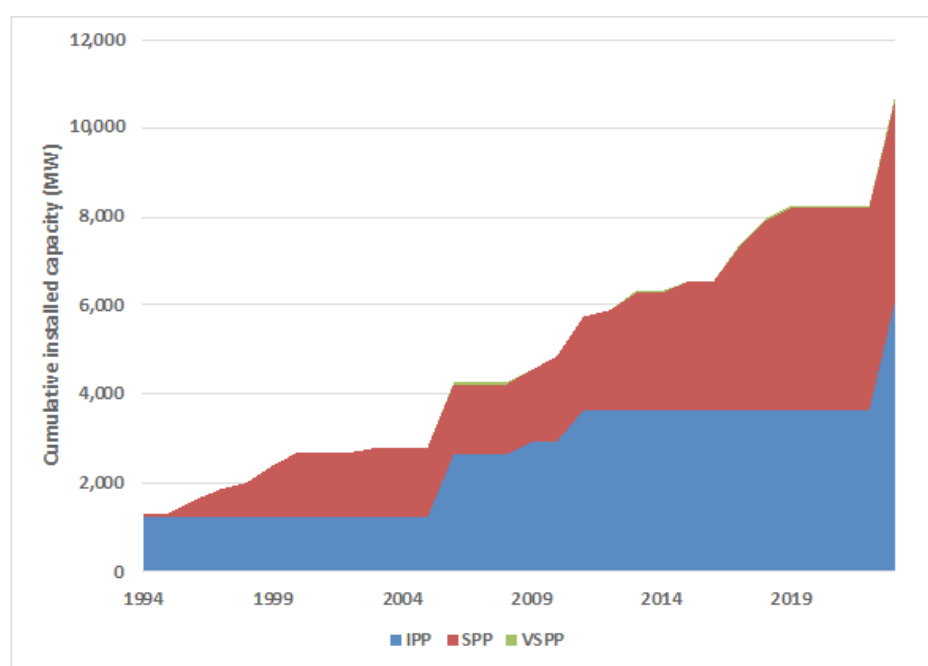
Figure 5-4: Comparing electricity generation capacity in Rayong Province with national capacity



* Source: Rayong Provincial Development Plan & Individual Generators

** Source: (EPPO 2019)

Figure 5-5: Cumulative installed capacity in Rayong by investment type 1994 - 2023

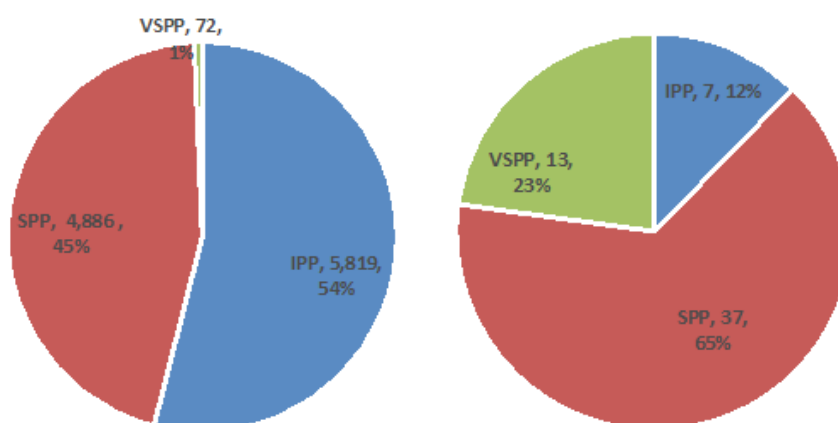


RPDP, 2018 & Individual Generators

²³ EIA, 2019, Thailand overview. Retrieved from <https://www.eia.gov/beta/international/analysis.php?iso=THA>

²⁴ Ibid.

Figure 5-6: Power plants by designation IPP, SPP and VSPP



RPDP, 2018 & Individual Generators

Energy sector development has been an essential part of economic growth in Rayong province. However, this development has brought with it a number of important

environmental impacts and risks. Tables 5-3 – 5-5 give an over view of the types of pollution risks that emerge from the sector.

Table 5-3. Emissions to air from energy sector activities

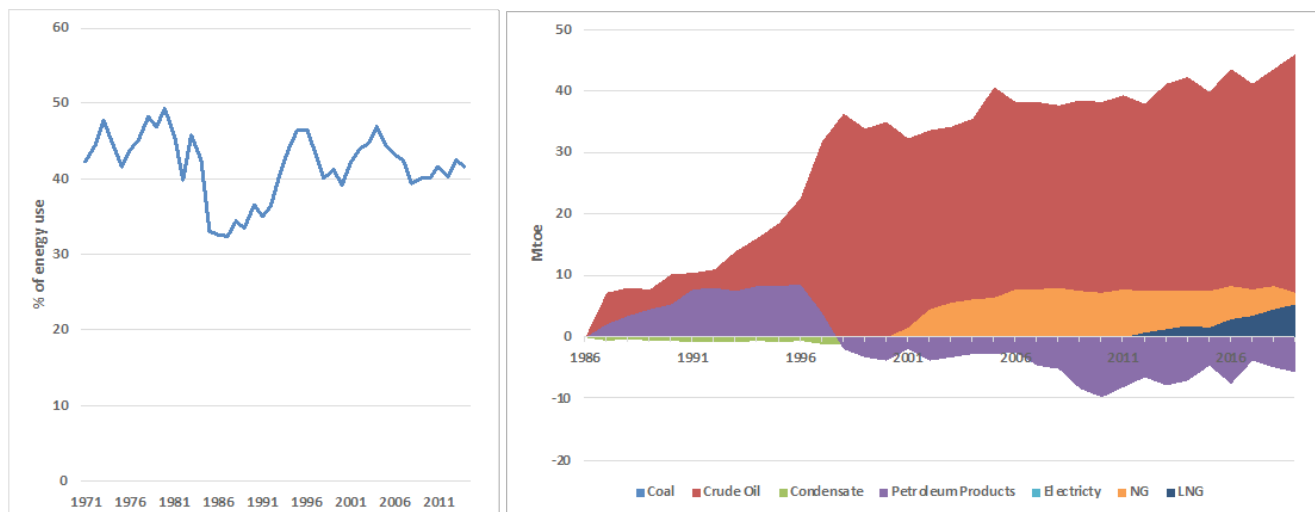
Activity	Source	Potential air pollutants
Natural gas, LNG transport and processing	Leaks (from including compressors, valves, pumps, flanges, gauges, and pipe connectors) and routine venting during processing ²⁵ . Engines and other combustion from transport/processing operations	CH ₄ , and other pollutants leading to the formation of ground level ozone, VOCs, hazardous air pollutants such as benzene, hydrogen sulphide, Formaldehyde Depending on the chemical composition of the NG and processing procedures
Oil transport	Engines and other combustion from transport/processing operations	VOCs, fugitive methane emissions, SO _x , NO _x , PM ₁₀ , PM _{2.5} from combustion (shipping in particular)
Coal transport and storage	Engines and other combustion from transport. Coal dust	SO _x , NO _x , PM ₁₀ , PM _{2.5} from combustion (shipping in particular)
Power generation - Oil	Combustion of oil in plant	SO _x , NO _x , PM ₁₀ , PM _{2.5} from combustion
Power generation - NG	Combustion of gas in plant	Minor Sulphur, mercury, and particulate emissions (PM ₁₀ , PM _{2.5}). More importantly NO _x (which are precursors to smog)
Power generation - Coal	Combustion of coal in plant	SO _x , NO _x , PM ₁₀ , PM _{2.5} from combustion. Heavy metals (e.g. Hg ²⁶ , As, Co etc.)

Source: ICEM 2013

²⁵ From Alvarez, A.R., 2018, Air pollution issues associated with Natural Gas and Oil operations. Website retrieved from <https://www.edf.org/sites/default/files/AWMA-EM-airPollutionFromOilAndGas.pdf>. "For example, one technology used throughout NG systems is pneumatic valves, which operate on pressurized NG and by design bleed small quantities of gas during normal operation. Additionally, gas is often vented from storage tanks, dehydrators, depressurization of equipment before maintenance, and wells after hydraulic fracturing or when accumulated liquids are removed."

²⁶ Emissions of mercury from coal-fired plants are dependent upon a range of factors including physical and chemical characteristic of the coal, combustion conditions and possible reactions with other emissions in the flue gas. In particular, the mercury content of the coal, the presence of halogens with which mercury can react in the combustion process, and pollution control processes including pre-washing coal and FGD technologies which can both serve to reduce mercury emissions (UNEP 2008, Sloss 2010).

Figure 5-7: Import dependency as share of energy use 1971-2014 (left) and total energy imports/exports by fuel 1996-2018 (right)



Source: World Bank, 2019, World Development Indicators; EPPO, 2019, Energy Statistics website retrieved from [http://www.eppo.go.th/index.php/en/en-energystatistics/summary-statistic?orders\[publishUp\]=publishUp&issearch=1](http://www.eppo.go.th/index.php/en/en-energystatistics/summary-statistic?orders[publishUp]=publishUp&issearch=1)

Table 5-4. Potential water emissions from thermal power plants by type

Activity	Source	Potential air pollutants
Natural gas, LNG transport and processing	Lubricants, degreasers, water treatment chemicals/effluent, detergents	Oil spills*, degreasers*, cooling system inhibitors, detergents
Oil transport	Oil and oil based products	Oil spills*
Coal transport and storage	Coal, coal dust, coal pile run-off	Suspended solids, acidic run-off, heavy metals
Steam cycle/pulverised coal, natural gas, oil	Coal, demineralised water, auxiliary fuel (fuel oil, natural gas, briquettes), lubricants, degreasers, water treatment chemicals/effluent, detergents	Chlorine, acids, alkalis, suspended solids, nitrogen, phosphorus, trace metals, oil spills*, degreasers*, detergents
Gas turbine/natural gas, distillate	Natural gas, auxiliary fuel (distillate, LPG), lubricants, degreasers, detergents, cooling system inhibitors	Oil spills*, degreasers*, cooling system inhibitors, detergents
Internal combustion engine/natural gas, LPG, distillate	Natural gas (oe LPG), auxiliary fuel (distillate), lubricants, degreasers, coolants	Waste coolant*, oil spills*, degreasers*, detergents

Source: EPA

*due to infrequent unplanned incidents

Table 5-5. Emissions to land from thermal power plants

Activity	Source	Potential land emissions
Natural gas, LNG transport and processing	Lubricants, degreasers, water treatment chemicals/effluent, detergents	Oil spills*, degreasers*, cooling system inhibitors, detergents
Oil transport	Oil and oil based products	Oil spills*
Coal transport and storage	Coal, coal dust, fly-ash	Acidic run-off, heavy metals
Steam cycle/pulverised coal, natural gas, oil	Coal, demineralised water, auxiliary fuel (fuel oil, natural gas, briquettes), lubricants, degreasers, water treatment chemicals/effluent, detergents	Ash, oil/chemical spills*, metals, wastes
Gas turbine/natural gas, distillate	Natural gas, auxiliary fuel (distillate, LPG), lubricants, degreasers, detergents, cooling system inhibitors	Oil spills*, wastes
Internal combustion engine/natural gas, LPG, distillate	Natural gas (oe LPG), auxiliary fuel (distillate), lubricants, degreasers, coolants	Oil spills*, wastes

Source: EPA

*due to infrequent unplanned incidents

Details of likely pollution loads to air, water and land resulting from energy sector operations in Rayong are not available. Drawing a link between these and air quality, and public health and other environmental impacts is also problematic, due in part to other sources of pollution (e.g. industry and transport), and due to a dearth of detailed studies.

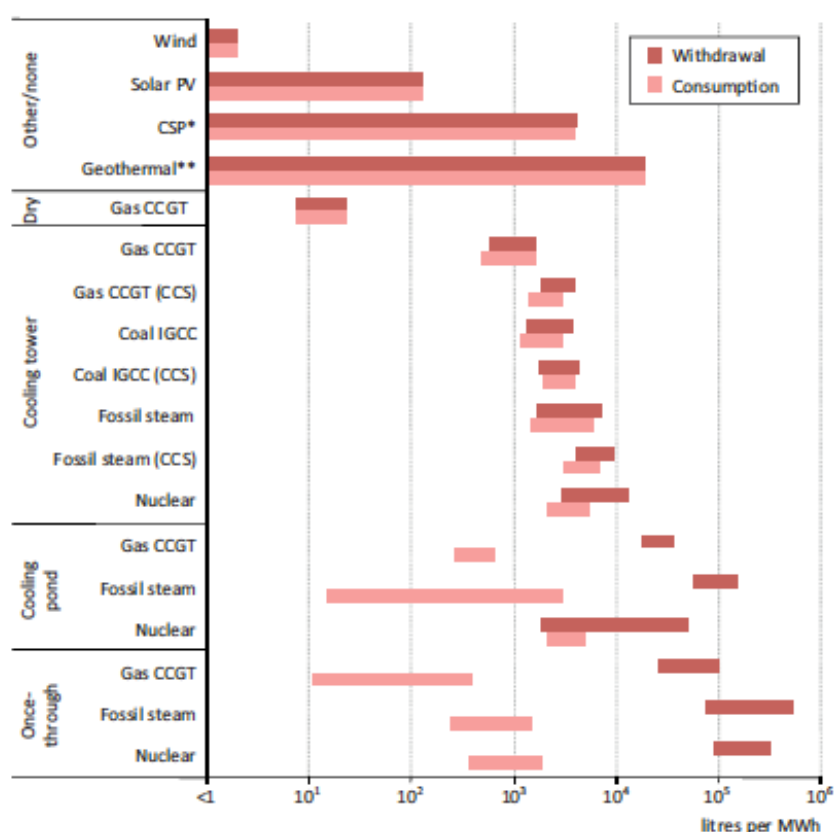
Nevertheless, there are known impact pathways between the potential pollution emissions identified here and important environmental and health impacts. At the global level these include the link between GHGs and climate change, and locally links between respiratory and cardiovascular conditions and air pollution. Similarly, there are known air quality issues in the area surrounding Map Ta Phut port and industrial area. Finally, it is important to stress the risk posed by accidental incidents, such as the 2013 oil spill which severely impacted tourism in Koh Samet, had important impacts on marine life and affected the local fishing industry. It is difficult to quantify this risk, but with an increase in port traffic and increasing volumes of fossil fuels being shipped to Map Ta Phut, these risks can only increase.

Water is essential for the operation of most power plants. Thermal plants depend on water for cooling, operating

steam turbines, cleaning, fuel preparation and treatment and for some pollution control technologies. Water needs vary considerably depending on external environment, fuel, plant type, cooling technology and operational factors amongst other things.

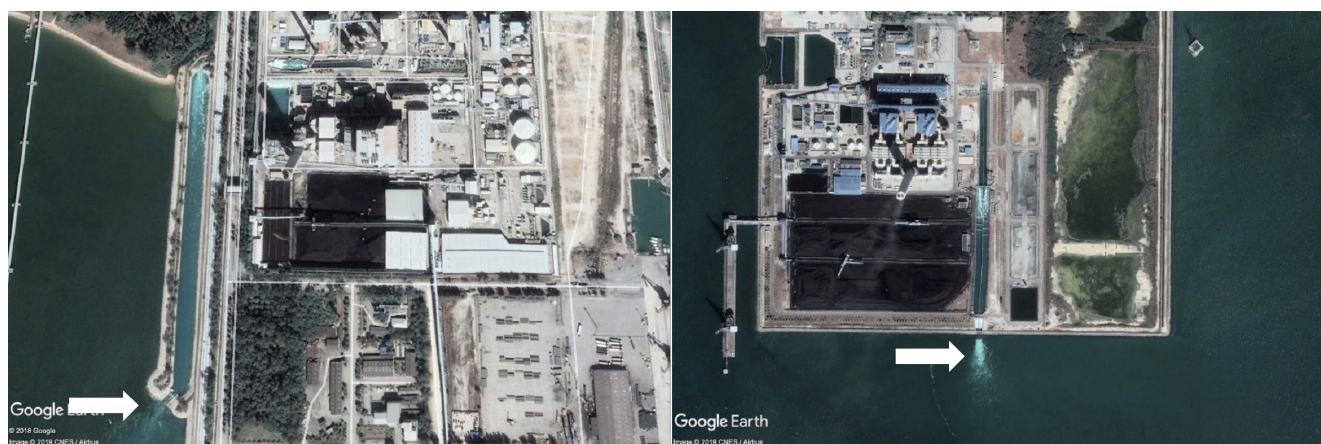
Figure 5-8 illustrates the key findings of a recent comprehensive literature review of water use for different types of power plants in the United States (Macnick et al 2012). Water abstractions can be quite large with once-through thermal plants needing over 200,000 litres/MWh generated, but also quite variable with CCGT using dry cooling technology only requiring a maximum of 15 litres/MWh. In terms of consumptive use of water (i.e. water that is not returned to the system), technologies that tend to have higher withdrawal needs – such as once-through cooling systems – have lower consumptive needs. Data on the cooling technologies used in power plants in Rayong are not available. However, as these figures suggest water needs for the sector can be substantial. For example, images from power plants in Map Ta Phut (Figure 5-9) suggest Gheo 1 and BLCP coal power plants use a once through cooling process. Median water withdrawal figures for this type of plant are around 138 m³ MWh.⁻¹

Figure 5-8: Water use and consumption in the power sector



Source: IEA 2012 based upon Maknick et al 2011

Figure 5-9. Coal power plant water discharges at Map Ta Phut Gheco 1 (left) and BLCP (right)



Source: Google Earth 2019

9. Future trends

- ✓ Rayong as a strategic energy hub for Thailand
- ✓ Continued growth of decentralized power generation
- ✓ Increased reliance on energy imports
- ✓ Environmental consequences of energy sector development

Rayong as a strategic energy hub and increased reliance on energy imports

Rayong will continue to be a major energy hub for Thailand into the foreseeable future. Energy demand from all sources is expected to increase along with GDP growth. Alternative energy sources and power imports (from hydropower and coal plants) are expected to increase in importance, but plans still imply a significant increase in the import of oil, LNG and possibly coal.

Similarly, electricity demand is expected to increase by around 2.6% per year (PDP 2015-2036), to a peak of 49,655 MW and an annual power demand of 326 TWh, or around 61%.²⁷ Increasing electricity demand will imply greater diversification of the generation mix and the development of significant new gas, renewables and import capacity (as well as significant energy efficiency efforts) (Table 5-6).

As such Rayong and Map Ta Phut port is expected to remain an important energy hub – although with the emphasis shifting to a significant increase in energy imports as domestic production declines. Government policies and plans support this shift, including plans for significant increases of LNG capacity in Rayong, a doubling in the size of Map Ta Phut industrial area and the development of additional port facilities.

Continued growth of decentralized power generation

Further installation of SPPs in Rayong is to be expected, however there are two forces that may counter this. Firstly, the national targets for the amount of gas in the power

Table 5-6. Comparing 2016 generation mix with proposed 2037 generation mix

Technology	2016	2037 ²⁸
Natural gas	59	56
Coal	18	13
Hydropower (imports) ²⁹	13	10
Alternative energy	10	21
Others	0.3	0.06

Source: IEA, 2019, Statistics Data Browser; DFDL Thailand, 2019, Thailand's 2019 Power Development Plan: What to Expect. Website retrieved from <https://www.dfdl.com/resources/legal-and-tax-updates/2019-power-development-plan/>

²⁷ Detailed information on the revised PDP has not been available, it is assumed the demand forecast remains the same.

²⁸ Excludes 6% of demand 'met' by energy efficiency savings.

²⁹ Based upon EIA figures for current electricity imports from lignite and hydropower plants in Lao PDR of 20 TWh in 2016. See EIA, 2019, Thailand overview. Retrieved from <https://www.eia.gov/beta/international/analysis.php?iso=THA>

generation sector may not allow more approvals for gas-fired SPPs. New SPPs may thus choose to install coal-fired plants, depending on whether small-scale coal is viable, something that is yet to be proven (see e.g. Proctor, 2018). Second, available land for industrial expansion. For example, currently 10-15% of land zoned for industry is still vacant in Rayong (interviews, Town and Country Planning Office, 2019). Since SPPs are almost exclusively co-located with industry, lack of room for industrial expansion would also limit the scope for further installation of SPP power plants in Rayong. Furthermore, it unclear what role the development of distributed renewables capacity may take in the province. High land prices may preclude large scale development of land intensive renewables, but it may be an option for vacant land adjacent to industrial areas.

Environmental consequences of energy sector development

The likelihood of the further, large scale development of the energy sector in Rayong implies a significant additional burden on the environment. Increased imports of LNG, coal and oil by tanker will increase the risk of an accidents similar to the 2013 spill. Any increased coal use will imply risks posed by large scale coal storage (such as particulate generation and potential issues with coal-pile run-off), as well as additional air and water pollution issues related to the combustion of coal in the area. Similarly, an increase in gas imports is likely to imply increases in fugitive emissions. Additional gas fired capacity, while much less polluting than coal or oil alternatives will still pose issues related to NOx generation, ground level ozone and smog.



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STRATEGIC THEME: INDUSTRY

1. Introduction

Since Thailand's Fifth National Economic and Social Development Plan (NESDB, 1981) was launched, Rayong has been on an industrialisation trajectory. Three key factors underlie the decision to promote Rayong as an industrial hub for Thailand;

1. The discovery of abundant natural gas reserves in the Gulf of Thailand;
2. Proximity to Bangkok as well as Thailand's north-eastern region; and
3. Suitability for a deep sea port and for landing of piped gas.

Rayong now has the highest per capita gross provincial product (GPP per capita) in Thailand, almost double Bangkok's per capita GPP². Rayong's industrial areas are home to more than half of Thailand's oil refining capacity, more than 90% of Thailand's petrochemical capacity³ and around 25% of national electricity generation capacity⁴, as well as automotive, electronics and bio-technology industries⁵. At the same time, industrial growth in the province has increasingly put environmental systems under pressure through pollution emissions and increasing natural resource use.

2. Scope

The three strategic issues of concern for the industrial sector were identified during the SEA consultation process as:

1. Rapid industrial growth;
2. Increasing generation of industrial pollution; and
3. Increasing resource use by industry.

Past trends and the current situation are examined for each of these three major issues, with a brief analysis of how the trends are likely to project into the future.

STRATEGIC ISSUES OF CRITICAL CONCERN FOR SUSTAINABLE DEVELOPMENT IN RAYONG

- ✓ Rapid industrial growth
- ✓ Increased generation of Industrial pollution
- ✓ Resource use in industry

SUSTAINABLE DEVELOPMENT OBJECTIVES¹:

- ✓ Environmentally sustainable development through the promotion of green industries using cleaner production technologies and resource efficient production
- ✓ Use of best international practice in environmental technologies and management to prevent the discharge of industrial pollutants to water, air and land
- ✓ Structural transformation increasing the capacity of local industry for value-addition, diversification, job creation and production in high-tech sectors

3. Links to other sectors and themes

Energy: Energy and industry sectors are very closely linked because industrial processes are large consumers of power, and because large parts of Rayong's industry are directly concerned with the petrochemicals sub-sector, including the refining industry and production of fuels.

Urban development: Industrial development in Rayong province, and employment generation in the sector has been an important attractor for in migrants, which have contributed to population growth in the region and the development of large urban areas.

¹ Based upon Thailand 4.0 and UNIDO principles, see <https://thaiembdc.org/thailand-4-0-2/>

See https://www.nesdb.go.th/nesdb_en/ewt_dl_link.php?nid=4317&filename=national_account

² See <https://thaiembdc.org/wp-content/uploads/2015/05/Petrochemicals.pdf>

³ Figures derived from Rayong Provincial Development Plan and EGAT, 2019, retrieved from <https://www.egat.co.th/en/information/statistical-data?view=article&id=80>

⁴ See [https://www.boi.go.th/upload/content/13.15%20-%2015.15%20\(4\)%20-%20EEC%20Act%20in%20Action_EN_5ab214187ff41.pdf](https://www.boi.go.th/upload/content/13.15%20-%2015.15%20(4)%20-%20EEC%20Act%20in%20Action_EN_5ab214187ff41.pdf)

⁵ See [https://www.boi.go.th/upload/content/13.15%20-%2015.15%20\(4\)%20-%20EEC%20Act%20in%20Action_EN_5ab214187ff41.pdf](https://www.boi.go.th/upload/content/13.15%20-%2015.15%20(4)%20-%20EEC%20Act%20in%20Action_EN_5ab214187ff41.pdf)



Environmental quality: Industry in Rayong is associated with significant pollution emissions and discharges. Industry is responsible for the generation of large quantities of waste. Issues of emissions to air, wastewater, solid waste and hazardous waste have all increased over the years. Map Ta Phut industrial estate was declared a pollution control zone in 2009, and pollution incidents related to the industrial sector remain frequent.

Social and Livelihoods: Industry has significantly changed the cultural and ethnic make-up of the population of Rayong, as well as changing employment patterns and living conditions. In addition, public health issues related to the impacts of industrial pollution on environmental quality are important.

Transport: Increasing transport demand have been associated with industrial development in the province. Increases in the volume of shipping, road freight and rail freight have largely been driven by the expansion of the industrial sector (for the import of raw materials and intermediate inputs as well as the transport of finished products). Industrial employment and related increases in local population have also been important factors in increasing commuter traffic.

Coastal and Marine: Industry links to coastal and marine zone because of the impact of port facilities on the coastal and marine environment, as well as through the impact of wastewater and solid waste discharges that make their way to the sea.

Water: Industry uses substantial amounts of water. For example, Map Ta Phut industrial estate has a water production capacity of 15,300 cubic metres per day, and the Eastern Seaboard Industrial Estate has a water distribution capacity (from Dok Krai Reservoir, Nong Pla-Lai Reservoir) of 36,000 cubic meters per day, plus water production capacity of 2,900 cubic metres per day.

Agriculture: Because of the heavy usage of water by industry,

industry can impact on availability of water for farmers. Industry also uses land that may otherwise have been able to be farmed.

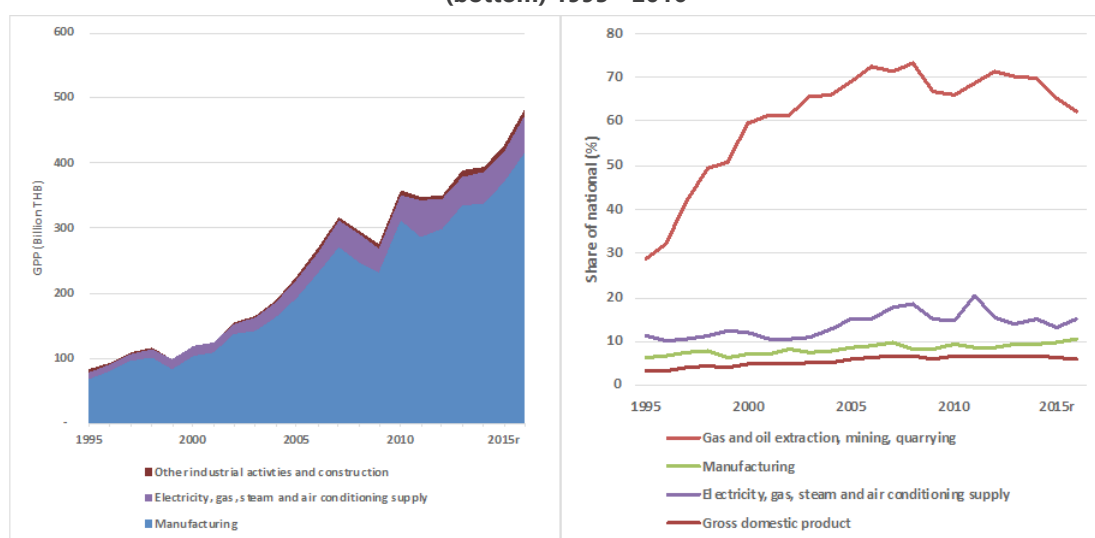
Climate change: Industry is a major emitter of various GHGs including CO₂ and CH₄. Industry is also the main water user in the province, which may make it vulnerable to any decreases in water availability due to climate change.

4. Overall context

Industrial development in Rayong has taken place in the broader context of industrial development and structural change in Thailand as a whole. In common with other developing countries, economic growth in Thailand has been driven by growth across all economic sectors, but also a shift away from production in primary sectors (such as agriculture, forestry and fisheries) towards sectors with higher levels of productivity (service and industrial sectors). Much of this structural change had happened prior to 1990, at which point agriculture constituted less than 10% of GDP, the service sector over half of GDP and the manufacturing sector around a third.⁶

Prior to the mid-1980s much of this growth, and industrial growth in particular was concentrated in and around the Bangkok region. The Eastern Seaboard Development Program (ESBDP) sought to create a more geographically balanced distribution of growth across Thailand.⁷ The ESDP was one of the largest infrastructure projects in Thailand, centered on deep-water ports in Laem Chabang (Chonburi Province) and Map Ta Phut (Rayong province) and including transportation, water and industrial infrastructure. Development in Rayong in particular was focused on the creation of a heavy petrochemical industry utilizing natural gas in the Gulf of Thailand.⁸ The plan was initially designed in the late 1970s by the National Economic Social Development Board and was financed mainly by the World Bank and the government of Japan.⁹

Figure 6-1: Rayong GPP for major industrial sectors (top) and share (%) of national GDP attributable to Rayong (bottom) 1995 - 2016



Source: NESDB, 2018

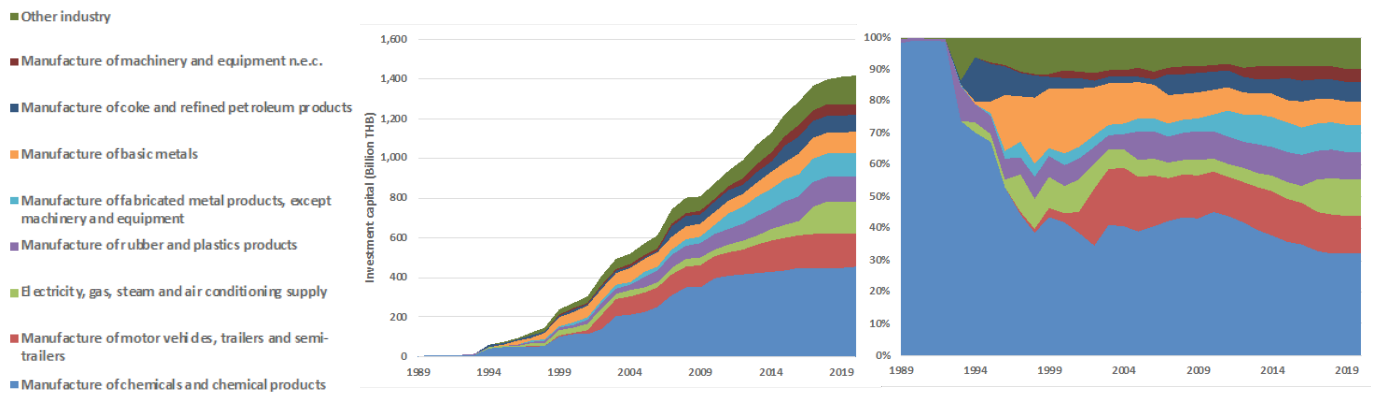
⁶ World Bank, 2019, World Development Indicators.

⁷ https://www.nesdb.go.th/ewt_w3c/ewt_dl_link.php?nid=6473

⁸ Construction of the first natural gas pipeline to bring gas from the gulf to Rayong commenced in 1981 (NESDB, 1981).

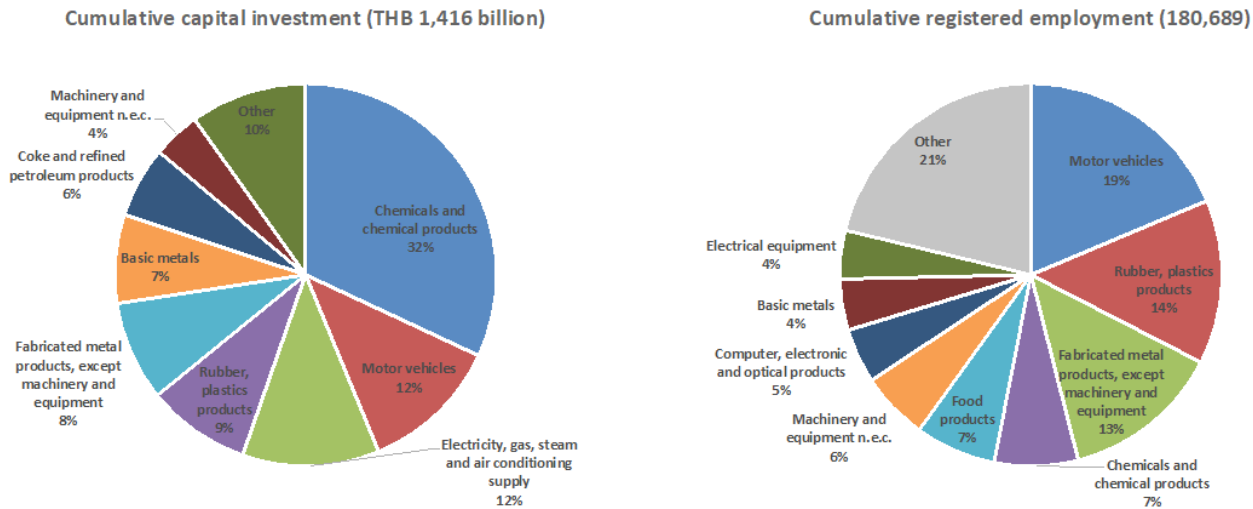
⁹ Mieno, F. 2013, The Eastern Seaboard Development Plan and Industrial Cluster in Thailand: A Quantitative Overview. In Aid as Handmaiden for the Development of Institutions A New Comparative Perspective.

Figure 6-2: Cumulative investment capital by major subsector 1989-2019 by value (left) and share (right)



Source: Rayong Provincial Industrial Office, 2019

Figure 6-3: Cumulative industrial investment capital and employment by major sub-sector in Rayong province 2019



Source: Rayong Provincial Industrial Office, 2019

Figures 6-2 and 6-3 illustrate the development of the industrial sector in Rayong province over time and in terms of the current conditions. These figures show the dominance of the petrochemicals sector in the province, by 2019 accounting for around 32% of cumulative investment in the industrial sector, followed by other sectors including manufacture of motor vehicles, energy services and rubber and plastics products.

In contrast, the motor vehicles sector is the single largest industrial employer in the province, followed by rubber and plastic manufacture and fabricated metal products. Employment in the chemicals sector only accounts for 7% of industrial employment in the province. This is explained by a much higher capital intensity in chemicals and energy sub-sectors in particular.

Rayong's industry is primarily located in industrial estates and industrial parks. There are currently 12 industrial estates in the province. These have been established in four districts over the period 1989 to 2014, and between them the industrial estates cover an area of almost 8,300 ha (Table 6-1). Aside from those located within designated industrial estates, which are administered by the Industrial Estate

Authority of Thailand, a large number of enterprises (over 2,000) are located outside these zones in industrial clusters administered by Rayong province.¹⁰

Figure 6-4 shows the rapid change in land use and development of industrial areas in Rayong province along the transportation corridor to Chonburi and Bangkok, and Figure 6-5 shows both the growth of the Map Ta Phut port and industrial complex and the development in the surrounding area. In both figures the extensive change in land use from agriculture to residential, infrastructure and industrial uses is clear.

Map Ta Phut port and industrial zone was at the heart of the ESDP in Rayong. Map Ta Phut began as a 960 Ha development and has since grown to 2,100 Ha. The industrial area was developed to house heavy, capital and technology intensive industry.¹¹ Currently, the Map Ta Phut industrial estates house 142 factories, including oil refineries, petrochemical, chemical, fertilizer, paint, gas separation facilities, steel and metal product factories, factories focused on rubber, plastic and leather products, as well as automotive spare-parts and electronics.

¹⁰ Interview with Rayong province department of industrial works

¹¹ Laem Chabang industrial estate, in Chonburi, by contrast was developed to house light, low polluting industry.

Table 6-1: Industrial areas in Rayong province 2014

Industrial Estate Name	Location (District)	Year Es- tablished	Land area (ha)
RIL Industrial Estate	Map Ta Phut	1989	270
WHA Eastern Industrial Estate	Map Ta Phut	1989	555
Map Ta Phut Industrial Estate	Map Ta Phut	1990	1112
Padaeng Industrial Estate	Map Ta Phut	1992	86
Eastern Seaboard Industrial estate	Pluak Daeng	1996	1437
Amata City Industrial Estate	Daeng	1996	1381
WHA Eastern Seaboard Industrial Estate	Pluak Daeng	1996	1280
Asia Industrial Estate	Banchang	2001	515
Rayong Industrial Estate	Ban Khai	2011	352
WHA Industrial Estate Eastern Seaboard 2	Pluak Daeng	2014	584
WHA Eastern Seaboard Industrial Estate 3	Pluak Daeng	2014	352
WHA Industrial Estate Eastern Seaboard 4	Pluak Daeng	2014	352

*Notes: Amata City Industrial Estate spans the Rayong Chonburi boundary

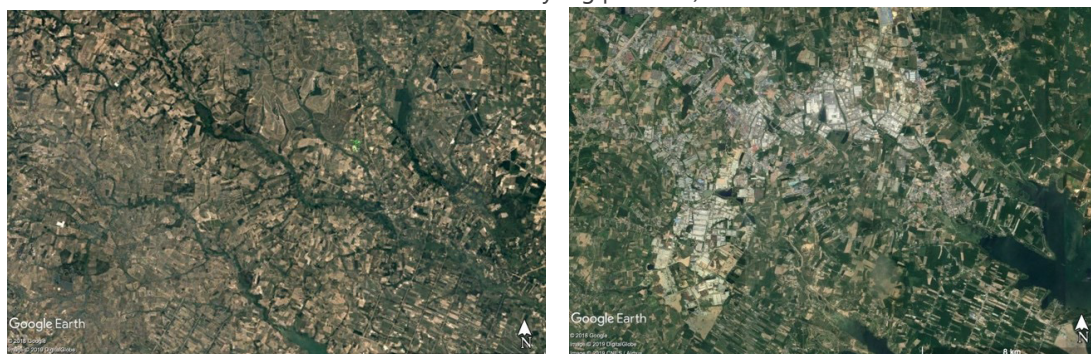
5. Industry Projects

The upgrade of the Map Ta Phut Port: The Industrial Estate Authority of Thailand (IEAT) has approved a budget of approximately US \$350 million for enlarging the Map Ta Phut Port facilities by 160 ha, specifically to increase capacity for importing liquid natural gas (LNG) as well as other public berths for shipping. An additional US \$63 Million has been approved to develop 240 ha of land for new generation industries such as robotics, renewable energy and digital industries, under the Smart Park project.

Eastern Economic Corridor of Innovation: Four hundred and eighty hectares (480 ha) of land has been allocated in the Wang-Chan valley of Rayong for to develop research and innovation facilities. It is not clear what the focus of the research to be conducted here will be.¹³

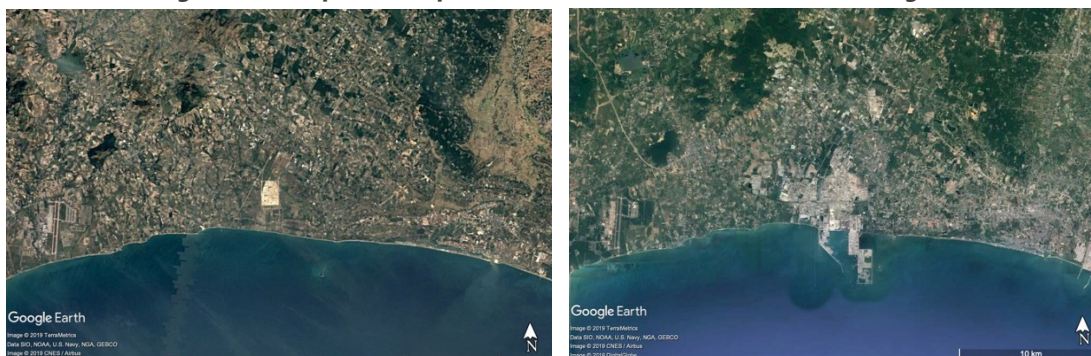
Digital Park Thailand: One hundred and thirteen hectares (113 ha) of land has been allocated in Rayong's Siracha district for the purpose of updating digital infrastructure and the establishment of the ASEAN data hub.

Figure 6-4: Development of industrial facilities in ESD 1984 (left) and 2016 (right) (northwestern border of Rayong province)



Source: Google Earth 2019

Figure 6-5: Map Ta Phut port and environs 1984 (left) and 2016 (right)



Source: Google Earth 2019

¹² <https://www.bangkokpost.com/business/news/1394374/b13bn-assigned-to-map-ta-phut>

¹³ <https://www.eeco.or.th/en/content/project-progress>

¹⁴ Poboon, C. Jongjaiphakdee, W. and Singkham, T. 2012, Air pollution management in Rayong's industrial area, Thailand. WIT Transactions on Ecology and The Environment, Vol 157.

¹⁵ Tremlova, J. 2017, Mercury in Fish from Industrial Sites in Thailand. Arnika.

6. Key stakeholders

- Industry and business
- Ministry of Energy
- Nearby communities
- Provincial Electricity Authority / Electricity Generating Authority of Thailand
- Industrial Estate Authority of Thailand
- Management Authorities for the 12 Industrial Estates in Rayong
- Industrial Parks and their owners
- Transport sector
- Eastern Economic Corridor Office

7. Key government targets that will influence industrial development in Rayong

Key government targets that are likely to influence industrial development in Rayong province include:

- **Thailand 4.0:** To create a value-based economy that is driven by innovation, technology and creativity, through increase R&D, resulting in higher economic growth. At the same time the strategy targets climate change resilience and a low carbon society;
- **EEC development:** Development of Thailand's first new economic growth region (with a focus on S-curve industries), as a centre for trade, investment, regional transportation, and a strategic gateway to Asia.
- **Energy efficiency targets in the revised Power development plan:** Reduction of energy consumption across all sectors of 5% relative to a BAU scenario.

8. Past trends and current situation

- ✓ Rapid industrial growth
- ✓ Generation of Industrial pollution;
- ✓ Resource use in industry

Rapid industrial growth: Growth in industrial sectors has been rapid, with real-term growth in provincial value-added, running at around 3.6% per year. This figure tends to understate the scale of industrial growth as a large proportion of growth has been in relatively low value-added, if strategically important, refining and petrochemicals sectors. The growth in the sector in terms of physical footprint, resource use and output has been of greater significance, in terms of provincial development, employment and environmental outcomes (see following sections).

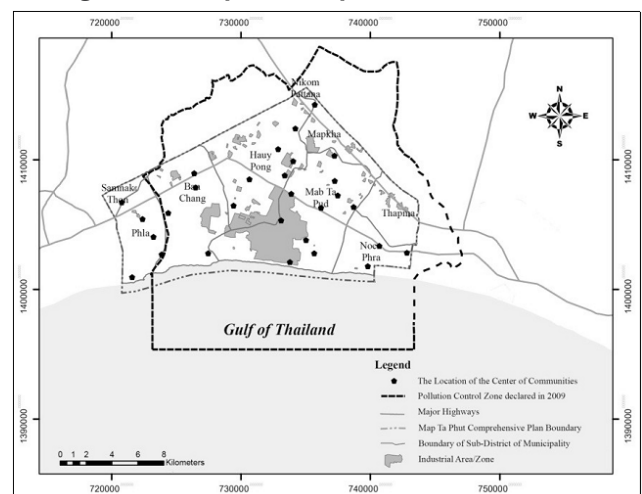
Generation of industrial pollution: Industrial growth in the province has been accompanied by significant growth in the generation of industrial pollution. Emissions to air, effluent discharges, and solid and hazardous waste generation have all increased with development of the industrial sector. At the same time limited controls on pollution have led to a deterioration in ambient environmental quality. Critical issues have developed with air quality and water quality.

Air pollution: Figures on emissions to air from the industrial sector in Rayong are not available. However, based on evidence on environmental quality and air pollution monitoring stations in the province it is clear that air pollution from industrial activities is a persistent problem. A wide variety of industries are located within the province, with concentrations of heavy industry and the petrochemicals sector in particular.

Industrial pollution in industrial areas housing petrochemical and refining activities mainly consists of VOCs, SO₂, and SO_x. Recent evidence points to the importance of Volatile Organic Compounds (VOCs), with over 40 types having been recorded. Of these, 20 are potentially carcinogenic. Of most concern are benzene, butadiene and 1,2-dichloroethene.¹⁴ Emissions from combustion in the production of heat or energy at industrial plants is another potential source of emissions to air (including SO_x, NO_x, PM₁₀, PM_{2.5}) as are other fugitive emissions. Concentrations of of persistent, bioaccumulative pollutants such as heavy metals (Hg, As) are also an issue in some areas.¹⁵

Pollution control measures are in place to limit the quantity and toxicity of emissions to air from industry, these include scrubbers and electro-static precipitators to remove pollutants from emissions stacks, flaring of fugitive emissions and the use of various filtration technologies. At the same time, around Map Ta Phut, a buffer zone has been implemented in an attempt to control land uses close to the industrial area and thus reduce exposure to air pollution, although there remain issues with enforcement and compensation for residences within the zone.

Figure 6-6: Map Ta Phut pollution control zone



Source: Phattraporn Soyong, P. & Perera, R., 2014, *Use of GIS Tools for Environmental Conflict Resolution at Map Ta Phut Industrial Zone in Thailand*. Sustainability 2014, 6, 2435-2458.

As a consequence of high levels of pollution and significant pollution incidents at Map Ta Phut and adverse health effects in the local population, in 2007 communities in Map Ta Phut successfully sued the National Environment Board (NEB) for ignoring communities' request for designation of the area as a pollution control area (Figure 6-6) in accordance with the Enhancement and Conservation of the National Environment Quality Act B.E. 2535 (Map Ta Phut Watch, 2011). Subsequent to this case being settled the area in and around Map Ta Phut was designated a pollution control zone, with stringent pollution control measures in place monitored by the pollution control board. Although more extensive monitoring is in place and some emissions have been reduced, issues with pollution continue.¹⁶

In common with the petrochemicals sector in other countries, unplanned, excess emissions (as opposed to regular emissions) remain a problem.¹⁷ Excess emissions include emissions from unplanned events, such as natural disasters, and emissions due to scheduled start-up, shutdown, and maintenance. Indeed, in some cases excess emissions can constitute the bulk of pollutant emissions. It should be noted that while most air pollution issues have centered around the concentration of industrial activities in and around Map Ta Phut, other industrial sites continue to present air pollution issues, albeit issues that are less well documented and are subject to fewer, less stringent pollution controls. For example, at the IPRC refinery in Rayong.¹⁸

Solid and hazardous waste: Another important issue of concern is management of industrial wastes. Thailand's eastern region produces large quantities of industrial waste, with most generated in Rayong and Chonburi provinces. The industrial sector is responsible for 2.29 million tons of waste of which 37% is hazardous (Table 6-2). Most of the hazardous waste material is generated in Map Ta Phut district. Waste collection and disposal is managed by the private sector, with Ratchaburi being the main disposal site.

Table 6-2: Quantity of industrial solid waste in Rayong 2016 - 2018

Year	hazardous industrial waste (millions of tons)	Non-hazardous industrial waste (millions of tons)	Total industrial waste (millions of tons)
2016	0.36	0.93	1.29
2017	0.37	0.88	1.26
2018	0.35	0.84	1.19

Source: Department of Industrial Works, 2019, Conclusion of Industrial Waste Collection Reported by Disposition Site. Ministry of Industry, Thailand. Retrieved from: <http://www.diw.go.th/hawk/content.php?mode=waste61>

Illegal disposal of industrial waste is an issue in the Map Ta Phut industrial area. Between 1999 and 2006 there were six reported instances of illegal industrial waste disposal within what was to become Map Ta Phut pollution control area alone.¹⁹ Many more cases within and outside the control zone go unreported (REO 2019). In the development plan for industrial waste, it is recognized that increasing numbers of industrial organizations in Rayong should be accompanied by more industrial waste disposal sites and effective treatment. These sites must be properly regulated, monitored and audited.

Water pollution: Water pollution from industrial sources remains a persistent problem. Water pollution from industrial sources can come in the form of direct discharges of effluent to water courses or indirectly through the generation of secondary pollutants, such as the acid formation (from SO_x and NO_x), and through leachate from inadequate solid waste land fill disposal. The species of water pollution emissions from industry differ depending on the industrial activity involved and any water treatment processes used. Common pollutants include organic matter, nitrates, phosphates, hydrocarbons, POPs and heavy metals. Industrial enterprises are required to meet effluent discharge parameters and, if necessary, treat wastewater to ensure these parameters are met. However, enforcement is weak, the level of fines for polluting establishments is low and complex institutional mandates mean that often pollution issues are not addressed.

The quality of surface water, the water in major rivers and ground water is generally poor in Rayong with some indications of decline in the last decade or so. Municipal wastewater and agriculture are large contributors to declining water quality. Nevertheless, given the importance of the industrial sector in the province and the limited level of pollution control, industry is an important source of pollution, particularly for hazardous effluents, and a significant contributor to declining water quality.

Resource use: Industrial expansion has also resulted in the increase of resource use. Land and water use have risen significantly with growth in the industrial sector.

Figure 6-7 shows cumulative land use by industrial estates (IE) and by industry more generally from 1989 to 2019. Designated IE land has risen from zero prior to 1989 to over 8,000 Ha in 2014. Provincial records show the area of land registered to industrial enterprises is around 14,000 ha. Around a third of industrial land is outside IEs. Not all industries are within IEs, and some IEs may have vacant plots especially soon after commissioning.²²

Industry is also a significant source of water demand. Industrial water users generally obtain their water from the utility supply, but in some cases they may rely on ground

¹⁶ Poboon, C. Jongjaiphakdee, W. and Singkham, T. 2012, Air pollution management in Rayong's industrial area, Thailand. WIT Transactions on Ecology and The Environment, Vol 157; consultations with Map Ta Phut district, Rayong and Rayong PCB.

¹⁷ ICEM with Rayong PCB; Texas Commission on Environmental Quality. Retrieved from <https://www.tceq.texas.gov/airquality/point-source-ei/psei.html>

¹⁸ The Nation, 26 May 2019, Time that Rayong Refinery Cleaned Up its Act. Retrieved from http://www.nationmultimedia.com/detail/your_say/30346309

¹⁹ Public Information Center, 2007, Industrial Pollution Map. Department of industrial works, Ministry of Industry, Thailand. Retrieved from: <http://www2.diw.go.th/PIC/map.html>

²⁰ ICEM with government agencies.

²¹ PCD, 2015, Thailand State of Pollution Report 2015.

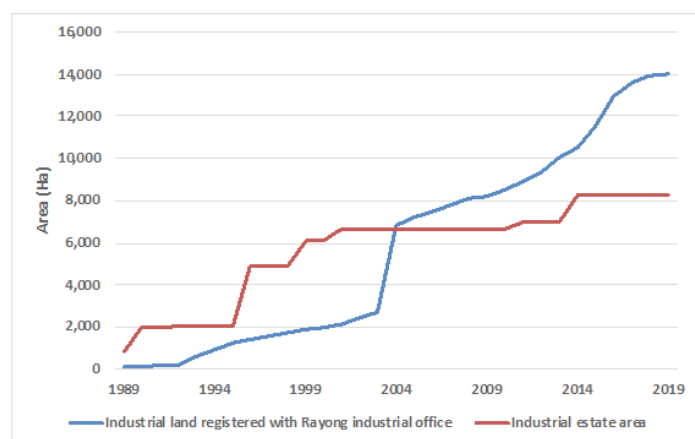
²² Rayong Department of Industrial Works Database.

Table 6-3: Estimated water demand by industrial subsector 2011

Sub-sector	Water Demand	
	MCM year ⁻¹	Share (%)
Mining and quarrying	6.8	2.0
Petroleum	0	0.0
Food manufacture	6.4	1.9
Coconut and palm oil	0	0.0
Sugar Refineries	0	0.0
Beverages and tobacco	0	0.0
Clothes, fur, paper	12.7	3.7
Basic chemical products	122	35.8
Fertilizer and pesticides	8.8	2.6
Other chemical products	112.9	33.1
Ceramics, concrete	4.3	1.3
Petroleum refineries	33.6	9.9
Basic metal	25	7.3
Motor vehicles	0	0.00
Repairing of motor vehicles	0.6	0.2
Construction	0.1	0.0
Electricity	6.8	2.0
Pipe-line	0.9	0.3
Total industrial use	341	100.0
Total provincial use (agriculture + industry + services)	678.4	50.3

Source: Jampanil, D. & Suttinon, J. 2013, *Application of input-output table for estimating impact of water demand under climate change in Thailand: Rayong province case study*.

Figure 6-7: Cumulative industrial estate area



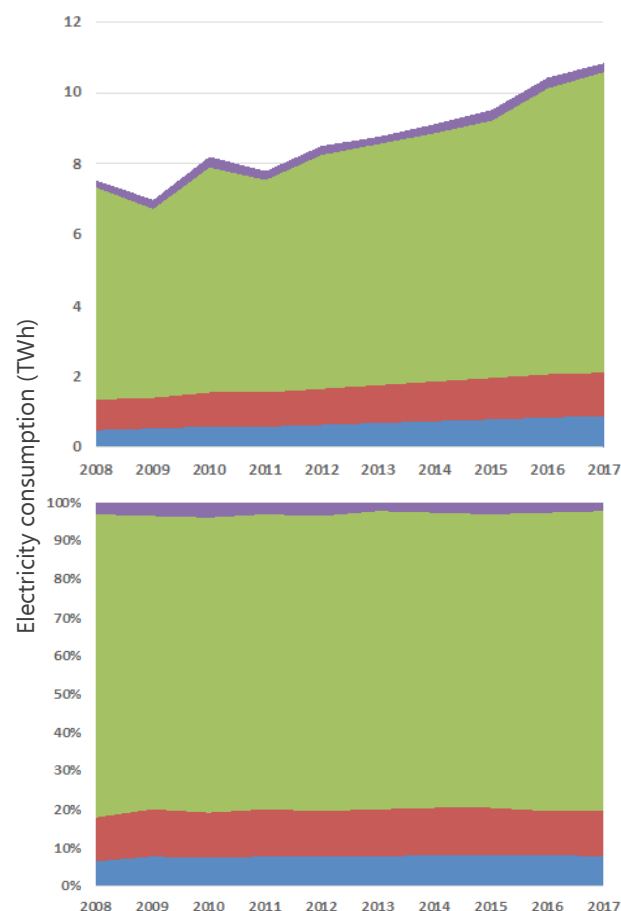
Source: Rayong Industry Office & Industrial Estate Authority of Thailand

Other
Large business
SMEs
Residential

or surface water sources, or a combination of all three. Table 6-3 gives estimated water demand for the industrial sector in Rayong based upon provincial output figures and national input-output tables. From these estimates it is clear that industry is the most significant user of water in the province accounting for around 50% of water use. Of this total, around 69% is from the manufacture of chemicals, with refining the third biggest sector accounting for around 10% of consumption.

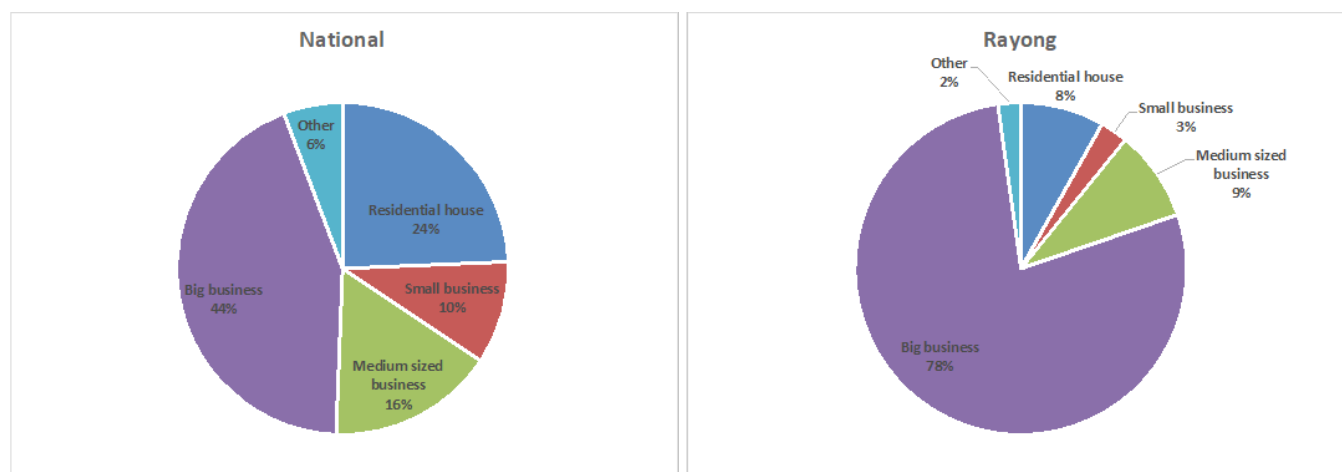
Energy usage by the industrial sector is also significant. Industry makes use of energy from a range of sources including electricity, natural gas, coal and fuel oil. Energy needs in the industrial sector has been an important driver of the development of CHP plants in Rayong province (see Energy baseline). While, data on industrial energy use in the province is limited, figures on electricity use by sector are available, illustrating the importance of the industrial electricity consumption in the province. Growth in industrial electricity demand between 2008 and 2017 has been at 3.9% for large businesses and 4.5% for SMEs, compared to a growth rate of 6.3% for the residential sector (Figure 6-8). However, given the dominance of the large-scale industrial sector in the province this has made little material difference to the relative share of electricity consumption. Thus, electricity consumption growth has largely been driven by large-scale industry accounting for approximately 76% of consumption growth between 2008 and 2017. Figure 6-9 serves to illustrate the importance of the large-industrial sector in the province relative to the nation as a whole. The large industrial sector in Rayong accounts for around 14% of electricity use by large industry nationally, and around 7% of total electricity use nationally.

Figure 6-8: Electricity consumption by sector 2008-2017



Source: Provincial Energy Department, 2019

Figure 6-9: Electricity consumption by sector 2019, national (left) and Rayong province (right)



Source: Provincial Energy Department, 2019

8. Future trends without the Rayong Provincial Development Plan

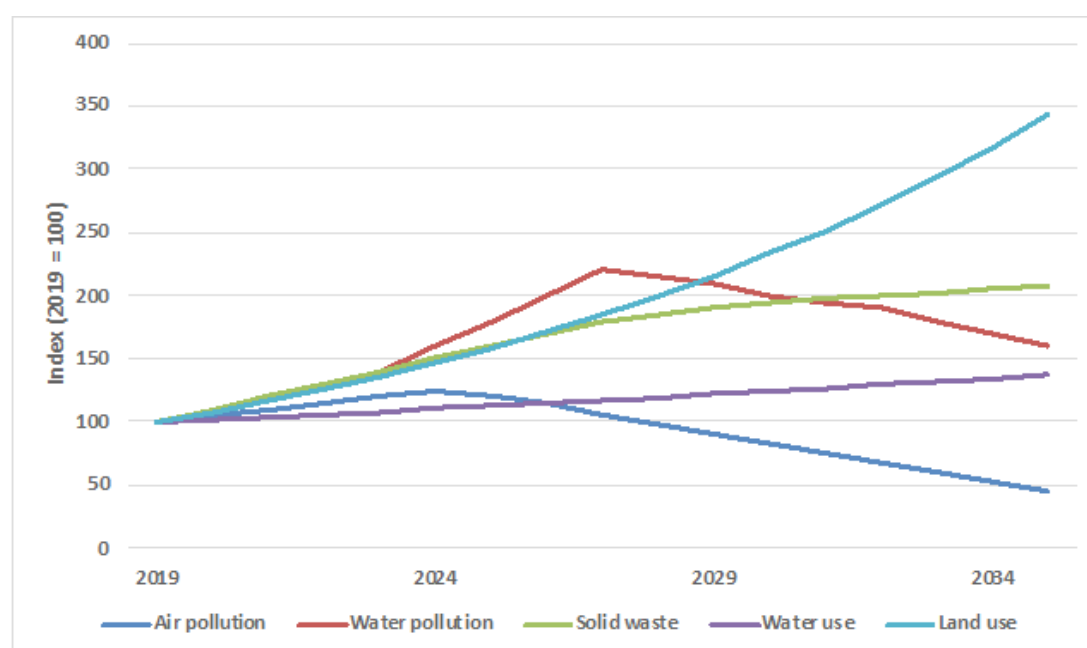
- ✓ Rapid industrial growth
- ✓ Increased generation of Industrial pollution
- ✓ Resource use in industry

It is expected that industrial sector value-added growth will continue in-line with overall GDP growth at around 4 % per year. That trend is roughly in line with the growth of electricity

consumption by large industrial enterprises in the province. The likely physical expansion of the sector is described in business-as-usual (BAU) projections (Figure 6-10).

In general, pollution emissions are likely to increase before they peak and decrease overtime as better pollution control measures are adopted and industry shifts towards less polluting sectors. Air pollution is expected to decline most quickly as it is the most pressing concern for the authorities. Solid waste and water pollution are also expected to decline but at slower rates reflecting a lower priority and greater difficulty in realising effective pollution control measures. A shift away from water intensive industrial sectors is similarly reflected in a slowing rate of water consumption growth. Land demand from industry is expected to continue on trend, with no likely change in rate of growth.

Figure 6-10: Likely trends in main industrial environmental impacts 2019-2035



Source: ICEM 2019

STRATEGIC THEME: TRANSPORT

1. Introduction

Development of the transport sector in Rayong has been instrumental in its recent economic growth, and the expansion of the industrial sector in particular. Since the 1980s and as a consequence of the Eastern Seaboard Development Program (ESBDP), Rayong has developed into a national hub for the import and processing of fuels (natural gas, LNG and crude oil) and heavy industry (with a particular focus on petrochemicals). This in turn has acted as a significant draw for migrant labour, and as a result Rayong's population has increased to around 1.2 million (see social and demographic issues baseline). In addition, in 2017 7.3 million, mainly domestic, tourists visited Rayong (see tourism issues baseline report). The development of the transportation sector (particularly highways and Map Ta Phut port) has been integral to the rapid development of the province, at the same time rapid increases in transportation demand and expansion of transportation infrastructure have brought a number of environmental concerns including air pollution and increased resource use.

2. Scope

The two main issues for the transportation sector were identified during the consultation process as: i) expansion of transportation infrastructure; ii) increasing air pollution due to increased transportation.² For each of these major issues, past trends and the current situation are examined, with a brief analysis of how these trends are likely to project into the future. As such this theme deals with environmental issues pertaining to changes in transportation.

3. Links to other sectors and themes

Energy: The majority of Rayong's transport is currently motor vehicles, including private cars, trucks and buses. These rely on diesel, petrol or natural gas for power. There are existing (non-electrified) railway lines linking Map Ta Phut port to Sattahip port and Bangkok.

STRATEGIC ISSUES OF CRITICAL CONCERN FOR SUSTAINABLE DEVELOPMENT IN RAYONG

- ✓ Expansion of transport infrastructure
- ✓ Increasing air pollution due to increased transportation

SUSTAINABLE DEVELOPMENT OBJECTIVES:¹

- ✓ Promote an equitable and safe transportation system, offering a choice of transport modes, and a geographical balance of development.
- ✓ Reduce transportation related emissions and resource use

Urban development: Rayong's urban population has been growing rapidly over the last 20 years. Transportation services such as mass transit options are important aspects of modern urban centres.

Environmental quality: The transport sector is a major emitter of pollutants including CO, SO_x, NO_x, VOCs, PM_{2.5} and PM₁₀, NO_x is also a precursor to tropospheric O₃.³ With Rayong's heavy industrialization, and associated freight requirements, it can be expected that Rayong's transport emissions are significant, despite the province's small population. Additional to the air pollution issues, there is a possibility that sump oil and other pollutants from vehicles are not being disposed of properly, and are finding their way into waterways and/or polluting soil.

Industry: Industry requires transportation services for freight, for waste collection and for workers to be able to get to and from their workplaces.

Climate change: In 2011 transport related greenhouse gas emissions in Thailand accounted for 27% of national emissions.⁴

¹ <http://www.eskema.eu/DownloadFile.aspx?tableName=tblSubjectArticles&field=PDF%20Filename&idField=subjectArticleID&id=208>

² Issue ii was changed from industrial development identified in the consultation process as this issue is addressed in the industrial theme

³ See https://www.eea.europa.eu/data-and-maps/daviz/contribution-of-the-transport-sector-5#tab-chart_4

Social and Demographics: Health impacts related to air pollution, including from particulate matter (PM) and nitrogen oxides (NO_x), are well known, including cardiovascular and respiratory disease (WHO 2018). While data for Rayong is incomplete, in Bangkok the transport sector is responsible for 80% of NO_x, and 54% of PM.⁵

Tourism: With over 7 million tourist a year visiting Rayong province, the sector also represents an important source of transport demand.

4. Overall context

Rayong is connected to the national road network, and in particular the ESB corridor through Chonburi province to the north and Bangkok, to the west. Rayong is linked to Pattaya via highway 7 and highway 36 (Sattahip port, Pattaya, Laem Chabang port), and to the north east of the country through highway 317 (Figure 7-1). In addition to the roads shown, there is single track railway connecting Map Ta Phut with Bangkok. Rayong is also home to an international airport at U-Tapao. Finally, the province is home to a number of port facilities, largest and most significant amongst these is Map Ta Phut which is an important hub for gas pipeline landing, oil and LNG imports and petrochemical's exports. Road transport is the most common mode of transport in Rayong for both personal use and for freight. Private vehicles are the main road users, followed by motorcycles and then public vehicles. Vehicle registrations for both public and

private vehicles have increased substantially in the province (Figure 7-2). In particular, amongst private vehicles, car, van/pick-up and micro-bus registrations have increased rapidly, suggesting a shift to greater household car use and ownership. By contrast the trip number for forms of public transport has remained relatively stable. Some modes of freight transport have seen growth in trip numbers, but these are likely off-set by declines in other freight modalities.

Figure 7-3 gives more detailed information on transportation demand by mode in terms of vehicle kilometers travelled. Although a clear trend in the 2008-2015 data is hard to discern, it seems motorcycle and public transport volumes have remained about the same over the period, while there has been some limited growth in the use of private vehicles. Yet, the trends in demand vary with external economic conditions (e.g. declines in 2009-2010 reflecting the global financial crisis and in 2013 reflecting domestic economic difficulties). Growth in transport demand and the shift to private car ownership has been driven by freight demand resulting from industrial activity, and population and income growth in the province. Currently rail links in Rayong are limited to a freight service connecting Map Ta Phut port with Sattahip port in nearby Chonburi.⁶

Map Ta Phut port is an important part of the province's transportation network. The port has over 12 berths, catering to oil, LNG, chemicals, fertilizer and bulk goods. The port capacity has been expanded incrementally, with recent additions catering for gasification of LNG imports. Shipping

Figure 7-1: Rayong's transportation network



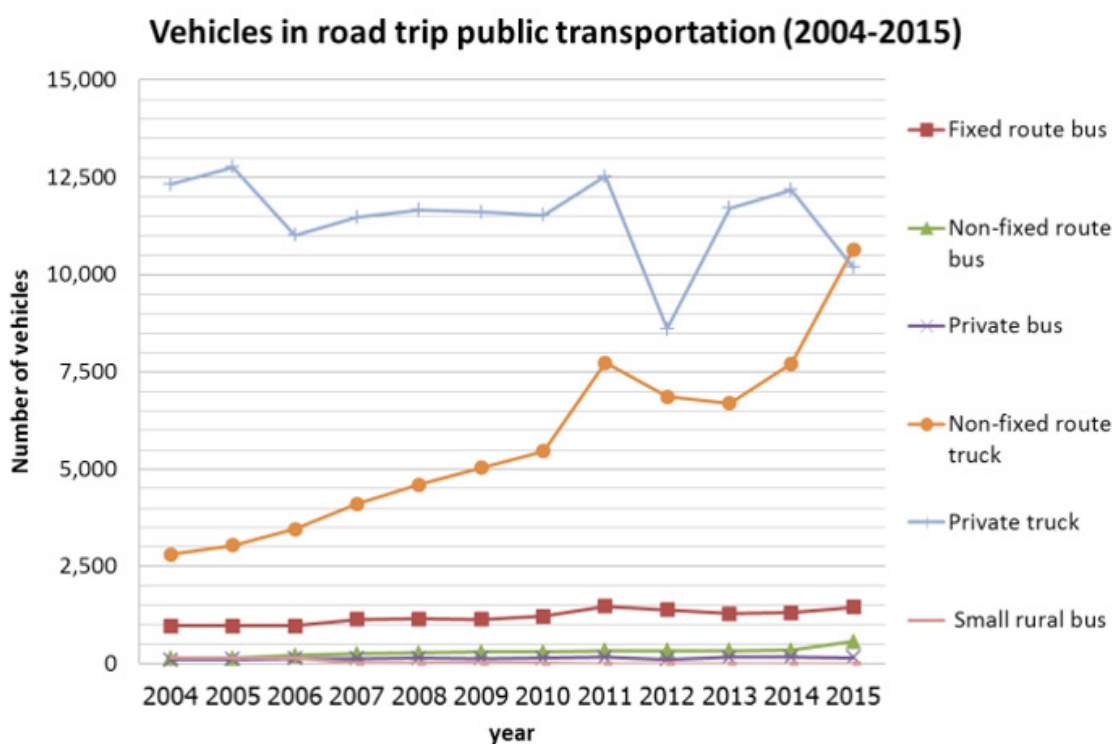
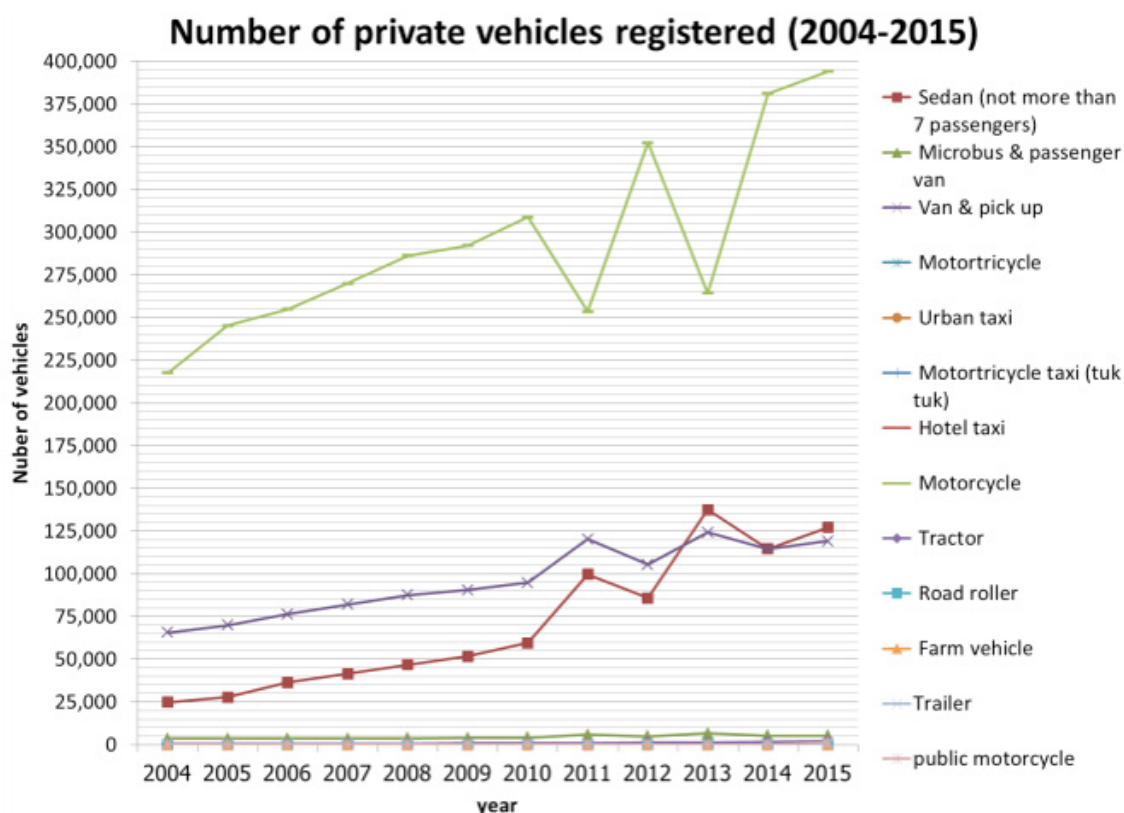
Source: ICEM 2019

⁴ <http://www.uncred.or.jp/content/documents/7EST-B1G4-6.pdf> (slide 10)

⁵ <http://www.uncred.or.jp/content/documents/7EST-B1G4-6.pdf> (slide 8)

⁶ <http://www.ceat.or.th/2010/index.php/traffic-a-transport/400-construction-supervision-for-the-sattahip-map-ta-phut-railway-project-name-of-company-thai-professional-engineering-co.html>

Figure 7-2: Vehicle registration in Rayong Province by type 2004-2015



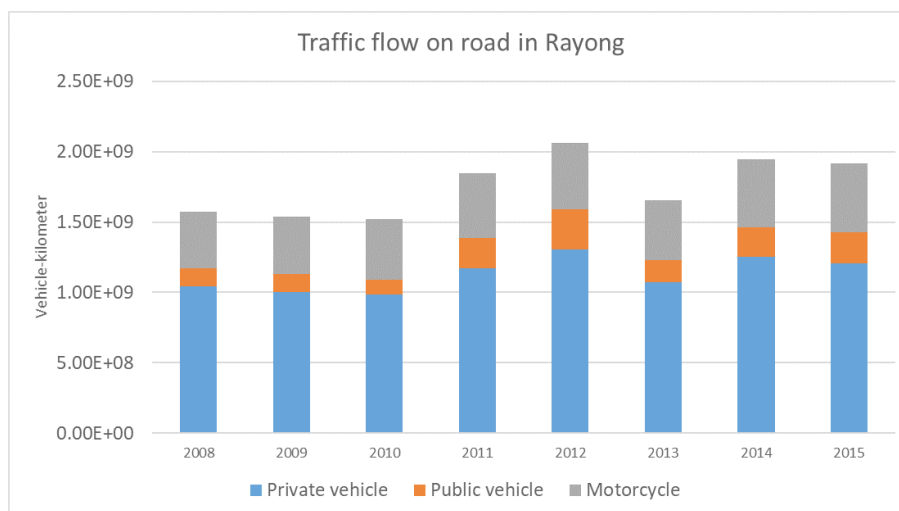
Source: Rayong Provincial Transport Office, 2019

volumes have gradually increased, with the number of vessels visiting the port up from just over 6,000 in 2011 to 7,000 in 2017. Cargo volumes have increased similarly, from around 30 million tons in 2011 to almost 45 million tons in 2017. Much of this traffic is made up of oil imports accounting for around 70% of vessels, and around 56% of cargo by weight (Figure 7-4).

Air transport in Rayong is limited, but growing. The number of passengers arriving at and departing from U-Tapao airport increased from 100,000 a year up to 120,000 a year between 2009 and 2015 (EECO 2019). According to aircraft transportation trends as shown in Figure 7-5 the number of

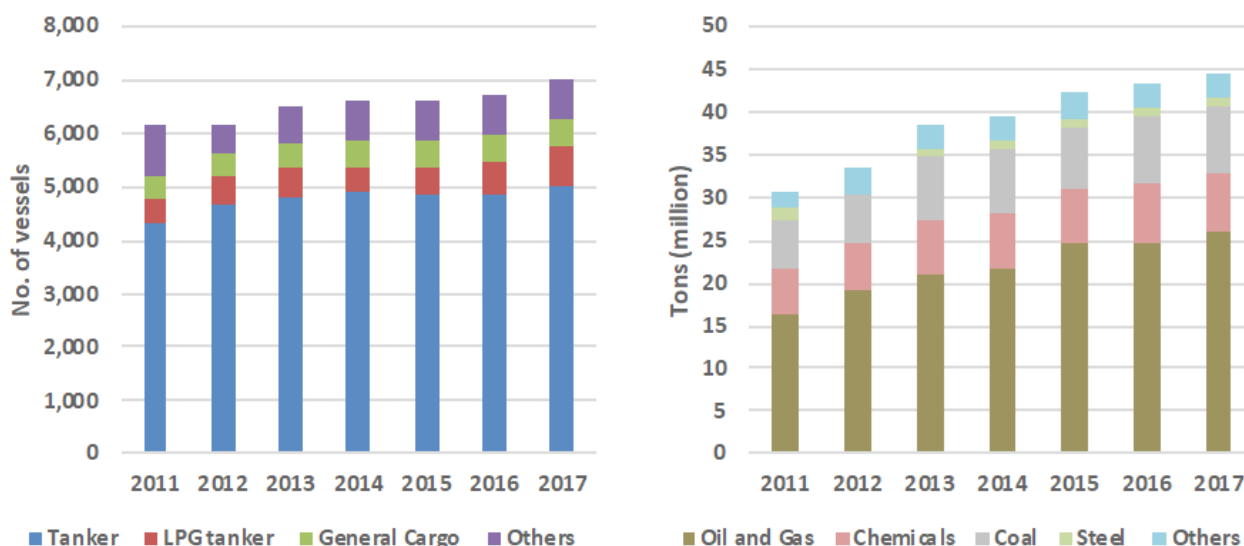
passengers increased by about 20% between 2009 and 2015. At the same time, the number of arriving and departing aircraft has decreased (Department of Civil Aviation, Ministry of Transport and Communication, 2016). That trend indicates that airlines are beginning to use larger aircraft for the Rayong route. This change implies a significant investment by airlines, and in conjunction with existing plans to upgrade the airport, indicates that air transport is likely to increase. News reports suggest expansion has happened even more quickly in recent years with the number of passengers flying into and out of U-tapao airport increased to 700,000 in 2016 and up to one million in 2017.⁷

Figure 7-3: Traffic flow on road for road vehicles in Rayong 2004-2015



Source: Rayong Provincial Transport Office, 2019

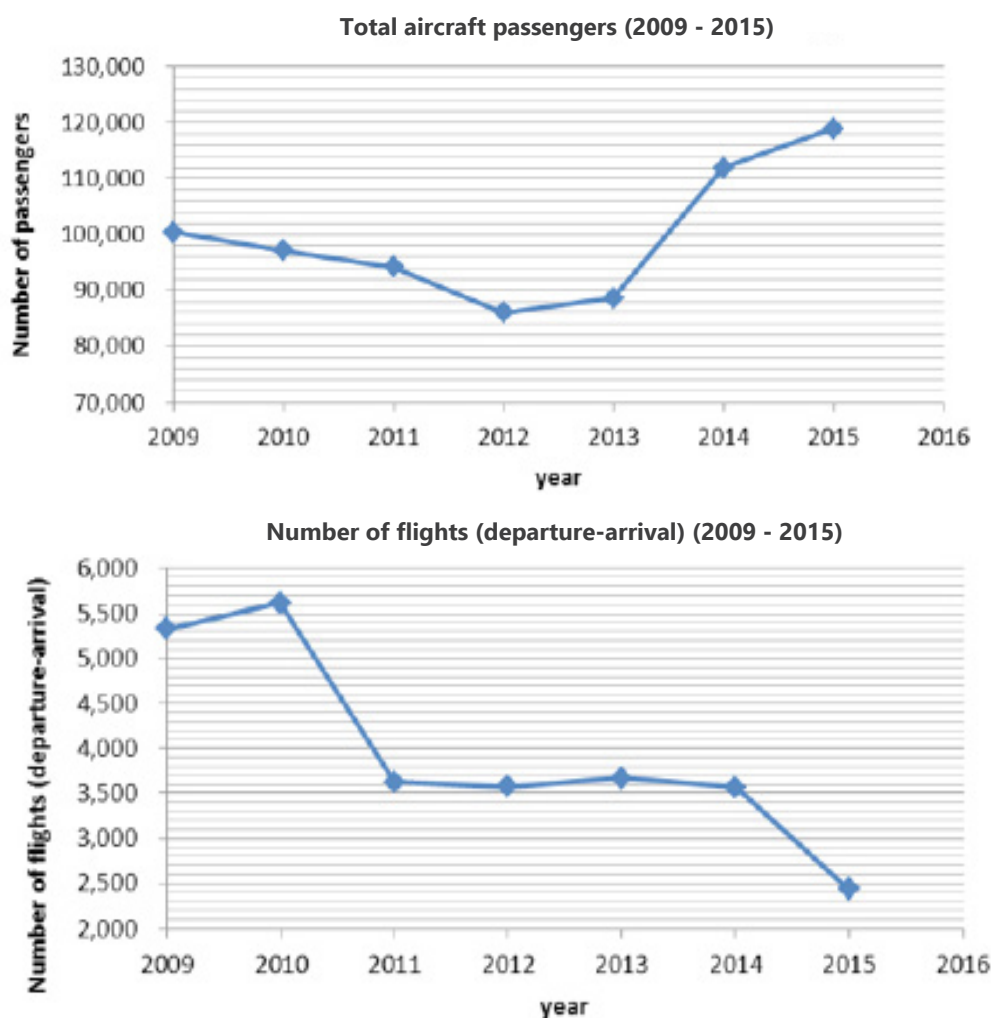
Figure 7-4: Number of vessels (left) and volume of cargo (right) handled in Map Ta Phut port 2011-2017



Source: IEAT Annual Report 2017

⁷ See <https://www.pattayaone.news/u-tapao-airport-plans-200-billion-baht-extension/>

Figure 7-5: Airport passengers and flight in Rayong 2009-2015



Source: Department of Civil Aviation, Ministry of Transport and Communication, 2016

5. Transport projects

- There is a planned upgrade for the Map Ta Phut, which will allow it to cope with expected rise in liquid natural gas imports.⁸
- Current expansion of national highway No. 36.
- Expansion of provincial road network to link with planned EEC road infrastructure upgrades.
- Planned expansion of U-Tapao port.
- Upgrading of current Map Ta Phut port with Sattahip port rail link to twin-tracks.
- Development of high-speed railway line (shinkansen) to U-Tapao airport.

6. Key stakeholders

- Ministry of Transport
- Industry and business
- Map Ta Phut Port
- State Rail of Thailand
- Industrial Estate Authority of Thailand

7. Government policies and targets

Draft 20 year transportation development plan (2017 - 2036): This plan includes a focus on green, efficient and inclusive transport systems with a target of reducing transport related greenhouse gas emissions in Thailand by 20% by 2036 from 2015 levels. The plan also highlights the need to support expansion of the transport systems for EEC development.

The environmentally sustainable transport Master Plan (2013): This plan has ambitious targets to promote a modal shift from road to rail, both for freight transport, and for people. This includes extensions of rapid transit systems such as the proposed high speed rail link connecting Don Mueang, Suvarnabhumi and U-Tapao airports. In 2016 a vehicle tax scheme was to be introduced based on carbon dioxide emissions.⁹

⁸ See <https://www.eeco.or.th/en/project/infrastructure-development/map-ta-phut-port>

⁹ https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/Thailand/1/Thailand_INDC.pdf

The government energy plans include the use of **bio-fuels (ethanol and bio-diesel) to replace diesel and gasoline use**. While it is not specified in the AEDP (2015), these products are designed for use in motor-vehicles (see e.g. Bloyd 2017). Thailand is cultivating cassava and molasses in order to manufacture these biofuels. The national target for 2036 is 11.3 million litres per day of ethanol and 14 million litres per day of biodiesel (Ministry of Energy 2015).

Under the **EEC Development Plan** there will be a high speed rail link built from Bangkok, which will cut travel times for passengers as compared to using roads, as well as double-track freight rail links connecting Map Ta Phut industrial zone with Laem Chabang and Sattahip ports (EECO 2019), which should reduce freight truck traffic.

The EEC Development Plan also includes **expansion of highways 3013 and 4058**, as shown in Figure 7-6.

The Ministry of Transport Infrastructure Investment Action Plan (2017) highlights three projects relating to Rayong: 1) The high speed rail link (US\$4,360 Million), 2) U-Tapao airport upgrade (investment not specified) and 3) Pattaya to Map Ta Phut Motorway (US\$510 Million).¹⁰

Highway 36 connects Chonburi with Rayong. This highway will be widened from 4 to 6 lanes. In 2016 this highway carried over 34,000 vehicles each day, of which nearly one third were heavy trucks).¹¹

European emissions standards for motor vehicles adopted by Thailand in 1998.¹²

Figure 7-6: Highways 3013 and 4058 scheduled expansion under the EEC Development Plan



Source: Department of Rural Roads, 2019, website <http://www.drr.go.th>

¹⁰ http://www.ntccthailand.org/images/articles_reports/Presentation---Towards-Sustainable-Transport---21-June-2017.pdf

¹¹ http://www.publicconsultation.opm.go.th/phs/new_phs_proj_view.asp?editId=P610116004

¹² See annex

8. Past trends and current situation

- ✓ Expansion of transportation infrastructure
- ✓ Increased resource use by the transportation sector
- ✓ Increasing air pollution due to increased transportation

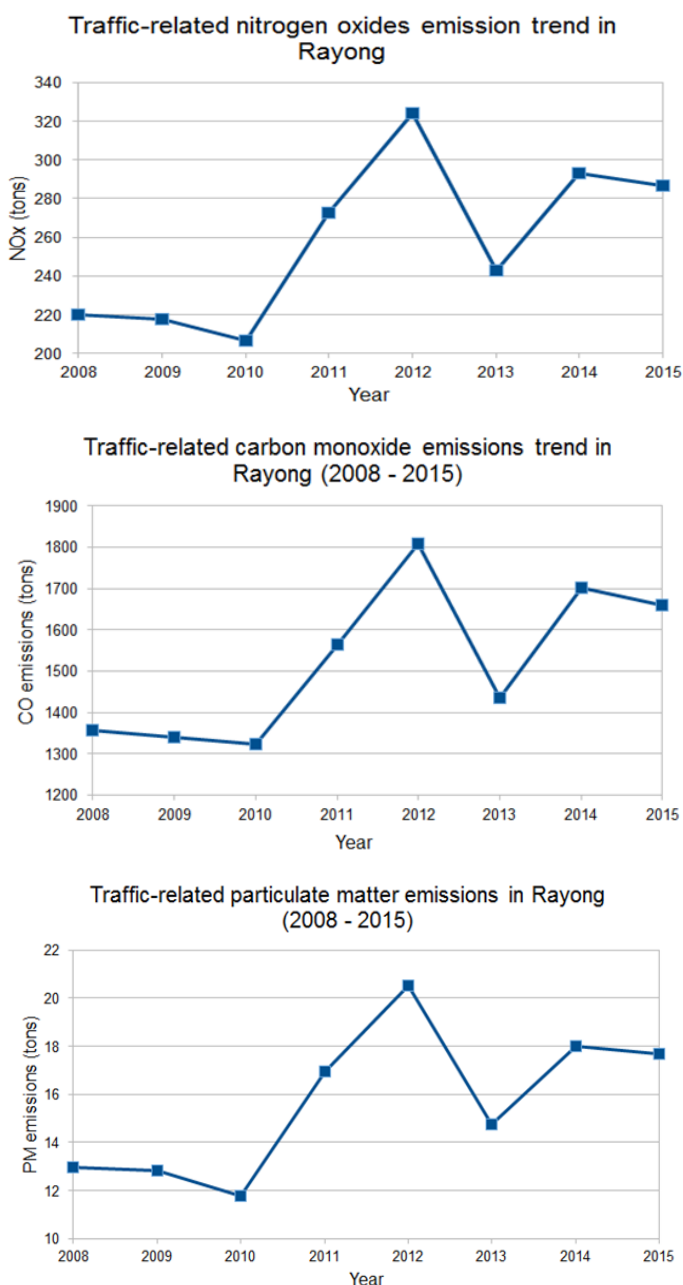
Expansion of transport infrastructure

Under the ESBDP transportation infrastructure in Rayong has been substantially upgraded and expanded. While quantitative data is not available on the extent of transportation infrastructure development in the province since the beginning of this program in the early 1990s key elements in its development include the development of Map Ta Phut deep-sea port (catering to vessels of up to 60,000 DWT) and extensive development of the road network including upgrading and expanding the national highways network to link Rayong west to Chonburi and Pattaya, north to Bangkok and to the north east of the country. In addition, during this period provincial/local roads have been upgraded and developed. The main driver has been government policy to develop the ESB region, although other factors have acted as secondary drivers to infrastructure expansion in terms of expanding demand including subsequent population and industrial growth.

Air pollution

Assuming all vehicles are emitting at the current standards,¹³ pollution emissions to air from road transportation are estimated based on figures for vehicle-kilometers by transport mode. For this estimate it is assumed that all private vehicles are light vehicles with petrol engines, that all public vehicles are heavy vehicles with diesel engines, and that all motorcycles have petrol engines.¹⁴ Based on those assumptions emissions of NO_x , CO and PM_{10} from transport are estimated (Figure 7-7). For all emissions there is a clear upward trend reflecting the trend in increased private transport use. It should be noted that for the purposes of these estimates it is assumed that there are no changes in performance of the vehicle fleet or engine type. If diesel engines have become more widespread in Thailand as elsewhere in the world, it is likely that NO_x and PM emissions will have risen accordingly.

Figure 7-7: Estimated historical emissions from road transport in Rayong 2008-2015



Source: ICEM calculation

¹³ Currently, light vehicles in Thailand are bound by the Euro IV standard, while heavy vehicles are bound by the less stringent Euro III standard. See http://www.jari.or.jp/Portals/0/resource/pdf/AAI%20Summit/H25/4.%20Emission_TAI.pdf/

¹⁴ In 2015 around 69% of vehicles on Thailand's roads were powered by petrol, with a further 26% having diesel engines. The remainder of vehicles were either bi-fuel (i.e. petrol or diesel with either compressed natural gas or liquefied petroleum gas) or gas powered. For the purposes of estimating historical emissions only petrol and diesel emissions are considered (at 27% diesel and 73% petrol)./

¹⁵ https://www.marinetraffic.com/en/ais/details/ports/464/Thailand_port:MAP%20TA%20PHUT

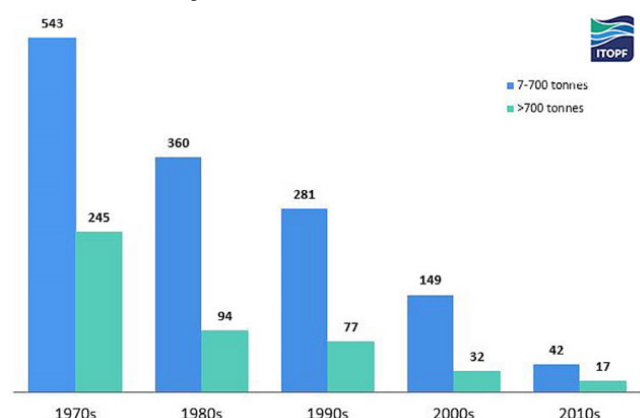
¹⁶ https://www.eea.europa.eu/data-and-maps/daviz/contribution-of-the-transport-sector-5#tab-chart_4

Water transport

Map Ta Phut Port hosts around 7,000 tankers and cargo vessels each year.¹⁶ According to European emissions data, sea traffic is a large contributor to SO_x and NO_x emissions as well as particulate matter emissions (particularly PM_{2.5}).¹⁷ Whether emissions from ships is of local concern may depend on prevailing wind conditions (i.e. whether these pollutants being pushed inland into residential areas or pushed out to sea). Weather data for Rayong shows that the wet season winds generally blow from the south-south-west (i.e. pushing shipping emissions onshore), while the dry season winds generally blow from the northeast (i.e. pushing shipping emissions away from land).

In addition to air quality, shipping comes with a risk of spills of the materials onboard. While these spills don't happen frequently, errors or storms do occasionally cause major spills of cargoes including oil and gas that lead to major environmental problems. In 2018, globally, there were three oil spills larger than 700 tons, including one in the east China sea, and three medium spills (between 7 and 700 tons).¹⁸ It is worth noting that the number of spills and quantity of oil spilt has trended downwards over the last 50 years, even as the amount of oil carried has increased (Figure 7-8).

Figure 7-8: Number of medium (7-700 tonnes) and large (>700 tonnes) spills per decade from 1970 to 2018 (only nine years of data for 2010- 2018)



Source: <https://www.itopf.org/knowledge-resources/data-statistics/statistics/>

Air transport is also likely an important source of pollution, including NO_x and PM_{2.5}. Data is not available on the likely level of emissions to air from U-Tapao airport, however, it is likely to have increased with increasing air traffic. Plans to increase air traffic further may mean air pollution from air transport becomes a more important problem in the future.

There is only one existing **railway line** in Rayong. This links Map Ta Phut port with Sattahip port to the west in Chonburi province. It is unlikely to be a significant source of emissions itself, however there is a possibility that freight dust could cause air and other environmental pollution. This would depend on the freight, and how it is secured in the cars.

9. Future trends

- ✓ Expansion of transportation infrastructure
- ✓ Increasing air pollution due to increased transportation

Expansion of expressways in Rayong, for example, highway 36 as well as highways 3013 and 4058 (see Transport Projects section), is likely to be accompanied by further growth in private motor vehicle ownership as well as increasing freight transport. In contrast, Thailand's environmentally sustainable transport master plan (2013 - 2032) targets a modal shift from road transport to rail transport,²⁰ and the draft transportation development master plan (2017 - 2036) includes targets to reduce transport related GHG emissions by 20% by 2036. Part of the strategy to create a modal shift is the planned construction of a high-speed rail link connecting Don Mueang, Suvarnabhumi and U-Tapao airports. The rail links are planned to have capacity for 147,000 passengers each day.²⁰ In terms of how this could impact on the number of vehicles on the road, Table 7-1, provides some basic calculations.

In 2015 around 69% of vehicles on Thailand's roads were powered by petrol, with a further 26% having diesel engines. The remainder of vehicles were either bi-fuel (i.e. petrol or diesel with either compressed natural gas or liquefied petroleum gas) or gas powered.²¹ For simplicity in estimating the emissions reductions attributable to the planned high speed rail link, only petrol and diesel are considered. Therefore we assume that 73% of vehicles that have trips replaced by the high speed rail link are petrol driven, and 27% are diesel

Table 7-1: How many cars will the high speed rail link take off the road?

High speed rail link		Notes
capacity is	147,000	people per day (in the first year)
equals	88,200	People each day (@60% capacity)
equivalent to	7,350	cars per day, assuming 3 people per car (but only 25% of them would have been travelling anyway – ie allowing the rail link to generate new demand)
equivalent to	1,102,500	vehicle kilometres per day (assuming each car off the road would have travelled 150km)
equivalent to	352,800,000	vehicle kilometres per year (assuming 320 days per year)

¹⁸ <https://www.itopf.org/knowledge-resources/data-statistics/statistics/>

²⁰ <https://www.railway-technology.com/projects/high-speed-rail-linked-3-airport-project-thailand/>

²¹ See <https://iea-amf.org/app/webroot/files/file/Country%20Reports/Thailand.pdf>

driven. We also assume that all vehicles replaced by the train will be light vehicles (i.e. that Euro IV standards apply). It is acknowledged that the majority of vehicles replaced are likely to be lighter vehicles, and that this may impact on the petrol/diesel mix. However in the absence of hard data this proportional mix gives a reasonable estimation. Thus, Table 7-2 shows the reduction in traffic emissions attributable to the high speed rail link, based on current Thai emissions standards.

Table 7-2: Emissions reductions estimate assuming Euro IV emissions standards apply

	Petrol-related emissions reductions (tons)	Diesel-related emissions reductions (tons)	Total estimated emissions reductions (tons)
CO	258	48	305
NO _x	21	24	44
PM	0	2	2

*Note that these calculations assume zero emissions of these pollutants due to the operation of the high speed rail link. Moreover, it is not clear that these emissions reductions are attributable to Rayong province alone and may be spread across the three EEC provinces.

The Table 7-2 calculations are based on Euro IV emissions standards, however a recent article in the Bangkok Post indicates that Thailand is planning to apply Euro V standards in 2021 and Euro VI standards in 2022.²² If this happens, these standards will apply prior to completion of the high speed rail link. The emissions reductions attributable to the high-speed rail link if Euro VI standards apply are given in Table 7-3.

Table 7-3: Emissions reductions estimate assuming Euro VI emissions standards apply by the early 2020s

	Petrol-related emissions reductions (tons)	Diesel-related emissions reductions (tons)	Total estimated emissions reductions (tons)
CO	258	48	305
NO _x	15	8	23
PM	1.3	0.5	1.8

The double track railway line that is planned to link Laem Chabang, Map Ta Phut and Sattahip is expected to increase capacity to 18 million TEU containers and 3 million cars annually.²³ However, no data on existing capacity is available.

Expanding industry will mean additional freight as well as

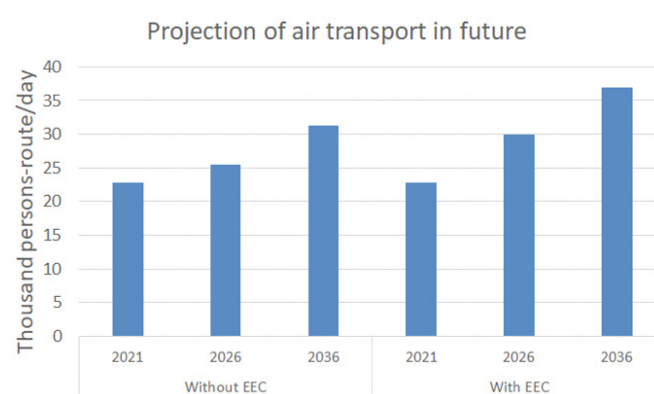
personal transport because of more workers commuting. The additional rail links (double track and high speed) will reduce emissions in the short term, but there will be a break-even point where increased traffic will drive road traffic emissions back to their current levels. However, it should be borne in mind that large structural changes in the automotive sector related to a growing market for hybrid and eclectic vehicles are likely to have a significant impact on road transport emissions in the medium to long term.

The expansion of the Map Ta Phut port will be accompanied by a significant increase in the number of ships offloading and loading cargo - this will be accompanied by an increase of emissions from shipping. For example, a diesel engine on a large cargo ship emits around 5,200 tons of SO_x during the 280 days it is running each year. While ships engines do not operate at full speed in port, emissions are still significant while there.^{24,25}

Air traffic into and out of Rayong is expected to increase dramatically in coming years. For example, the current passenger processing capacity is 3 million people per year, however as part of the EEC plan, this processing capacity is expected to be upgraded to 15 million passengers.²⁶ The development plan of U-Taphao Airport is shown in Figure 7-10 below. The EEC plan also includes development of avioincs and other aviation focused industries in the U-tapao area (EEC, 2018), which will help drive air transport demand. According to a 2018 study conducted by the EEC, air transport will increase by 62% between 2021 and 2036, as shown in Figure 7-9.

The drivers for this growth will be the development of the aviation industry hub, associated population growth, as well as the connectivity with Bangkok via the planned high speed rail link.

Figure 7-9: Projection of air transport demand in 2021, 2026 and 2036 in case of with and without EEC



Source: EEC, 2018

²² <https://www.bangkokpost.com/news/environment/1676592/a-clear-path-to-cleaner-air->

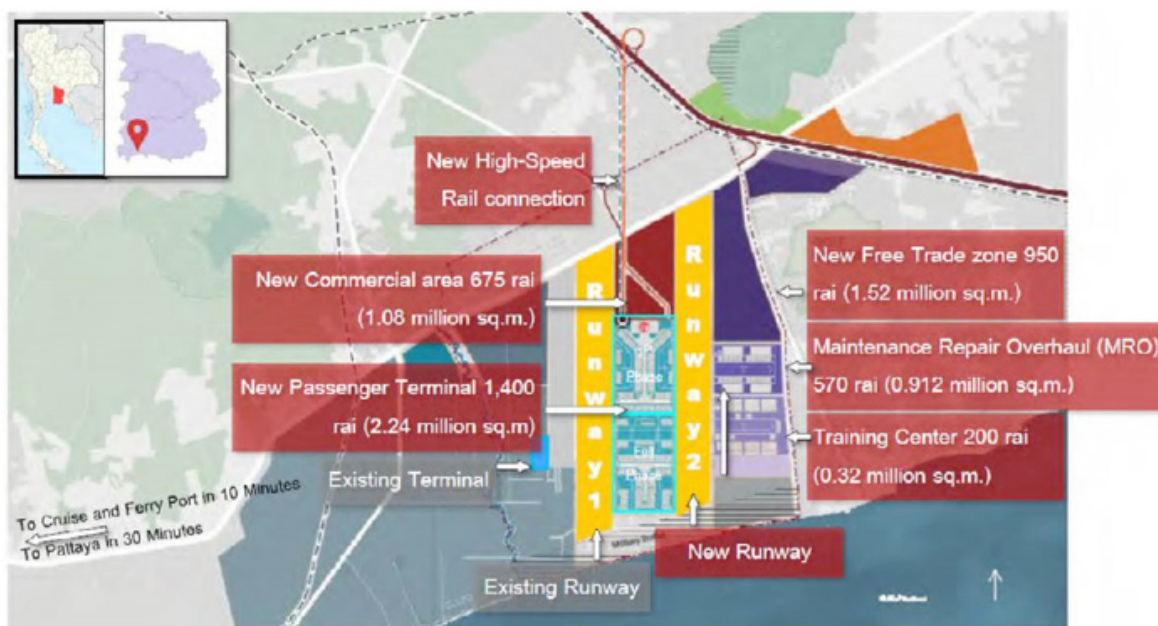
²³ [https://www.boj.go.th/upload/content/13.15%20-%2015.15%20\(4\)%20-%20EEC%20Act%20in%20Action_EN_5ab214187ff41.pdf](https://www.boj.go.th/upload/content/13.15%20-%2015.15%20(4)%20-%20EEC%20Act%20in%20Action_EN_5ab214187ff41.pdf)

²⁴ Data in the list from: <https://www.itf-oecd.org/sites/default/files/docs/dp201420.pdf>

²⁵ In 2011 in-port shipping emissions around the world included, CO₂ – 18 million tons; NO_x – 0.4 million tons; SO_x – 0.2 million tons; and, PM₁₀ – 0.04 million tons. See <https://www.transportpolicy.net/region/asia/thailand/>

²⁶ <https://www.pattayaone.news/u-tapao-airport-plans-200-billion-baht-extension/>

Figure 7-10: Development plan for U-Taphao Airport under EEC 9



Source: https://www.uobgroup.com/assets/pdfs/research/FN_170516B.pdf

Table 7-4: Emissions standards in use and being planned for implementation in Thailand

Standard	CO (g/km)	THC (g/km)	NO _x (g/km)	HC + NO _x (g/km)	PM (g/km)
Euro III (petrol)	2.3	0.20	0.15		
Euro III (diesel)	0.66		0.50	0.56	0.05
Euro IV (petrol)	1.0	0.10	0.08		
Euro IV (diesel)	0.5		0.25	0.3	0.025
Euro V (petrol)	1.0	0.1	0.06		
Euro V (diesel)	0.5		0.08	0.17	0.005

Source: <https://www.rac.co.uk/drive/advice/emissions/euro-emissions-standards/>

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STRATEGIC THEME: URBAN DEVELOPMENT

1. Introduction

Prior to 1980 Rayong was a sleepy agricultural backwater. The discovery of large quantities of natural gas in the Gulf of Thailand together with the associated ESB development program has led to fundamental changes to Rayong's economy, demographics and environment. Now Rayong now has the highest per capita gross provincial product (GPP) of any Thai province, almost double that of Bangkok (NESDB, 2016). Economic growth has attracted many immigrants to the area, with Rayong's urban population growing more than tenfold from around 24,000 in 1980 to 354,000 in 2018,¹ equivalent to an average of more than 6.9% population growth per year.²

In addition, many migrants who have moved to Rayong are not registered as living in the province and are excluded from these figures meaning the actual provincial population is much higher.³ This rapid urban population growth places significant demand on local authorities for additional services and amenities, including housing, water supply, solid waste collection and management, wastewater management, as well as medical and education services.

2. Scope

The two strategic issues identified for urban development in Rayong during the consultation process are:

- i) Urban expansion; and
- ii) Waste management (solid waste and wastewater).

For each of these major issues, past trends and the current situation are examined, with a brief analysis of how these trends are likely to project into the future. As such this theme deals with environmental, quality of life and urban planning issues linked to high rates of population growth.



STRATEGIC ISSUES OF CRITICAL CONCERN FOR SUSTAINABLE DEVELOPMENT IN RAYONG

- ✓ Urban expansion
- ✓ Waste management (solid and water)

SUSTAINABLE DEVELOPMENT OBJECTIVE:

- ✓ Urban areas are planned for energy and water conservation, transit oriented design and equity emphasising green infrastructure and nature based approaches;
- ✓ Pollution and waste streams in urban areas are effectively managed, creating a pollution free environment.

3. Links to other sectors and themes

Industry: Urban development in Rayong is being driven by industrial growth, with migrants coming to the province seeking work in industry.

Environmental quality: Urbanizing trends have numerous impacts on the environment: expansion of hard surfaces which change rainwater runoff patterns, reduced vegetation drives temperatures higher, untreated municipal solid waste and wastewater emissions affect water quality, and traffic congestion compounds local air and noise pollution issues.

Social and demographics: Rapid urbanization is often accompanied by significant quantities of sub-standard housing that lacks basic services such as clean water and

¹ Some estimates put the urban population in the province as high as 532,000 in 2019, higher estimates probably include unregistered population living in the area (see <https://populationstat.com/thailand/rayong>)

² Compared to Bangkok's average annual population growth over the same period of around 2% (<http://worldpopulationreview.com/world-cities/bangkok-population/>) and 1% for the country as a whole (<https://www.macrotrends.net/countries/THA/thailand/population>)

³ The National Economic and Social Development Board (NESDB) estimated in 2010 that there were more unregistered people living in Rayong than registered people (NESDB 2010), with actual provincial population being 2.2 times the official figure. However, more recent estimates based upon provincial consultations suggest an unregistered provincial population of around 500,000 (please refer to the social and demographic issues baseline for greater discussion)

sanitation facilities (see e.g. Lanrewaju, 2012; Moore, Gould, & Keary, 2003; Mukiibi, 2012). In addition, with rapid urbanization there is a higher likelihood of residential development in inappropriate areas such as flood plains, with associated impacts on health and well-being.

Transport: Urbanization means higher population density. This often means more concentration of vehicles, congestion, increased air pollution and the development of air quality issues, but high density areas also provide opportunities for the development of public transport.⁴

Coastal and marine: Effluent from urban centres impacts negatively on coastal and marine water quality. In Rayong the three wastewater treatment centres in the province (Rayong City, Map Ta Phut Municipality, and Banpae Sub-district Municipality) are operating well below capacity because there is insufficient funding in municipal budgets for the purpose, and because of questioning of the original design and siting which prevents gravity fed inflow of wastes (interviews, PCD & Map Ta Phut Municipality). Raw sewage now flows directly to the sea (interviews, PCD & Map Ta Phut Municipality).

4. Overall context

Rayong has seen high levels of economic growth based on the development of extensive heavy industry in the province. This economic growth has generated employment and other economic opportunities that have been a significant factor in attracting migrant to the urban centres around industrial areas. Rayong's population grew at an average annual rate of 1.8% between 2000 and 2017. In December 2018, the registered population was 723,000, up from 522,000 in 2000. The province consists of eight districts, with the capital district of Rayong city having the largest population, with a total registered population of 64,000⁵ in 2016.

Provision of basic facilities and services such as water, housing, and waste management are vital components of urban development. With the rapid pace of urbanization in Rayong, development of urban services have not been able to keep up with the needs of residents. For example, septic systems are non-existent in many houses, non-functional in others, and municipal waste-water treatment systems are not being used, or being used well below capacity, because of limited connectivity (interviews, Regional Environment Office, 2019). The inability for authorities in the region to ensure the provision of urban services keeps pace with rapid urban population growth is well documented, as are the negative impacts on poorer socio-economic groups in urbanizing areas (see e.g. Lanrewaju, 2012; Moore et al., 2003; Mukiibi, 2012). Similarly, the government of Rayong faces challenges providing services and facilities, with these challenges magnified because of discrepancies between registered and actual populations.

There are no up to date figures on water supply, however in 2018, Rayong City used 40.4 m³ of water each year. This

water was drawn from three reservoirs: Khao Chuk Reservoir (6.5%), Nong Pla Lai Reservoir (61.7%) and Bang Phai Reservoir (31.8%).⁶ Across the province, between 89,000 m³ and 132,000 m³ of wastewater is generated daily, with only a small proportion of that treated. Most grey water and sewage goes directly to rivers, canals and the sea, a situation which belies Rayong's status as one of the wealthiest provinces in Thailand.

Municipal solid waste (MSW) is generated at a rate of around 1,000 tons/day, including the importing of 400 - 500 tons/day of MSW from Pattaya City. However, landfill sites are close to capacity and large portions of MSW is disposed of improperly. MSW clogs the provincial transfer station because managers are not able to keep pace with needed separation and treatment (interviews, Regional Environment Office, 2019). In Map Ta Phut Municipality, the waste is collected but accumulating.

5. Urban projects

Waste to energy: In February 2019, The Global Power Synergy Public Company Limited (GPSC), a subsidiary of PTT was granted a permit for waste-to-energy incinerating plant with installed capacity of 9.8 MW in which 8.0 MW will be sold to the grid.⁷ The project will receive approximately 500 tons of MSW per day, and GPSC expects to be able to use 30-40% of this for electricity generation.⁸ The facility is not yet operational (e.g. interviews, Regional Environment Office, 2019).

In 2004 an anaerobic digester power plant was installed in Rayong with a capacity of 70 tons of organic waste per day, however waste sorting issues have plagued the project, and it has only averaged around 20 tons per day. From a pollution perspective the electricity produced with the system has resulted in an annual reduction in methane emissions of 0.34 Gg (equivalent to 7.15 Gg of CO₂) (Jutidamrongphan, 2018).

Recycling: Rayong has implemented a 3Rs program that has been successful in reducing the amount of waste going to landfill (Chinda, Leewattana, & Leeamnuayjaroen, 2012).

MSW collection: Two municipal solid waste transfer stations will be constructed in the Rayong area, in Huaykwang Municipality and in Map Ta Phut Municipality. These will be capable of handling 515 tons/day and 100 tons/day, respectively. Furthermore, Rayong will establish a central solid waste disposal center in Rayong Province and in Klaeng Sub-district Municipality to handle 325 tons/day and 50 tons-day of waste, respectively.

Land use planning: Rayong province has an existing land zoning system that includes heavy industrial areas, such as Map Ta Phut industrial area, light industrial areas (significantly more land area than for heavy industry), residential zones, agricultural zones, and protected areas. By the end of 2019 the current zoning will be superseded by land zoning to accommodate the Eastern Economic Corridor requirements.

⁴ For example, in Klaeng District a free public transport service has been established to help reduce vehicle use and fuel consumption. (see <http://www.uncred.or.jp/content/documents/7EST-B1G4-6.pdf> (slides 37 - 43))

⁵ <http://www.rayongcity.go.th/index.php/2016-07-22-06-13-38/2016-07-22-07-07-50/2016-07-22-07-59-41?showall=&start=2>

⁶ Water theme baseline

⁷ <http://www.energynewscenter.com/>

⁸ <http://gpsc.listedcompany.com/news.html/id/668277>

The EEC land zoning changes some usage compared with the existing land zoning. For example, under the EEC land zoning a city area in Klaeng District has been further expanded for residential purposes, as shown in Figure 8-1 (EEC, 2019).¹⁰

- Town planning authorities (e.g. Town and Country Planning)
- Urban residents
- Waste and waste-water management authorities
- Housing developers
- Water authorities
- Health care / Public health authorities

● Large cities
● Medium sized cities
● Small cities

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The districts in Rayong that are the most densely populated, and have seen the largest population increases, are those that are adjacent to industrial areas. This includes Rayong city, as well as Ban Chang, Pluak Daeng and Nikhom Patthana districts. Conversely, those districts that are primarily used for agriculture have no population growth over the last two decades. This includes Klaeng, Khao Chaomao and Wang Chan districts (see Social and Demographics baseline chapter).

Despite the rising density of some urban areas, such as Rayong city (from 360 persons/km² in 2000 to nearly 550 persons/km² in 2017), the population density of urban settlements in the province remains low when compared to other urban areas in Thailand (for example Bangkok has a population density of 5,300 persons/km²). The low density of the urban areas in the province is reflected in patterns of land use clearly illustrating the extent of urban sprawl and ribbon development in particular (Figure 8-3).

As a consequence of urban sprawl the area of urban land has increased dramatically, with the built-up area of the province increasing from 25,900 Ha in 2006, to 35,800 Ha by 2018, an increase of 38%.¹³

The main causal factor in explaining the expansion of the urban area is urban population growth linked to the generation of employment and other economic opportunities in Rayong. The low density of this development, and the extent of ribbon development along transportation corridors is illustrative of a lack of control over land use and limited application of land use planning.

It should be noted that the consequences of the lack of effective land use planning in the province are significant:

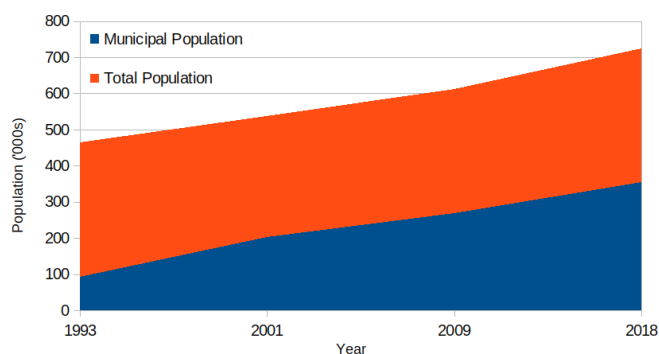
- Inefficient use of land resources, encroachment on agricultural land uses, mixed land uses compounding issues surrounding industrial pollution (for example issues still persist with residential land within the pollution control buffer zone around the Map Ta Phut industrial complex);
- Dispersed settlement patterns make residents more dependent upon personal transport, and typically cars. This entails increased congestion in urban areas, air pollution, and inefficient energy use in the transport sector;
- Conversely, the absence of high-density urban areas makes the provision of economically viable public transportation more difficult;
- Greater expense in providing services to urban residents including water supply and environmental sanitation services.

Overall, the development of large industrial estates and transportation corridors and facilities has been carefully planned as part of the ECB development program. Other forms of development and land use (with the exception of protected areas), have proceeded in a relatively ad hoc, unplanned and unregulated fashion, resulting in low density urban sprawl and attendant problems.

Municipal solid waste management

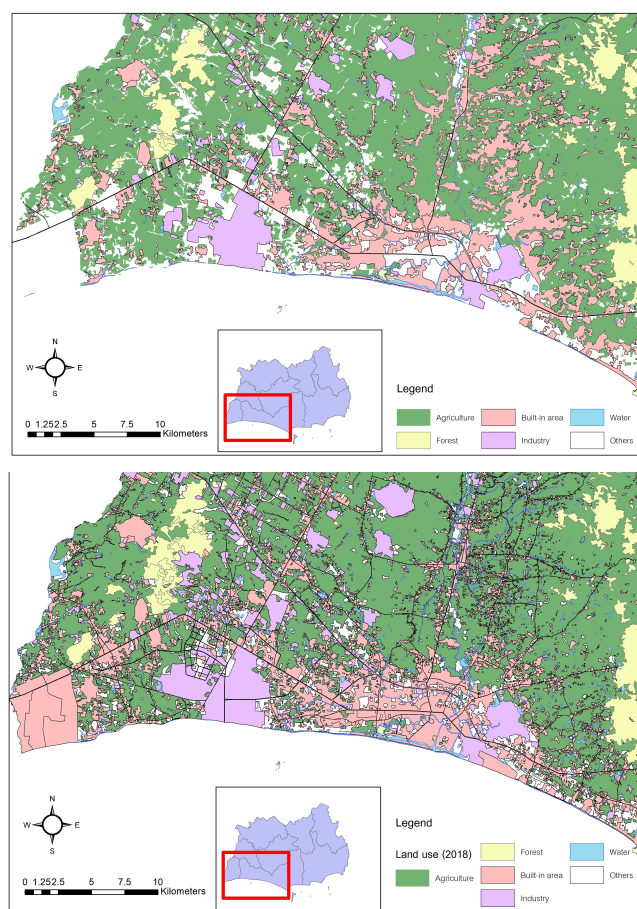
Figures on the amount of waste generated in Rayong vary. During fieldwork in the province interviewees suggested

Figure 8-2: Municipal Population Growth in Rayong 1993 - 2018



Source: RPAO (2018)

Figure 8-3: Land use map in 2006 (top) and 2018 (bottom) in Rayong



Source: Land Development Department (2019)

around 1,200 tons/day were received at collection stations in the province.¹⁴ However, other figures suggest solid waste collection in Rayong province of around 990 tons/day (Figure 8-4).¹⁵ Further figures on waste treatment and disposal in the province suggest that there is capacity to treat around 1,000 tons/day at the sanitary landfill site in Map Ta Phut¹⁶ as well as additional capacity at various waste-to-energy and recycling plants. Up to around 100 tons of waste may be disposed of at these plants daily).

While there is some variation between these figures, they do

¹³ This figure excludes industrial land uses

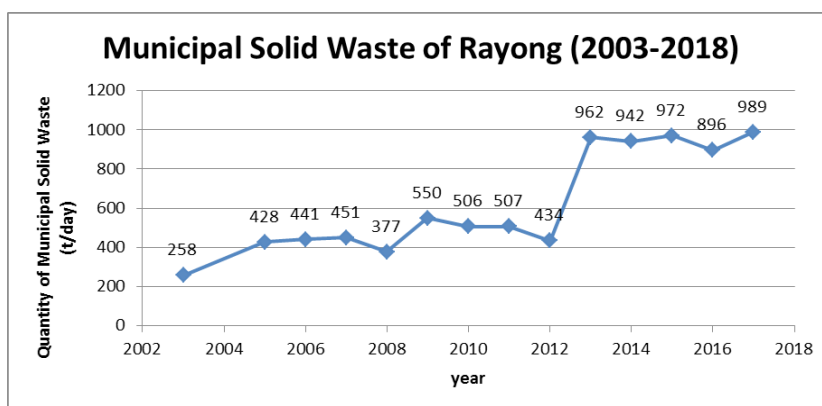
seem in broad agreement. An anomaly is the trend in Figure 8-4 which suggests no general increase in MSW generation between 2002-2012, or 2013-2018. This runs contrary to national trends of increasing per capita solid waste generation and to the increasing population in the province. Figure 8-5 gives MSW generation figures for Rayong province of around 800 tons/day based on the official population and of around 1,400 tons/day including the unregistered population. This suggests a growth rate in MSG of between 2% and 3% per year, which would be broadly in line with the national picture.

This analysis suggests that the figures given in Figure 8-4 represent the actual amount of waste collected in province. The lack of an increase suggests that the collection systems are working at or around capacity, and that MSW generation

in the province significantly exceeds treatment capacity. MSW imports to Rayong from Chonburi province of 400-500 tons /day has not been confirmed, and is not included in these figures.¹⁷

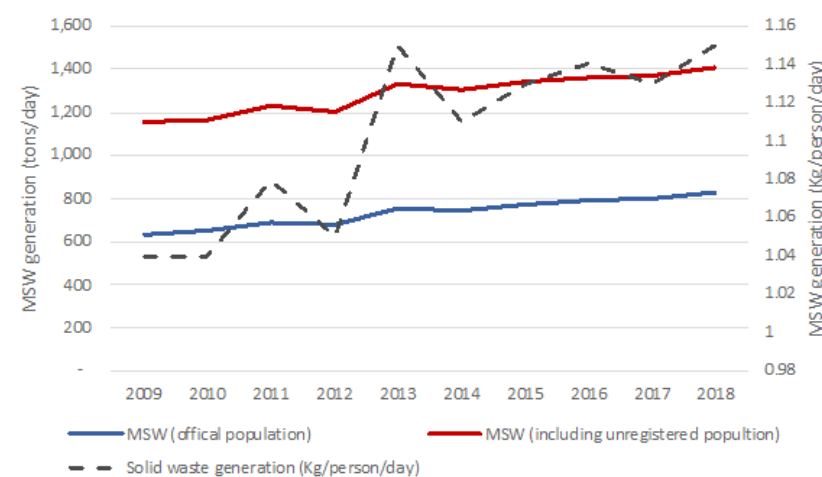
Consistent figures for the treatment and processing of MSW have not been available. However, based upon the discussion above and national figures relating to the efficacy of solid waste systems in the country it is likely that not all solid waste is disposed of in a controlled and sanitary manner and recycling rates are low by international standards. For example, nationally in 2018 around 34% of waste was not disposed of in a proper manner, 39% was disposed of in a proper manner (i.e. at a sanitary landfill site) and 27% was recycled in some manner.¹⁸

Figure 8-4: Daily MSW generated in Rayong between 2003 and 2018



Source: National Statistical Office (2018)

Figure 8-5: National trends in per capita MSW generation and derived estimates of MSW generation in Rayong province 2009 - 2018



Source: ICEM calculations based upon PCD, 2018, Booklet on Thailand State of Pollution 2018 and NSO population estimates

¹⁴ Interviews, Regional Environment Department

¹⁵ The graph is somewhat misleading, however, because of a change in data collection methods at the end of 2012. Up to 2012, the pollution control department (PCD) simply estimated of waste quantity, but from 2013 local government measured waste quantities directly.

¹⁶ Inside Thailand, 7 July 2018, Waste Management in Rayong Recognised as a Model for Local Administration. Retrieved from https://thailand.prd.go.th/ewt_news.php?nid=6921&filename=index

¹⁷ Interviews, Regional Environment Department

¹⁸ PCD, 2018, Booklet on Thailand State of Pollution

Reportedly, through Thailand's 3Rs program (Reduce, Reuse & Recycle Program) Rayong succeeded in reducing the amount of garbage going to landfill by two fifths – but this is not reflected in any of the other available data. Overall, indications are that the implementation of waste separation is still just beginning, and links to a lack of integrated waste management across local governments. There is a waste-to-energy project in Rayong, although there have been issues with the composition of waste and high moisture content leading to the plant only functioning at a fraction of its capacity.¹⁹ Furthermore, budgetary allocation and area for landfill development for management of MSW is limited.

Despite this success, waste separation remains a problem, with waste accumulating at the provincial transfer centres because separation is taking too long. Efforts have been made to encourage source separation, but have had limited success because of resistance by residents and garbage collectors (interviews, Regional Environment Office, 2019).²⁰ Landfill sites are unattractive, and lead to local resident concerns about smells, and about leaching into nearby waterways. For example, residents of Tambon Samnak Thong in Muang district have complained about landfill related air and water pollution.²¹

The main drivers of MSW generation in the province are:

- Population growth;
- Changes in consumption habits linked to urbanization and higher levels of consumption leading to higher level of per capita waste generation.

Waste-water management

In 2018, municipal wastewater in Rayong was generated at

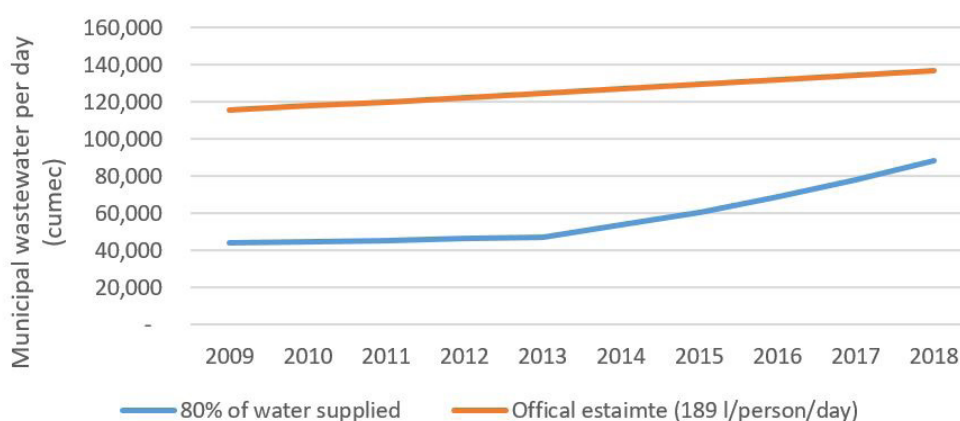
a rate of around 137,000 m³/day.²² This has been estimated based upon an official figure of 189 litres of wastewater generated each day per capita of the registered population.²³

However, as Figure 8-6 demonstrates this is likely to lead to an overestimation of municipal wastewater generation in the province. Particularly when we consider that in 2018, residential water supplies were only around 153 litres/person/day in 2018. If we estimate that 80% of water used is discharged as wastewater then in 2018 municipal wastewater discharges would be around 89,000 m³ per day, 35% lower than the official estimate. Water supplied through other means such as boreholes or springs may go some way to explaining the divergence between official wastewater estimates and estimates based on water supplied. But if the unregistered population is included, then municipal wastewater figures would exceed recorded water supplied for residential use by more than 100%.

The divergence in these figures illustrates the degree of uncertainty in understanding the wastewater situation in the province. For the purposes of this discussion we adopt the lower estimate of 89,000 m³ per day.

Rayong has three municipal wastewater treatment plants, located in Map Ta Phut Municipality, Banpae Sub-district Municipality and Rayong Municipality. These plants have capacities of 15,000 m³/day (Map Ta Phut), 8,000 m³/day (Banpae) and 41,000 m³/day (Rayong City).²⁴ However, the wastewater influent volume to each plant was only 1,275 m³/day (8.5% of capacity), 2,000 m³/day (25% of capacity) and 0 m³/day (0%), respectively.²⁵ A total of 3, 275 m³/day, or less than 4% of total wastewater, even if all three plants were operating at full capacity this would account for a

Figure 8-6: Estimated wastewater generation 2009 - 2018



Source: Water theme baseline, ICEM estimates based upon PCD figures. Note: it was assumed that water consumption remained at 90 l/person/day between 2009 and 2013 for the wastewater estimate based on 80% of water supplied.

¹⁹ Cherdasitkul, C., 2012, Generation and disposition of municipal solid waste (MSW) management in Thailand. It should be noted that given the composition of MSW in Thailand (The waste is primarily organic matter (47%) followed by plastics (14%)), the potential for biogas digesters and composting in reducing the portion of waste disposed of at landfills is significant.

²⁰ Interviews, Regional Environment Department

²¹ <https://www.bangkokpost.com/news/general/1062101/rayong-people-complain-about-landfill>

²² Equivalent 48.2 million m³/year, this estimate is actually larger than residential water supply in Rayong province of 40.4 million m³/year (water theme baseline), this may be explained by some residential users relying on other water sources for their supply such as boreholes.

²³ <https://drive.google.com/file/d/0Bws-qTXZ5yY2aDB1RHh5MWY4Rm8/view>

²⁴ PCD, 2018, Booklet on Thailand State of Pollution

little over 70% the municipal wastewater generated in the province. According to local officials, the limited operation of the wastewater treatment systems is because of factors including:

- Lack of O&M budgets for the plants;
- No clear institutional remit for funding WWT plant operations;
- Disagreement over the original design which does not operate on a gravity fed system
- Limited coverage of the sewage network – also reflecting budgetary constraints; and,
- Reliance of households and commercial establishments on septic tanks for wastewater treatment.

Where houses are not connected to the sewer, there is a requirement to have septic tanks installed, however this requirement is not applied retrospectively. Thus there are older houses with no septic systems. New houses generally have septic systems installed, however they are not inspected and many are non-functioning (interviews, Regional Environment Office, Pollution Control Department, 2019). Thus, most effluent in Rayong is untreated or minimally treated before reaching waterways. This is a serious concern for water quality and for the Rayong River and some canals the situation is now critical.

8. Future trends without the Rayong Provincial Development Plan

- ✓ Urban expansion
- ✓ Waste management (solid and water)

Under the EEC, the Thai government is planning to develop three Eastern provinces, including Rayong, as a world-class industrial hub. The employment opportunities under the EEC development will be primarily high skilled labour to support high-tech industry such as robotics and avionics. The government has identified that the current Rayong labour market is not skilled in the right areas for the main EEC-related work opportunities, and will open a labour management centre in the EEC (e.g. MoL, 2018; see also the social and demographics chapter of this report). For this reason, continued immigration into Rayong province is expected as job seekers come looking for work opportunities. Even without the EEC in-migration is likely to continue as Rayong continues to be a hub for industrial development (albeit at a rate somewhat reduced from the levels seen in the 1990s).

These immigrants will move to urban areas and contribute to continued urban expansion, particularly in urban centers located close to new factories and industrial developments. U-tapao and Klaeng in particular are likely to see urban

expansion. In U-tapao, expansion will be driven by the EEC objective of establishing high-tech aviation industries in the area. Klaeng district is a large district in the east of Rayong, bordering Chantaburi Province. It is sufficiently large that it currently manages its own waste and landfill, rather than being included in the central waste management processes (interviews, Regional Environment Office, 2019). In EEC land zoning, the residential area of Klaeng City has been extended significantly (interviews, Town and Country Planning, 2018).

Development of the EEC program thus envisages expansion of the urban area by approximately 16,300 ha.²⁶ Without a concerted effort to control land use and urban development according to a comprehensive urban area plan following sustainability and good design principles, ad hoc development is likely to continue, resulting in inefficient land use and continuing environmental and quality of life problems as described in the baseline.

Solid Waste Management

The main drivers of the upwards trend in MSW are increasing population and changing consumption patterns. Existing programs and policies to encourage recycling, reuse of waste as well as reduction in waste production at national and provincial levels will serve to reduce waste generation.

Yet, unless a concerted, comprehensive and well funded response is developed based on increased responsibilities and authority to local government and environment agencies, MSW generation is likely to continue in line with the historical trend with a growth rate in the BAU scenario of 2-3% per year.

Wastewater management

Waste-water is a critical issue for Rayong. With three non-functioning or minimally functioning waste-water treatment systems, and legislation for septic systems that isn't enforced, water quality in the province will continue to decline (interviews, Regional Environment Office, 2019).

The primary driver of wastewater generation is population (PCD, 2017). Under EEC plans, there will be many more migrants moving to Rayong. For example, the EEC plan envisages the creation of 100,000 jobs for highly skilled workers on an annual basis across the three EEC provinces.²⁷ Because of an existing lack of skilled workers in Rayong itself, the new jobs figures indicate that Rayong should expect immigration at the rate of at least 20,000 to 30,000 people per year. Thus wastewater generation is likely to increase in line with population growth, at a slightly accelerated rate of 1.8-2% per year.

Already the local environment is suffering because of a lack of wastewater treatment. Until local governments are able to manage the waste-water issue through waste-water treatment systems, as well as rigorous inspection and enforcement, the amount of raw effluent being pumped directly into Rayong's water courses will continue to rise.

²⁵ Pollution Control Department, 2017, Environmental situation in eastern region 2016, <https://drive.google.com/file/d/0Bws-qTXZ5yY2aDB1RHH5MWY4Rm8/view>, accessed 29 May 2019

²⁶ Personal correspondence.

²⁷ <https://www.eeco.or.th/sites/default/files/EEC-Hopes%20for%20the%20Future%20of%20Thailand%20Driving%20Challenging%20Opportunities%20for%20Everyone.pdf>

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STRATEGIC THEME: WATER RESOURCES



1. Introduction

The water theme addresses issues related to quantity and quality of water supply necessary to meet the rapidly growing demand in Rayong Province, particularly within the industrial sector. It includes reference to East Water, a major industrial water service provider in the Province. As demand will soon outstrip supply sourced from within Rayong province, the discussion also refers to plans to draw on additional water from neighbouring provinces, and divert it to Rayong. The water theme relates to the industrial and agriculture themes, and those sectors are major consumers of water, and also major polluters of water. It also relates to the biodiversity theme, as the forested watersheds of Rayong and neighbouring provinces are the source of the natural water capital. Yet, plans for new water infrastructure may also have negative impacts on the remaining forests.

2. Description of current status

River systems

Thailand has 25 major river basins covering the entire country. The Eastern region of Thailand includes the Bang Pakong River Basin, the Prachinburi River Basin, the Tonle Sap River Basin and the East Coast Gulf River Basin, with a combined area of almost 38,000 sq.km. Within the Eastern Region, the East Coast Gulf River Basin has a total basin area of 13,830 sq.km. and consists of a number of relatively short rivers, flowing from the western part of the Cardamom mountain range to the sea in the eastern part of the Gulf of Thailand. The East Coast Gulf River Basin includes the Trad River; the Chantaburi River; Khlong Tanote and all the river systems of Rayong province. As part of the East Coast Gulf River Basin, Rayong has two main river systems – the Rayong River (or Khlong Yai) with a catchment area of 1,730 sq.km.; and the Prasae, with a catchment area of 2,138 sq.km.

The Rayong River flows 50km from its headwaters in Kong Song and Khao Phanom Sat to Pak Nam sub-district of Meuang District where it empties into the Gulf of Thailand. The Prasae River has its headwaters in Khao Yai, Khao



STRATEGIC ISSUES OF CRITICAL CONCERN FOR SUSTAINABLE DEVELOPMENT IN RAYONG

- ✓ Water demand and supply
- ✓ Water quality (surface and ground water)

SUSTAINABLE DEVELOPMENT OBJECTIVES:

- ✓ Rehabilitate and manage river basins and water resources for ecological sustainability and environmental quality;
- ✓ Provide a secure supply of clean water that meets demand in each sector within ecological limits, without causing conflict between different user groups or with neighbouring provinces;
- ✓ Use water efficiently and equitably to eliminate wastage and reduce demand.

Ag Rue Nai, Khao Hin Rong, and Khao Ang Kraden, which give rise to many streams that eventually join to create the Prasae River which flows for 120km into the sea at Ban Pak Nam, Pak Nam Sub-District, Klaeng District.¹

In total, Rayong has 170 different waterways with water all year round. These include the 67 tributaries of the Prasae River system and the 58 tributaries of the Khlong Yai river system, as well as another 45 small tributaries and rivers in the eastern and western coastal sections of Rayong. Some of the important sub-catchments of the Khlong Yai system include Khlong Dok Krai with a length of 45 km, from Khao Chak Kluay in Bang Lamung District of Chonburi Province; and Khlong Nong Pla Lai which forms from the confluence of tributaries including Khlong Rawing, Khlong Kra, Khlong Pluak Daeng arising from the headwaters in Khao Nam Joan, Khao Chompu, and Khao Rua Dok, in Chonburi Province; and flows 42km through Rayong Province before emptying into Khlong Yai at Nong Bua Sub-district of Ban Kai District. Khlong Tap Ma is 12km long and flows into the Rayong River in Mueang District.

¹ Including Khlong Prasae, Khlong Pling, Khlong Bor Tong, Huay Hin Khom, Khlong Jawaek, Khlong Da Kluay, Khlong Com Saeng, Khlong Pai Neua-Dai, Khlong Kwak, Khlong Pang Wai, Khlong Jaka, Khlong Chai, Khlong Waen, Khlong Plo, Khlong Ta Si Kaew, Khlong Nong Plong.

Important sub-catchments of the Prasae system include Khlong Plo, which is 38km long, with headwaters in Khao Cha-mun, Khao Cha-em, and Khao Pla Lai and which flows into the Prasae River in Klaeng District. Khlong. Khlong Rak is 10km long and flows from Khao Chamao into Khlong Plo which subsequently flows into the Prasae River. Some portions of the watersheds that give rise to Rayong's Rivers are located in neighbouring provinces (see Figure 9-1).

Water Supply

Thailand receives around 832,000 million cubic metres (mcm) of rainfall each year, about 225,000 mcm of which is available as run-off. Nationally there is about 68,000 mcm of storage capacity – representing around 30% of available run-off. This consists of 650 large and medium size reservoirs, and over 60,000 small scale reservoirs, covering an area of almost 5 million hectares (31 million rai) – or almost 10% of the land area of the country (Sethaputra et. al., 2000). The East Coast Gulf Basin receives around 26,000 mcm of rainfall, of which 6,500 mcm is available as run-off, while the three EEC provinces have a combined reservoir storage capacity of 1,600 mcm.

According to the 25 rainfall monitoring stations spread across Rayong province, different parts receive different amounts of rainfall, ranging from 1,200mm to 1,900mm per year. On average, 25% of total rainfall is available as surface run-off. As a result, the Khlong Yai system has an average annual run-off of 679 mcm, while the Prasae system has 971mcm, giving a combined total of 1,560 mcm of run-off on average each year (Table 9-1).

Table 9-1: Annual surface water run-off in Rayong Province

River System	Catchment Area (sq.km.)	Annual Run-off (mcm)
Khlong Yai	1,730	679
Prasae	2,138	971
Total	3,868	1,560

Source: RID

Due to the particular geology of Rayong Province, overall availability of sub-surface water is quite low. The area with greatest availability of ground-water supplies is a zone covering about 200 sq.km. between Muang District and Klaeng District, along the Klaeng fault line, which stores water more efficiently due to the numerous fissures. In this area tube wells could potentially pump 10-25 cubic metres/hour from depths of 50-80m.

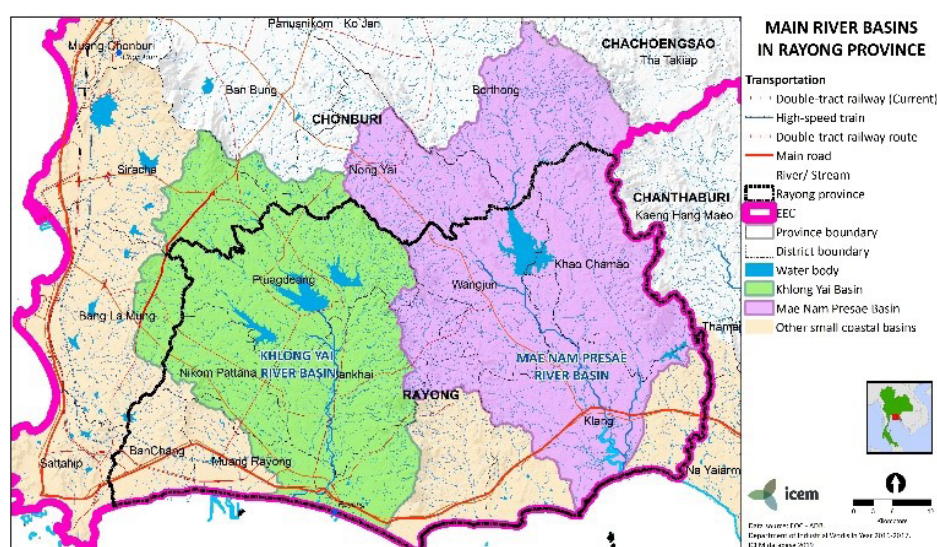
The Province has 2 large reservoirs and 2 medium size reservoirs as well as 10 smaller reservoirs, which until 2017 had a combined storage capacity of 600 mcm, and a total inflow of 652 mcm/year. During the last two years storage capacity has been increased by a further 90mcm, and in the coming two years, an additional increase of 107mcm is planned (Table 9-2).

Water Demand

Forty years ago, Rayong was still largely an agricultural province and most water consumption in the province was for agriculture. Since the launch of the Map Ta Phut Industrial Estate, industry has continued to grow, and quickly became the dominant economic sector in the province, as well as a major consumer of water. East Water was established in 1988, as the primary supplier of raw water to industry in Map Ta Phut as well as other areas in Rayong and neighbouring provinces of Chonburi and Chachoengsao. In recent years water consumption by the industrial sector has outstripped use by all other consumers combined (Table 9-3).

Industrial demand: In the Eastern Region of Thailand, Industrial Estates account for about 30% of total water use by the industrial sector, whereas large factories outside industrial estates account for 49% and the rest is consumed by smaller factories scattered throughout the area. In the three provinces of the EEC there are approximately 2,250 factories inside industrial estates, and 6,750 registered factories outside industrial estates. The breakdown of the proportion of water used by different types of factories reveals that chemical factories account for the biggest proportion (24%), and motor repair factories (8%) the lowest (Figure 9-2).

Figure 9-1: Map of Rayong's river basins



Source: ICEM 2019

Table 9-2: Water storage capacity of reservoirs in Rayong Province

Reservoir	Storage 2017 (mcm)	Storage 2019 (mcm)	Proposed by 2021
Prasae	248	295	Additional 50 mcm pumped storage
Nong Pla La	163	186	Additional 5 mcm pumped storage
Dok Krai	71	81	
Khlong Yai	41	51	
Luang, Khlong Pan Thong Khlong Ra-ok and other reservoirs	76.77	76.77	Additional 27mcm storage Additional 20mcm storage Additional 5mcm storage
Total	599.77	689.77	796.77

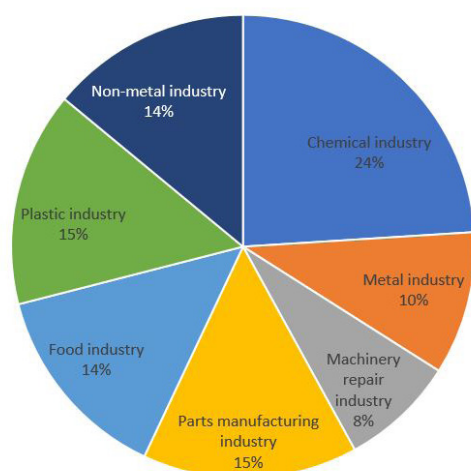
Source: RID

Table 9-3: Water consumption by sector in Rayong (mcm)

Sector/Year	2013	2016	2019
Residential and tourism	21.6	40.4	73.8
Agricultural	125.9	125.9	125.9
Industrial	173.1	191.4	293.8
Environmental	54.0	54.0	54.0
Total	374.6	411.7	547.5

Sources: Rayong Provincial Development Plan 2018-2022, presentations provided by Provincial office of Agriculture and Cooperatives presentation, Provincial Water Authority, East Water and <https://www.researchgate.net/publication/268146800>

Figure 9-2: Industrial water use by different sectors



Source: Puwiphiromkhwan, 2016

In Rayong, 92% of water used by industry is from piped water supply, while 8% is from pumped ground water. These figures do not include the possibility that some small factories are using unlicensed ground water supplies which are not metered. In considering Table 9-3, it is important to bear in mind that the figures for industrial water consumption reflect only consumption within Rayong Province. However in addition, East Water is providing water sourced from reservoirs in Rayong province to industrial customers in neighbouring provinces. The total water consumption for all industry using water from Rayong via East Water is around 300 mcm/year (Table 9-4).

Table 9-4: Water consumption by East Water Clients

Province/Year	2019 (mcm)	2021 (mcm)
Rayong	232	242
Chonburi	75	77
Chachoengsao	14	16
Total	321	335

Source: East Water presentation

East Water is a major water supplier in the EEC. In Chonburi and Chachoengsao Provinces East Water supplies a variety of consumers, but in Rayong their biggest market is industry. The company obtains water from three major reservoirs, namely Dok Krai (116 mcm), Nong Pla Lai (120mcm), and Prasae (84mcm). Water is allocated to East Water by the Royal Irrigation Department. Each year the Irrigation Office 9 will hold a meeting among non-agricultural water users (general and industrial consumers) to agree on allocation for users with water consumption licenses. The yearly water allocation starts in November and lasts until October of the following year. During the water allocation period, meetings will be held to monitor water consumption, which varies with the water situation, in order to arrange for additional water allocation when inflow water to reservoirs increases. In 2016 East Water pumped a total of 303mcm from the reservoirs. In 2017, East Water's annual allocation totaled 319.7mcm out of the available water capital of 390 mcm, but they only pumped 252.78 mcm.

Agricultural demand: Much of the agriculture in the province is rain-fed. Figures for agricultural water use or demand therefore only reflect water use/demand in agricultural areas that have irrigation, or where farmers use other forms of water supply where consumption can be measured. Agricultural water use figures do not include the direct use of rainfall, and agricultural water demand figures do not include the unmet demand from farmers who do not have access to irrigation but would like to have it. Currently only about 13.5% of farmland is irrigated - 201,700 rai out of a total of about 1.5 million rai of farmland in the province (Table 9-5). Over 50% of all the irrigation water provided is used in Klaeng District (supplied by Prasae and Khlong Ra-ok) with Wang Chan and Ban Khai Districts each accounting for another 15% (supplied largely by Nong Pla Lai and Khlong Yai). The Rayong Provincial Development Plan (2018-2022) suggests total agricultural water use (i.e. both inside and outside the irrigated area) is around 1,000mcm/year.

Table 9-5: Irrigated area in Rayong Province

Reservoir	Irrigated area (rai)
Prasae	137,000
Nong Pla Lai	36,000
Khlong Yai	20,000
Khlong Ra-ok	7,500
Dok Krai	1,200
Total	201,700

Source: Rayong Provincial Development Plan 2018-2022

To illustrate the unmet agricultural water demand, surveys of 300 farming families in Chonburi, Rayong, Chantaburi and Trat revealed that only 3% of fruit tree farmers; 4% of rubber tree farmers; and 10% of field crop farmers, say they have an adequate water supply, while 45%, 47% and 37% respectively of those same farmer groups say they face critical water shortages (Figure 9-3).

Residential and tourism demand: In Rayong, 50% of the inhabitants of the province receive their water supply from the Provincial Water Authority, which has 7 water treatment plants, with a combined capacity of 7,400 cubic metres/hour. In addition, Klaeng Municipality and Map Ta Phut both run their own water treatment plants with capacities of 500 and 400 cubic metres/hour respectively. The rest of the population is served by village water supplies.

There are 223 village water supplies in Rayong Province using surface water, and 148 village water supplies using ground water. In total, 803,440 people are currently using piped water supply. Of whom, 572,950 people are consuming 62 mcm/year of water supplied from surface water; and 230,490 people are consuming 11.8 mcm/year of water supplied from groundwater.

Rayong is not a stranger to water supply shortages. In 2005, 13,000 families in Ban Chang and Map Ta Phut spent a four days without water and subsequently only had water supply on alternate days. According to the water authority, the crisis was due to a reduction in piped water from Eastern Water Resource Development and Management Plc (East Water) which had dropped by half - from 20,000 to 10,000 cubic metres per day. At the time, East Water's senior officer in Rayong claimed the company knew nothing about the problem, adding that it would never supply less water to the area intentionally. East Water considered that the problem might have been because the local water system is too small to handle growing demand.²

Koh Samet island receives less rainfall than the rest of the province and water supply is not enough to meet the needs of this island which has been significantly developed for tourism and is often crowded with foreign and local tourists, especially on weekends and long holidays. The need to supply water to the island from the mainland has steadily grown over the years. In 2016 the Provincial Waterworks Authority (PWA)

joined hands with the Rayong Provincial Administration and the Khao Laem Ya-Koh Samet National Park to address the clean water shortage on the island. The three agencies signed an agreement under which the PWA will improve its water distributing station at the national park under a budget of 54 million baht, while the local administration will lay four kilometres of underwater pipes from the station to the island with its 250-million-baht budget.³

Demand for environmental flows: Environmental flows are the flows of water through a river system from upstream to downstream areas that are necessary to maintain the ecological functions of different parts of the river system at different times of year. Under those conditions, the ecologically acceptable flow regime is designed to maintain a river in an agreed state. Environmental flows become a compromise between water resources development and the maintenance of river health. They reflect competing demands – there is an environmental demand similar to agricultural, industrial or domestic water demand. Consequently, the amount of water which is released to flow down a river is a standard set by the river management authorities. When setting that standard, difficulties arise in the estimation of environmental flow levels. This is due to the lack of understanding of and quantitative data on relationships between river flows and multiple components of river ecology. In the absence of this solid science evidence base, the standard setting is shaped by expert judgement and political and social imperatives. In those situations, stakeholder engagement in setting environmental flow levels is essential.

The major criteria for determining environmental flows should include the maintenance of both spatial and temporal patterns of river flow, i.e., the flow variability, which affect the structural and functional diversity of rivers and their floodplains. Thus, any standard should respond to the amounts of water needed, and when and how this water should be flowing in the river. Setting standards for environmental flows needs to consider all aspects of a river and drainage system. This means looking at the basin from its headwaters to the estuarine and coastal environments and including its wetlands, floodplains and associated groundwater systems. It also means considering environmental, economic, social and cultural values in relation to the entire system.

In the Thai context the environmental flows is usually calculated with reference to natural minimum flows in the dry season. Water is also released from reservoirs as part of environmental flows to help dilute pollution in the lower parts of the river, and to ensure enough flow to push back salt-water intrusion in the dry season.

In Rayong Province, the critical condition of the Klong Yai River is evidence of river ecology under acute stress and that the current approach to setting the environmental flows regime is not working effectively. Currently, RID allocates about 7% of water releases from its reservoirs for environmental flows. Those releases are not well monitored and their effects on downstream water quality and ecosystem health is not properly assessed. The 7% level and actual releases are likely based on water demand from industry, domestic and agriculture and water availability at any time during the year rather than on river ecology considerations. The river

² The Nation, 2005

³ The Nation, 2016

condition shows that 7% is definitely not enough to sustain river health and to safeguard downstream water users and livelihoods depending on river services.

One reason for this failure in river management is that environmental water requirements are viewed as a competing demand. An alternative system would explicitly reserve environmental water by subtracting it from water available for other purposes. Another reason is that the environment flow requirement will vary from one month, season or year to the next. An effective system needs to function on a daily basis against a set of principles and objectives for a river and including a comprehensive monitoring and feedback program.

Globally, dating back to the 1970s, there have been a variety of methods with differing degrees of complexity used to determine minimum suitable flow rates. For example, one of the first methods to correlate environmental flows with resilience of fish species concluded that for dry periods of the year that 10% of minimum mean annual flows (MAF) allows for survival level habitat, 20% MAF allows for good habitat and 30% allows for excellent habitat. The corresponding figures from this study for the wet season were 30%, 40% and 50%.⁴ Without actual measured or observed data in Rayong, environmental flows should be maintained at the medium level for dry season flows (20% MAF), and for this regime to be assessed for its affect on river health. Alternatively a system in which the average low flow (from past flow records) and the number of days during the dry season the flow level dips below that average are determined as guidance environmental flow releases. Such a system would require RID to maintain an optimum (not minimum) environmental flow during the whole dry season

Water Quality and Waste Water

Thailand faces several problems related to wastewater – a fact highlighted in October 2017, by a massive die-off of giant freshwater stingrays in the Mae Klong River because of poor water quality due to upstream wastewater discharge. Most of the problems with poor water quality occur in the river basins which are the main industrial base for the country, including the Rayong River. However, in terms of volume, the agricultural sector is the largest water pollutant as the country's farms discharge up to 39 million cubic metres of wastewater per day, while the industrial sector ranks second discharging about 17.8 million cubic metres per day, and the residential sector ranks third with 9.6 million cubic metres per day. Nationally only around 50% of residential waste water is treated.⁴ In Rayong, the percentage is extremely small, only around 2.5% and residential waste water is a major source of water pollution especially in some parts of the Rayong River where there are large numbers of people living right on the riverbank and discharging waste directly into the river.

Surface water quality: Nationally in 2015, 41% of surface water was determined to be of fair quality, 34% was good and 25% was poor. The quality of water resources in the northern region was better than any other regions, followed by the northeast, the south and the east. The eastern region had most water resources in the fair category. The parameters which could not comply with the surface water quality

standards were BOD, DO, TCB and FCB. The main cause of the problems was generally considered to be waste water effluent from community and agricultural activities such as horticulture and aquaculture, but in the case of the Rayong River, wastewater effluent from industrial plants and factories was identified as an additional source of wastewater.

Time series data is not available, but Lower Rayong surface water quality has been poor for at least a decade, with domestic sewage as a leading factor in deteriorating water quality. That problem has reached critical levels due to increasing populations and densities. In agricultural areas, ammonium is a common pollutant and an indicator of pollution from fertilisers (interviews, Regional Environment Office, 2019). The Pollution Control Department (PCD) monitors surface water quality across the province (Figure 9-4).

Data from 2015 to 2016 from 79 sampling points monitored by PCD shows there was a general decrease in water quality across a broad range of parameters (Table 9-6). In particular, Organic pollutants were found to exceed permitted standards in surface water.

Table 9-6: Surface water samples not complying with water quality standards

Water quality parameter	2015	2016
Dissolved oxygen (DO)	35%	53%
Biochemical oxygen demand (BOD)	81%	98%
Total coliform bacteria (TCB)	74%	80%
Faecal coliform bacteria (FCB)	85%	76%
Nitrate (NO ₃)	3%	3%
Ammonia (NH ₄)	33%	37%
Arsenic (As)	36%	39%
Manganese (Mn)	4%	4%
Lead (Pb)	3%	
Total	474.7	511.8

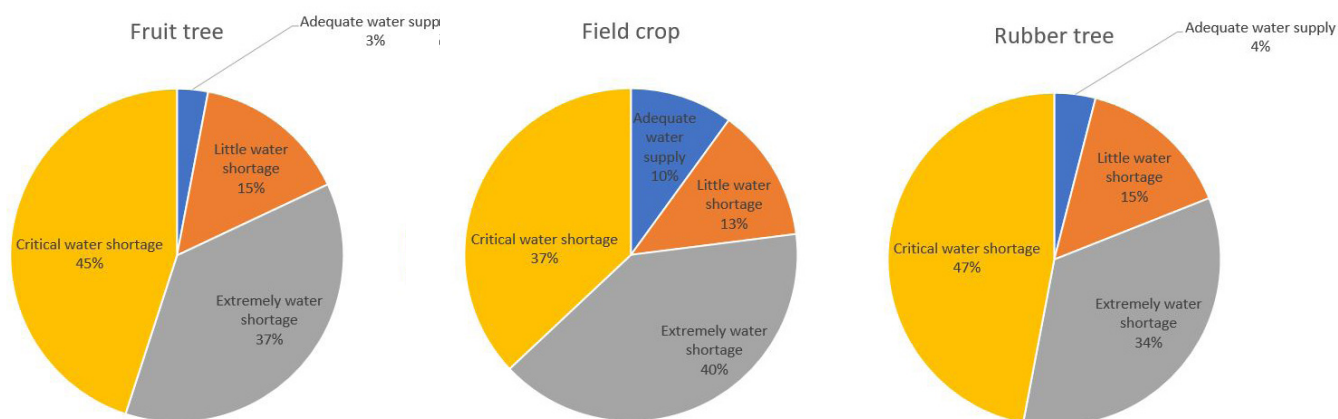
Source: PCD

Water quality in the Prasae River generally conformed to category three – safe for consumption with normal water treatment processes. BOD exceeded the limit for category 3 only about 5% of the time, and was not found to be a critical issue anywhere in the Prasae river. In about 10% of samples TCB and FCB both exceeded category 3 standards, and this was found to be particularly critical around the Prasae river mouth. Excessive ammonia was found in 15% of samples, with the most critical area being ban Ta Krabak in Thung khwai Gin sub-district of Klaeng District.

In the Rayong River, the section from the river mouth to km 19 at the bridge on the Chantaburi-Rayong Road in Choeng Noen sub-district of Muang District has been designated

⁴ Tennant, D.L., 1976. Instream flow regimens for fish, wildlife, recreation and related environmental resources. Fisheries, 1 (4), 6–10.

Figure 9-3: Farmer level of satisfaction with available water supply in the EEC provinces (fruit tree farmers; field crop farmers; and rubber tree farmers)



Source: Puwiphiromkhwan, 2016

category 4 – highly degraded. Further upstream from the bridge the Rayong River is still designated category 3. Ammonia frequently exceeded the limits particularly around Tesaban 8 bridge, Ban Pak Khlong and Chaloemchai bridge, while DO was consistently below acceptable limits. BOD consistently exceeds the limits and is critical, especially at Ban Khai bridge, and Lahanraisangkham Temple bridge. TCB is also a problem at Ban Khai, while manganese has occasionally exceeded the limits in Ban Khai (e.g. in November 2013 and February 2014).

Sub-surface water quality: In Rayong, groundwater is also a source of water supply. There are over 2,600 tube wells in Rayong province, that have been developed by the ground water department alone for various users. In addition, there are many more created by users themselves, especially factories outside of the industrial estates, as well as some large farms. Most of these have legal permission and are registered, but there are an unknown number of unregistered wells.

Over the last two decades, rapid development has increased the potential for groundwater contamination from various sources – including domestic, agricultural, and industrial. Generally, heavy metal contamination can be caused by human activities including mining, wastewater irrigation, leakage of septic tanks, industrial processes which leave heavy metal residues in their wastes, and non-point surface run-off. In addition, heavy metals in ground water may come from natural sources such as weathering and erosion of rock. Any of these activities may result in heavy metals being transported into ground water.

Previous studies have found that most groundwater sources water quality were below the groundwater quality standards for drinking purposes set by Ministry of Natural Resources and Environment, Thailand (PCD, 2004). Groundwater sources in the Eastern Thailand in general have problems with iron (Fe), manganese (Mn), fluorine (F), Sulphate (SO), chlorine (Cl), permanent hardness (non-TH) and TDS (PCD, 2015). In 2009, thirty-one samples of groundwater were taken in the dry and rainy seasons in Rayong (March and September). Results showed the groundwater generally to

have low ion concentrations and low salinity. The averages of pH, electrical conductivity (EC), total dissolved solid (TDS), and hardness were 7.08, 324.43 mg/L, 277.60 mg/L and 78.53 mg/L, respectively (Makkasap and Satapanajaru, 2010).

The geospatial trends of Cd, Zn and Hg revealed low concentrations in the northwestern part of Rayong, high concentrations of Zn and Hg in the southeast, and highest concentrations of Cd in the east and southwest. For Zn and Hg the pattern was the inverse of the distribution pattern of pH. (Makkasap and Satapanajaru, 2010). The high heavy metals concentrations in some areas might therefore be attributed to the low pH in those areas, because heavy metals are more easily dissolved in low pH than high pH. In addition, the geology of northwestern Rayong consists of carboniferous granite containing high concentrations of heavy metals (Suthirat et. al., 2007; Singer, 1974), whereas south-eastern Rayong consists of alluvial deposits and beach sand. Groundwater flow direction is downward from the north to the south (Department of Groundwater Resources, 2007), so groundwater can leach and dissolve heavy metals in the parent rock from the north to the south. At the same time, the southeast area of Rayong is mainly agricultural and residential areas. The major sources of heavy metals may therefore also derive from anthropogenic activities, domestic sewage, or some pesticides (Al-Ahmari, 2006; Mehrjardi et. al., 2008).

Overall, identification of the major sources of heavy metals contaminating groundwater in Rayong province is inconclusive – it is likely coming from both natural and anthropogenic inputs such as parent rocks and wastes from industrial, residential wastewater, and agricultural sources (Makkasap and Satapanajaru, 2010). PCD has begun monitoring sub-surface water quality, which, over 2015- 2016, varied with depth. Deeper monitoring wells detected levels of iron, manganese, lead and arsenic above national standards, while from shallower wells several VOCs were also detected. The monitoring has all been done in the vicinity of the Map Ta Phut industrial area, because of the PCD pollution control zone covering that region (Table 9-7).

Table 9-7: Percentage of shallow and deeper samples not complying with standards

Shallow underground water quality parameter	2015	2016
Iron (Fe)	29%	
Manganese (Mn)	13%	19%
Lead (Pb)	1%	
Arsenic (As)	25%	22%
1,2 Dichloroethane	2%	2%
Carbon tetrachloride	2%	2%
Tetrachloroethylene	1%	
Trichloroethylene	2%	2%

Underground water quality parameter	2015	2016
Iron (Fe)	88%	75%
Manganese (Mn)	50%	50%
Lead (Pb)	38%	50%
Arsenic (As)	25%	25%

Source: PCD

Table 9-8: East Water forecast growth of demand from existing and new customers

Service area	2019	2021	2026	2031	2036
Existing customer growth	321	335	369	409	439
1.1 Rayong	196	203	222	237	251
1.2 Pluak Daeng-Bo Win	36	39	44	50	55
1.3 Chonburi	75	77	86	103	112
1.4 Chachoengsao	14	16	17	19	21
2. New EEC opportunities	29	60	107	115	122
2.1 Industrial estates in EEC	22	38	49	52	55
2.1 Other factories	7	22	58	63	67
Total (1) + (2)	350	395	476	524	561

Source: East Water

3. Past trends and drivers of change

- ✓ Water supply and demand
- ✓ Water quality (surface and ground water)

Water Supply and Demand

In 2017, the National Office of Water Resources found that total water supply in the whole Eastern Region was around 2.936 billion cubic metres (bcm), while current water supply in the three EEC provinces was 1.682 bcm. However, demand for water from all economic activities in the Eastern Region was 3.833 bcm, while in the three EEC provinces the demand was 1.984 bcm (300 mcm in excess of current supply). The ONWR study also estimated that water demand in the three EEC provinces would rise to around 2.242 bcm by 2027, based largely on demand in the industrial sector increasing to 680 mcm (Figure 9-4).

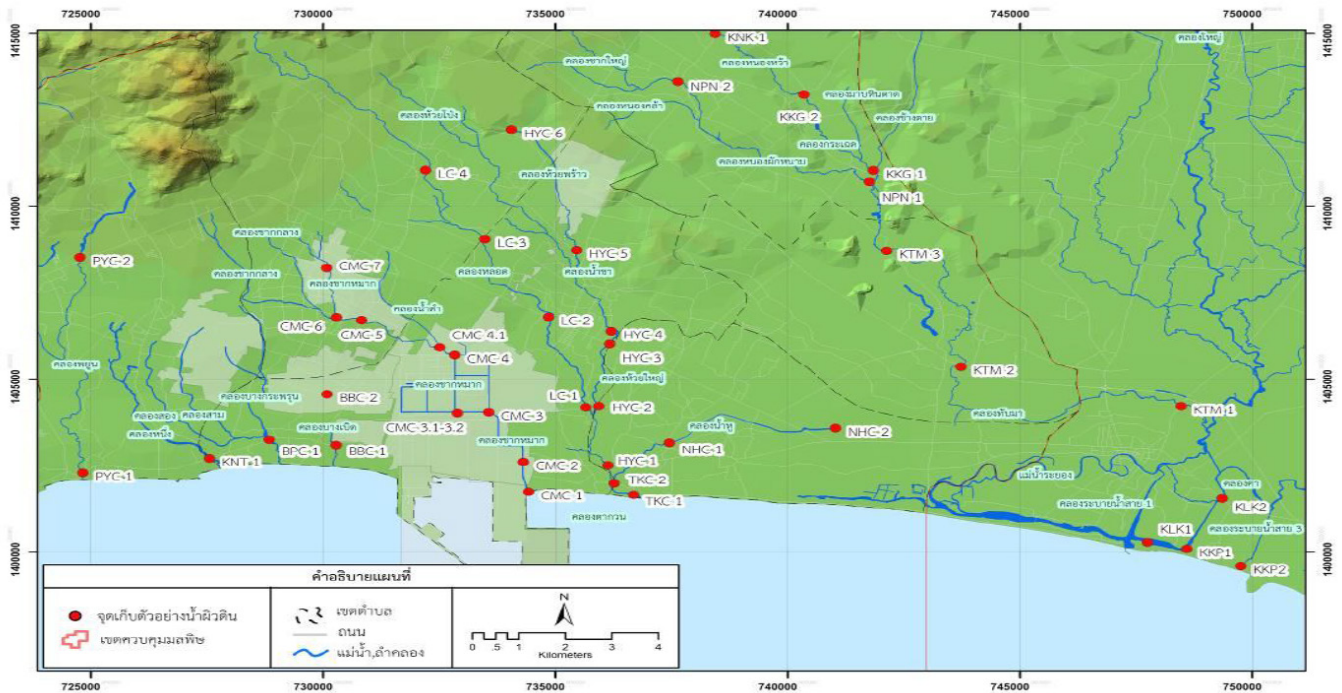
Figure 9-5 summarizes the information on water supply and demand in geographical context. Particularly, the figure highlights the existing inter-basin transfer systems linking the three EEC provinces. Further, on the right hand side of the map, the Khlong Wang Tanot reservoir (in Chantaburi Province) is shown, from which it is planned to pipe water to the Prasae reservoir in Rayong.

East Water forecasts that demand for piped raw water from their customer base will increase from the present demand of around 350mcm/year to 561 mcm/year by 2036 (Table 9-8), while also forecasting that their available water capital will increase to 719 mcm in the same period (Table 9-6)). A large proportion of this increase is intended to come from additional allocations to East Water of 120 mcm from the Prasae reservoir, and 70mcm from Klaeng District water diversion (Figure 9-6).

Increasing allocations of water from the Prasae reservoir to East Water to supply industrial users is a sensitive topic with the Prasae River Basin Committee. When construction of the Prasae reservoir was first planned, there were objections from the local communities, concerned about its environmental impacts. Local opposition subsided following assurances that the Prasae reservoir would be used to support irrigation for local farmers. The total capacity of the Prasae reservoir is 240mcm. East Water's current allocation from this source is 60 mcm – with the planned additional allocation of 120 mcm, East Water would absorb 75% of Prasae reservoir capacity.

The mandate of the Royal Irrigation Department is first and foremost to provide water to farmers. Yet, in Rayong Province, RID is increasingly focused on providing water to East Water – at 50 satangs/cubic metre – while East Water sells the same untreated raw water at a much higher price to industrial and domestic users. The provincial irrigation department in Rayong takes the view that, in the irrigated area, farmers can get all the water they need and that East Water is not taking water away from the agricultural sector.

Figure 9-4: Surface water quality sampling location by PCD



Source: PCD

Figure 9-5: Water Supply and demand in the Eastern Region and the EEC

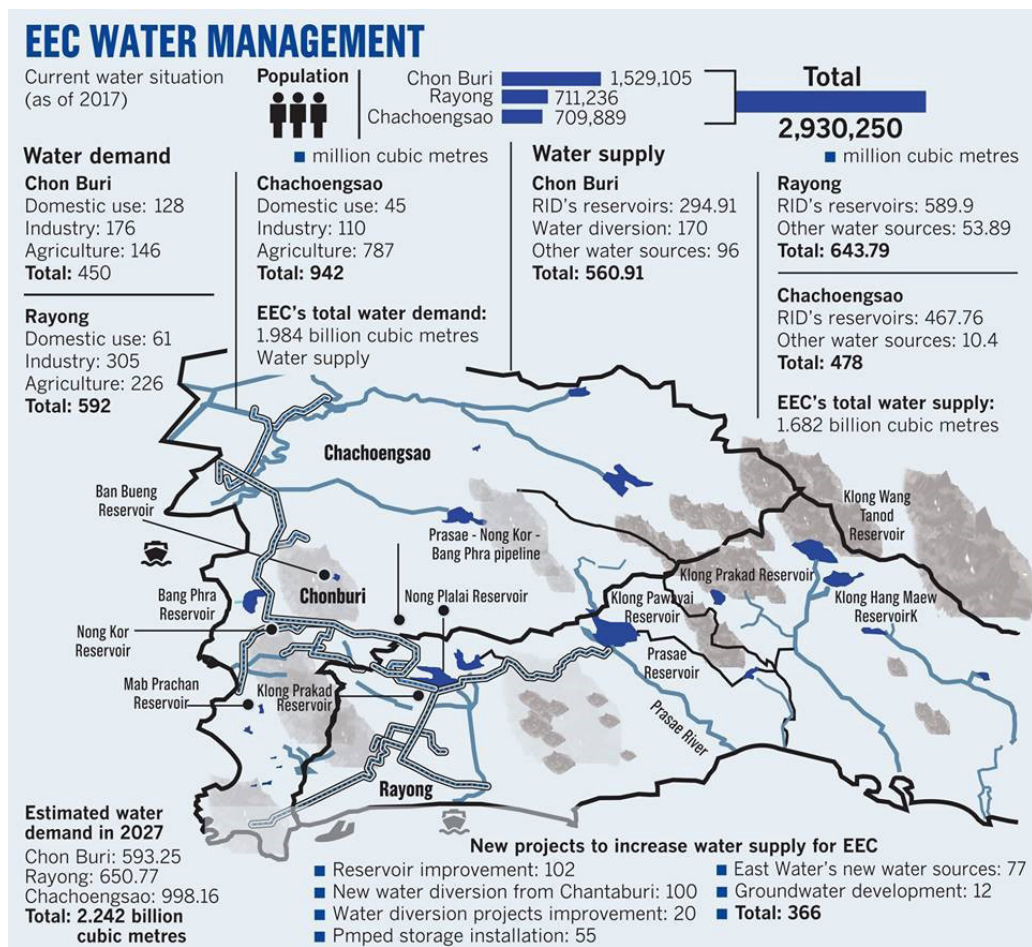
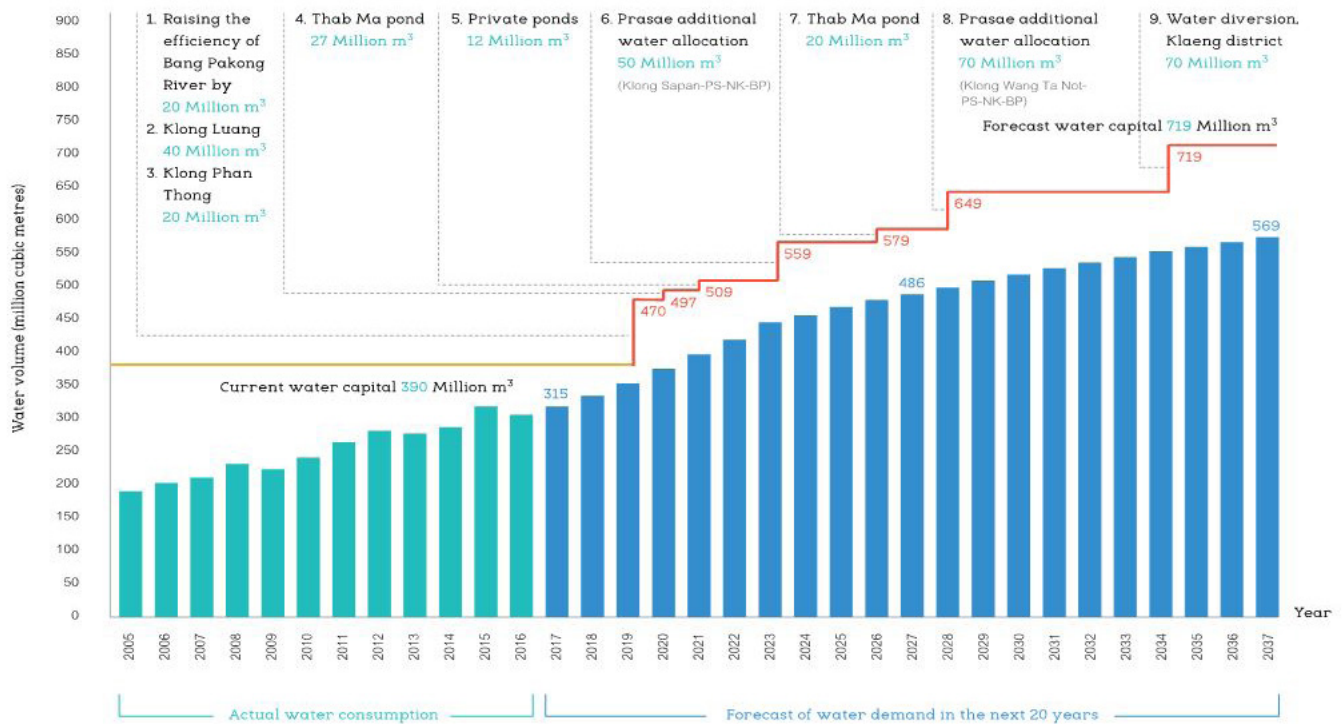


Figure 9-6: Water capital and demand forecasts of East Water (Source East Water Sustainability Report 2018)



Source: East Water Sustainability Report 2018

There are many more farmers in Rayong who would welcome expansion of the irrigation system, and the opportunity to have an all year round water supply. Yet, RID does not plan to expand irrigation in Rayong. Future increased allocations of water to East Water from the Prasae reservoir would curtail the possibility of expanding the irrigation system. The plan to divert water from Chantaburi province into the Prasae would help alleviate this issue for Rayong but in turn is likely to meet resistance and cause problems in Chanthaburi.

East Water has established a fund to support farmers living in the Prasae Reservoir catchment area, with an additional 10 satangs for each cubic metre of water it purchases from RID. This fund could provide a starting point for a payment for ecosystem services (PES) scheme. A new Water Law was passed in January 2018, and implementing regulations are still being worked out. The mandate and level of authority that will be given to River Basin Committees (RBCs) may have important ramifications for future water allocations from the Prasae River, inter-basin transfers from Chanthaburi to Rayong, and PES schemes.

Water Quality and Waste Water Treatment

In terms of a national 10-year trend (2006 – 2015), overall water quality has remained relatively stable, with water resources categorized as “fair” on average. At the same time, expansion of wastewater treatment systems have not kept pace with wastewater generation. Around 94% of domestic waste water goes untreated to receiving bodies. 25 surface water sources have been deteriorating, including both the Upper and Lower Rayong Rivers (PCD, 2015). Until the early 1980s, the population of Rayong depended almost exclusively on agriculture for their livelihoods. The discovery of abundant natural gas deposits in the Gulf of Thailand, combined with

Thailand’s pursuit of economic growth, led to industrialisation in eastern seaboard provinces, especially in Rayong. That change in economic activity signalled a steady deterioration of environmental quality in the province. According to the Eastern Economic Corridor (EEC) Environmental Management Plan (MONRE, 2019), many surface waters are now heavily polluted.

Summary

Water demand in Rayong Province is anticipated to grow rapidly over the next 2 decades, especially with increasing demand from industry, in line with the government’s expectations that the EEC will be a significant driver of economic growth, and Rayong’s major role within the EEC. Even when the water resources of the province are fully utilized in the most efficient way possible, shortfalls in supply to meet growing demand are likely unless inter provincial transfers are established. Ultimately water imports from neighbouring countries may become necessary. The RID, and the major industrial water supplier in the EEC, East Water are preparing for those options.

At the same time discharge of waste water from industrial, agricultural and residential areas is already in excess of the capacity of waste water facilities in the province. There is also heavy metal contamination of ground water sources but it is not clear to what extent this is from natural weathering of parent rock, or from recharge by contaminated water. agricultural and residential areas is already in excess of the capacity of waste water facilities in the province. There is also heavy metal contamination of ground water sources but it is not clear to what extent this is from natural weathering of parent rock, or from recharge by contaminated water.

4. Future trends and drivers of change without the Rayong Provincial Development Plan

- ✓ Water supply and demand
- ✓ Water quality

Water Supply and Demand

Water supply in the EEC is limited, but demand is already high and set to continue growing rapidly. While most of this expansion in demand is directly linked to industrial development, an increasing urban population through immigration from other parts of the country and abroad seeking employment will increase domestic demand. Continued growth of water demand in the agricultural sector can also be expected. Existing crops (such as rubber, which is mostly rain-fed) are being replaced by more water hungry crops such as durian. The trend of large-scale expansion of durian plantations in Rayong and Chanthaburi to meet the upsurge in demand for Thai durian in China may continue for some time. One durian tree consumes more than 150 litres of water daily, which means one rai (0.16 hectare) requires close to 1,200 to 1,500 cubic metres of water per year. According to figures from the Office of Agricultural Economics, reported in the Nation, Rayong already has 207,483 rai of durian plantations, and irrigating

Table 9-9: Expected growth in water demand (mcm) in Rayong Province

Sector/Year	2022	2027	2032	2037
Residential and Tourism	96	126	162	207
Irrigated Agriculture	157	178	178	178
Industrial	328	351	374	388
Environmental	54	55	56	57
Total	635	705	780	830

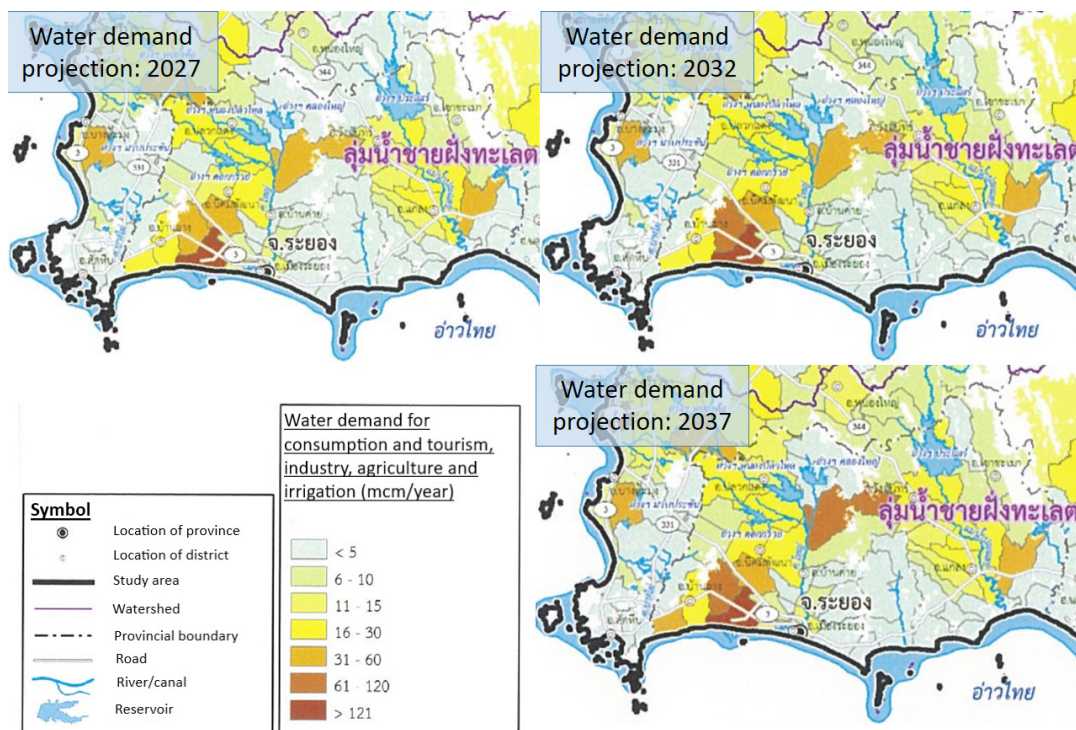
Source: ONWRC Eastern Region Water Resources Study, 2019

these durian plantations alone to the full satisfaction of the farmers would require around 103 million cubic metres/year in Rayong.⁵ The data is inconsistent. An ONWRC study on the Eastern Region Water Resources (2019) suggests Rayong has around 44,000 rai of durian which would require considerably less water to irrigate.

Projected growth in overall water demand in Rayong is given in Table 9-9. The geographic spread of water demand from different parts of the province is displayed in Figure 9-7.

Current EEC thinking is that it is necessary to look beyond Rayong and divert water resources from other basins to meet growing water demand. The Eastern Economic Corridor Office (EECO) is working with related agencies, primarily the Royal Irrigation Department (RID), to identify more water sources in the nearby provinces of Chanthaburi, Trat, Prachin Buri and Sa Kaew. The RID is spending Bt11.2 billion to build

Figure 9-7: Water demand in Rayong (mcm/year) for all uses (except e-flows) in 2027



Source: Study on Water resources of the Eastern Region, 2019, Prepared by PTC Ltd. and A Group Ltd. for The Office of the National Water Resources Commission

⁵ The Nation, 2018

⁶ The Nation, 2018

16 new irrigation projects in the three EEC provinces to boost the volume of available water by an additional 260.67 mcm, specifically to feed the industrial sector. The RID is also developing 10 new reservoirs in Sa Kaew, Chanthaburi and Trat, which should store up to an additional 570 mcm of water.

In addition to new reservoirs and water diversion, ONWR is coordinating with the Groundwater Resources Department to tap more groundwater to meet the EEC's demands. It is forecast that the three EEC provinces still have potential to pump an additional 1.187 billion cubic metres of groundwater per year up from the current groundwater use of 1.31 billion cubic metres per year. The industrial sector in the EEC is also being encouraged to reuse water and to develop capacity for desalination of seawater.⁶

Rising demand for water in the three EEC provinces – Chon Buri, Rayong and Chachoengsao – may lead to conflicts between sectors and within communities, spilling over to nearby provinces. Other problems such as land expropriation and deforestation to make way for new reservoirs have been raised as concerns. The future emergence of strong river basin organisations, mandated by the new water law could have important consequences in resolving these issues.

Water Resources Development Strategy

RID has developed a water resources development strategy to support the EEC development. According to this strategy, RID will continue to provide the water, while East Water, the Provincial Waterworks Authority and local administrations will use the water. The strategy involves:

1. Improving existing water sources and developing new water sources
2. Connecting water sources through a network of pipes
3. Developing "monkey cheeks" and small water storage ponds and reservoirs
4. Flood prevention
5. Coordinated management of different water sources

The plan envisages three implementation phases as follows:

Phase 1 (5 years)

- Build new small and medium size reservoirs
- Increase capacity of Nong Pla Lai reservoir by 23 million cubic metres;
- Increase capacity of Dok Krai Reservoir and Khlong Yai reservoirs by 10 million cubic metres each

Phase 2 (6-10 years)

- Construct 4 new reservoirs in Chanthaburi Province – Pra Kaed (60.2 million cubic metres); Pawa Yai (68.1 million cubic metres); Khlong Kaeng Hang Meo (80.7 million cubic metres) and Khlong Wang Don (99.5 million cubic metres)
- Transfer water from these reservoirs to the Prasae Reservoir in Rayong Province

10 years +

- A feasibility study is being carried out looking into the possibility of transferring water from the Streung Manom River in Cambodia, with a capacity of 1,200 million cubic metres which would be brought into Thailand in Trat province, and from their piped into the Prasae Reservoir in Rayong

Water Quality and Waste Water Treatment

The number of industrial operations, and the number of people living and working in Rayong will grow significantly over the next decade. This will put additional pressure on waterways and on water quality, which is likely to deteriorate further. Population growth, community development and expansion – especially in riverside communities which directly release wastewater into rivers, as well as generation of waste water from industrial and agricultural activities will continue to degrade water quality in Rayong's canals and rivers. Polluted rivers/untreated waste water flowing into the sea will also impact the coastal environment, and fishing as well as aquaculture livelihoods.

There has been growth in the number of factories that emit toxic waste-streams that impact on effluent loadings. This brings with it urgent challenges for water management in Rayong. Factories of particular concern include those engaged in the petrochemical industry, as well as those in the paper and leather industries. The current use of ambient standards poses an ongoing challenge, because of the lack of compatibility with enforcing factories to adhere to point source reductions if/when ambient loads are breached. Other areas that require further study include heavy metal contamination related to recycling, smelting and landfill sites.

In addition, unclear or inappropriate land-use zoning, and/or limited enforcement, have resulted in new factories being located in some upper watershed areas, and in some cases, wastewater is flowing down into the reservoirs. For example, factories in Pluak Daeng are polluting water flowing into the Nong Pla Lai Reservoir. This trend is likely to get worse without concerted action and funding from all levels of government and from the private sector. Recent changes in the level at which permission is granted for factories to operate, have given local sub-district administrations the authority to approve factories with power ratings up to 50kw (formerly they could only approve up to 10kw). More small factories are anticipated in Rayong, scattered in different locations, most often outside of industrial estates. These factories may use groundwater sources they develop themselves, and may not have resources to treat their waste-water.

Major challenges include the lack of waste-water treatment facilities, of budgets and local capacities for operating existing facilities, a lack of piping infrastructure, and a lack of capacity to inspect and enforce. Legislation needs to be revised to tighten incentives for good performance and increase monitoring and enforcement capacities with environmental and local agencies. On the more positive side, East Water has a new vision and strategy to transform itself from a provider of raw water to into a total water services provider. This would include new business lines in waste water treatment and water recycling. Also moving further into the future new "greener" industries operating under more rigorous environmental and development controls are anticipated. Two major waste-water treatment projects have been proposed but have not yet been approved. They will both be submitted again for consideration in the 2022 budget planning cycle.

- Waste-water treatment project in Pluak Daeng (960 Million Baht)
- Waste-water management project for eight sub-districts in Rayong district (1,400 Million Baht)

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STRATEGIC THEME: AGRICULTURE

1. Introduction

The Agriculture theme focuses on agricultural production throughout Rayong Province, with emphasis on tree crops including rubber, oil palm, durian and other fruit- tree crops including rambutan and mangosteen; as well as field crops such as cassava and pineapple. There is also a geographic focus on Khao Wong District where farmers are amongst the poorest in the eastern region of Thailand, with many living inside or close to protected areas, without secure land titles; and on Meuang District, which is facing rapid changes in agricultural livelihoods.

Farming in Rayong is undergoing a transformation. The number of farming households and the total area farmed are steadily decreasing. The price of land is increasing, and some farmland is being converted to urban settlement and industrial areas. Agricultural commodity prices fluctuate according to global market demands, and are generally low, while the average farmer has less than 1.6 hectares and competition is high. Traditional farming lifestyles are changing and the average age of farmers is increasing, as younger generations of Thais seek employment in the urban areas. Agricultural labour in Rayong is increasingly dependent on migrant labour (especially rubber tappers from neighbouring Cambodia).

For these reasons, stakeholders have identified transformation of the agriculture sector (with an emphasis on reduction in agricultural land, and labour) as a strategic issue of concern to the agriculture sector in Rayong Province. Water is vital to crop production and many farmers are experiencing water shortages, especially in the dry season. Competing water demand from other sectors (industrial, commercial, domestic) is increasing. Irrigation only covers about one-third of the available farmland. In addition, climate change projections suggest changes in rainfall patters, leading to changes in availability of water supply at different times of year.

Other aspects of climate change – including changes in location frequency and intensity of storms and typhoons will also have impacts on agriculture. For those reasons, stakeholders identified securing water supply for crop production as the second key strategic issue of concern to the agriculture sector.



STRATEGIC ISSUES OF CRITICAL CONCERN FOR SUSTAINABLE DEVELOPMENT IN RAYONG

- ✓ Transformation of the agriculture sector, including land-use change and shortage of agricultural labour
- ✓ Securing water supply for crop production

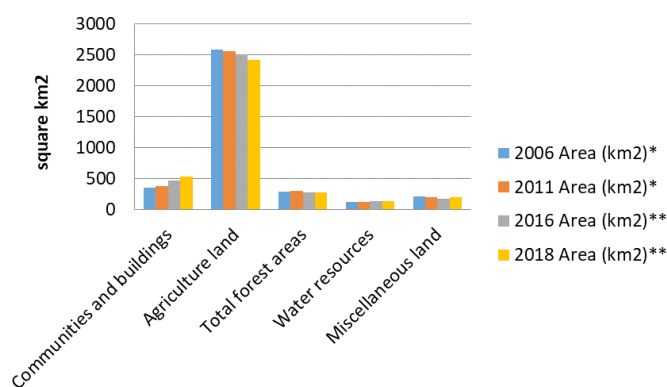
SUSTAINABLE DEVELOPMENT OBJECTIVE:

- ✓ Modernize the sector to international standards through sustainable production models for small-holders and commercial agriculture;
- ✓ Farmers reduce environmental pollution, adopt sustainable land management practices and enhance biodiversity;
- ✓ Farmers build resilience to climate change through diversity in production and nature based solutions;

2. Current status

Rayong province covers an area of 3,552.00 km². Land use areas from 2006 to 2018 are shown in Table 10-1 and Figure 10-1. In 2018, agriculture occupied 2,413.12 km², or 67.92% of total provincial area. In 2018, perennial plants occupied 71.19% of total agriculture area or 48.36% of total provincial area. During the 12-year period, there was a marked increase

Figure 10-1: Land use in Rayong Province in 2006, 2011, 2016 and 2018



Source: Land Development Department & Office of Agricultural Economics

Table 10-1: Land use in Rayong Province in 2006, 2011, 2016 and 2018

Land use	2006		2011		2016		2018	
	Area (km ²)*	% of total provincial area	Area (km ²)*	% of total provincial area	Area (km ²)**	% of total provincial area	Area (km ²)**	% of total provincial area
Community and building areas	348.09	9.80	380.73	10.71	469.51	13.22	527.41	14.86
Agriculture	2,557.60	72.57	2,555.04	71.94	2,500.87	70.41	2,413.21	67.92
Forest	290.13	8.16	297.20	8.37	281.39	7.92	279.37	7.86
Water resources	119.80	3.37	123.02	3.46	130.03	3.66	136.69	3.85
Miscellaneous	216.38	6.10	196.01	5.52	170.19	4.79	195.33	5.51

Source: Land Development Department & Office of Agricultural Economics

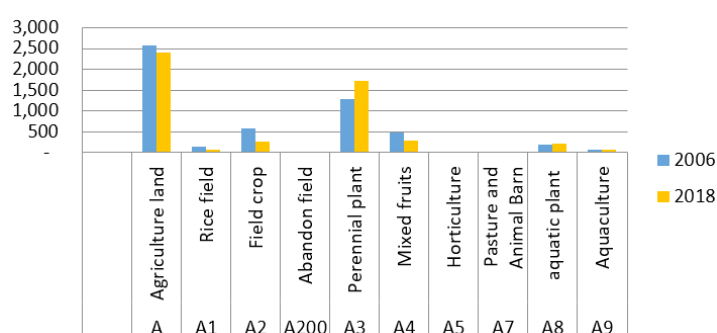
in the area devoted to perennials of 20.96% of total agriculture area or 9.92% of total provincial area. Under the fruit tree category, mixed fruit trees occupied 17.32% of agricultural area in 2006 decreasing to 3.77% in 2018. The area of field crops also declined by about 50% from 22% of agricultural area to 11% of agricultural area (Table 10-2).

Within the perennials category, para-rubber (categorized as a perennial tree), occupies 47.23% of agricultural area or 34.27% of total provincial area in 2006 rising to 66.03% of agricultural area or 45.04% of total provincial area in 2018 – an increase of close to 19% of agriculture area in the 12-year period. Within field crops, the areas devoted to both cassava and to pineapple each decreased by about 50% - declining from around 10.6% to around 5.3% of total agricultural area in both cases. While mixed fruit plantations declined, durian increased. Durian occupied only 0.34 % of agricultural area in 2006, but increased 4.03% in 2018 (Table 10-2).

The most important crops economically are para-rubber, cassava, durian and oil palm as shown in Table 10-3 and illustrated in Figures 10-4 (a) – 10-4 (c) for 2010 and 2018. By 2018, the planted areas for para-rubber, cassava, and durian had decreased, while oil palm increased. While pineapple was not listed amongst the top 4 economic crops of Rayong the Province is the second highest producer of pineapples in Thailand (after Prachuap Kiri Khan) – accounting for about 250,000 tons/year, or about 20% of Thailand's total pineapple production. Most is sold to canning factories for export markets. The harvested areas for each crop are somewhat lower than the total planted areas, and showed the following changes:

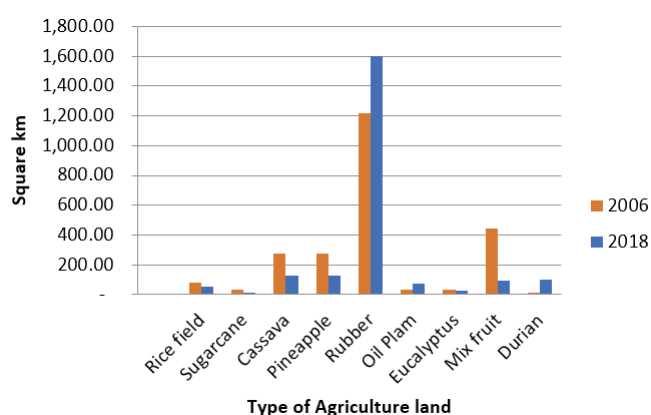
- The proportion of total para-rubber planted area that was harvested increased from 67% in 2010 to 86% in 2018 – suggesting that in 2010 many of the rubber trees were still immature and where not yet producing, whereas by 2018, more of the trees had reached maturity.
- The same pattern is seen for oil palm, where the proportion of harvested area increased from 67% to 83%, presumable with the same explanation.
- For durian, while the planted area expanded significantly, the harvested area dropped slightly from 89% of the planted area in 2010 to 87% in 2018 reflecting that some of the newly planted trees were not yet providing fruit (presumably those planted between 2015-2018).

Figure 10-2: Agricultural land use in Rayong Province in 2006 and 2018



Source: Land Development Department & Office of Agricultural Economics

Figure 10-3: Land-use type categorized in agricultural area in 2006 and 2018



Source: Land Development Department & Office of Agricultural Economics

- For cassava the harvested area is almost the same as the planted area, and was no different between 2010 and 2018 – as would be expected for an annual field crop.

During that 8 year period, in terms of production yield (ton) per area (km²) cassava increased by 63.20% while durian yield increased by 11.48%. On the other hand, para- rubber yield decreased by 28.57% and oil palm yield decreased by 11.48%. On the other hand, para- rubber yield decreased by 28.57% and oil palm yield decreased by 4.25%.

The increase in durian yield can be explained by trees growing and producing more fruit. The huge increase in

Table 10-2: Agricultural land use in Rayong Province in 2006 and 2018

Symbol	Land use type	2006		2018	
		Area (km ²)	% of total agricultural area (% of total provincial area)	Area (km ²)	% of total agricultural area (% of total provincial area)
A	Agriculture area	2,557.60	(72.57)	2,413.21	(67.92)
A1	Rice field	142.51	5.53 (4.01)	71.36	2.96 (2.01)
A2	Field crop	581.29	22.55 (16.37)	266.93	11.06 (7.51)
A200	Abandon field	1.17	0.05 (0.03)	1.31	0.05 (0.04)
A3	Perennial plant	1,294.60	50.23 (36.44)	1,718.03	71.19 (48.37)
A4	Mixed fruits	493.29	19.14 (13.89)	283.90	11.76 (7.99)
A5	Horticulture	0.57	0.022 (0.016)	0.93	0.04 (0.03)
A7	Pasture and animal barn	2.98	0.12 (0.08)	3.40	0.14 (0.10)
A8	Aquatic plant	182.00	7.06 (5.12)	214.00	8.87 (6.02)
A9	Aquaculture	62.09	2.41 (1.75)	68.31	2.83 (1.92)

Source: Land Development Department & Office of Agricultural Economics

Table 10-3: Land-use type categorized in agricultural area in 2006 and 2018

Symbol	Land use type	2006		2018	
		Area (km ²)	% of total agricultural area (% of total provincial area)	Area (km ²)	% of total agricultural area (% of total provincial area)
A	Agriculture area	2,557.60	(72.57)	2,413.21	(67.92)
A1	Paddy field	142.51	5.53 (4.01)	71.36	2.96 (2.01)
A101	Rice field	76.94	2.98 (2.17)	50.03	2.07 (1.41)
A2	Field crops	581.29	22.55 (16.37)	266.93	11.06 (7.51)
A203	Sugar cane	30.76	1.19 (0.87)	8.98	0.37 (0.25)
A204	Cassava	273.74	10.61 (7.71)	129.73	5.37 (3.65)
A205	Pineapple	272.61	10.57 (7.67)	126.61	5.25 (3.56)
A3	Perennial trees	1,294.60	50.23 (36.44)	1,718.03	71.19 (48.37)
A302	Para-rubber	1,217.38	47.23 (34.27)	1,599.98	66.30 (45.04)
A303	Oil palm	31.32	1.21 (0.88)	70.20	2.91 (1.98)
A304	Eucalyptus	32.88	1.28 (0.93)	25.72	1.07 (0.72)
A4	Fruit trees	493.29	19.14 (13.89)	283.90	11.76 (7.99)
A401	Mixed fruit trees	446.56	17.32 (12.57)	91.06	3.77 (2.56)
A403	Durian	8.73	0.34 (0.25)	97.25	4.03 (2.74)

Source: Land Development Department & Office of Agricultural Economics

cassava yield has a more interesting history. Rayong has always been at the epicenter of improvements in cassava yield in Thailand. Thai cassava breeding started in 1937 with introduction of 20 varieties from Malaysia and the Philippines in the 1930s and 65 varieties from the Columbia and Virgin Islands between 1963 and 1977 (Rojanaridpiched et. al., 2002). Production greatly increased only after the release of the first Thai cultivar "Rayong 1" in 1975, produced at the Rayong Field Centre. From the 1970s onwards, Thailand capitalized on the European market with opportunities for dried chips and pellets (Hershey and Debouck, 2010). "Rayong 1" was dominant in cassava production in Thailand for some 20 years from the mid 1970s (Wangsomnuk et. al.,

2013). Six new cassava cultivars were released between 1983 and 1993. In 1994, the government started a programme for rapid multiplication of recommended cultivars which by 1997 were used in almost two-thirds of the 1.4 million hectares of cassava planted in Thailand (Sarakarn et. al., 2002). Further research and development in the 2000s added additional productivity gains, and cassava is now one of the most important economic crops in Thailand with 80% of the fresh root production of animal feed and starch exported to the European Union and Asian countries (Ratanawaraha et. al., 2000). In Rayong, cassava is now planted mostly in Klaeng, Wang Chan and Meuang Districts, and the favoured cultivars are Rayong 3, 5, 60, 90 and Kasetsart 50. (POAC, 2018).

In 2016, another study of was undertaken with 258 farmers in Tapong Sub-District of Mueang District, (Suwanmaneepong et. al. 2016). The majority of fruit farmers were found to be female (63.2%) with ages between 51-60 years old (35.7%). Most of them (69%) graduated from primary school. The majority of the respondents (53.5%) had family sizes of 4-6 persons. Most of the fruit farmers (62.4%) had more than 20 years farming experience. Most of the respondents (87.6%) were members of farmer organizations. Members of groups or farmer associations made more profit than those who were not. Also, they were able to access and share market information. Most of the respondents (70.5%) cultivated area was less than 1.6 hectares and the majority of the respondents (96.1%) rented lands for fruit production.

Over 40% of the 258 farmers in Tapong had participated in a relevant GAP training. Overall the average score of the 258 farmers surveyed revealed a moderate score on implementation of GAP. The highest score was for use and handling of hazardous chemicals, while pre- and post-harvest handling, transport, storage and personal hygiene also all scored highly. Lower scores were achieved on the matters of using planting areas and water sources free from potential contamination and hazardous substances; while the lowest score of all was for data recording and traceability. The level of application of GAP was found to be strongly correlated with the number of years of farming experience, and whether or not the farmers had received training. (Suwanmaneepong et. al. 2016). Adherence to GAP practices, and obtaining GAP Certification, allowing access to higher value markets, is one growing trend that adds value to fruit production in Rayong Province. Another is the promotion of agro-tourism. This is happening particularly with larger fruit farms such as Suan Lamai, which markets itself as the “Kingdom of Fruit on the Mountain” and covers more than 80 hectares.

Figure 10-4 (a): Planted and harvested areas for selected crops in Rayong Province

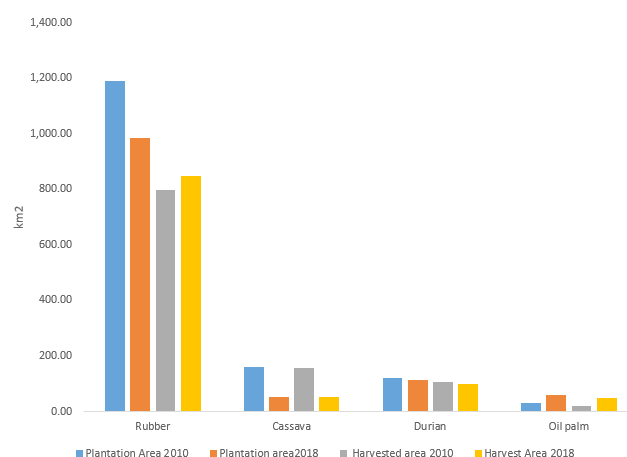


Figure 10-4 (b): Total tonnage of selected crop production in Rayong Province

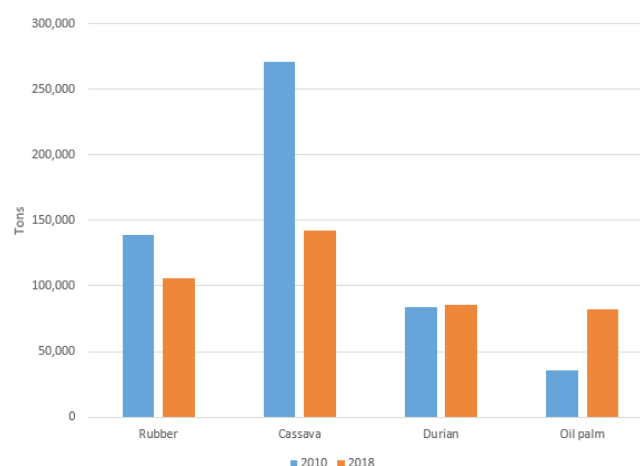
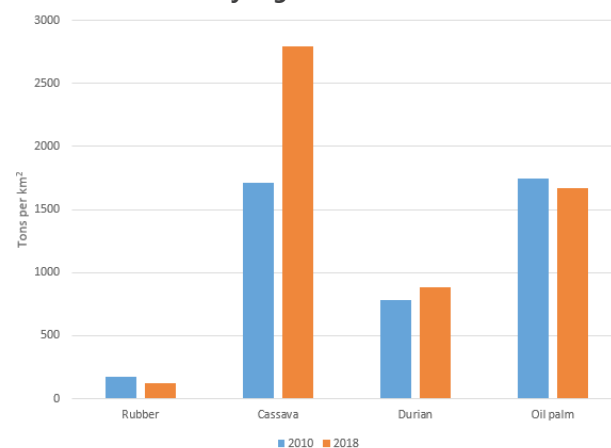


Figure 10-4 (c): Yield per area for selected crop in Rayong Province



title; while 83 had land outside the protected area with ရာဇဝတ်ခံ
certificates. For 68, rubber was their main source of income,
while for 32, durian and other fruits were their main source
of income. 76% stated that water shortage and drought
was the main factor impacting their production, while 24%
said that damage to their crops by elephants was the main
factor. (Puwphiromkhan, 2016).

Table 10-4: Planted area, harvested area, production and yield of economic crops in Rayong Province

Crops	Plantation area (km ²)		Harvested area (km ²)		Production (tons)		Yield (tons/km ²)	
	2010	2018	2010	2018	2010	2018	2010	2018
Para-rubber	1,191.53	985.71	795.91	847.51	139,283	105,939	175	125
Cassava	162.02	52.30	158.2	51.06	270,810	142,670	1,712	2,794
Durian	120.55	112.71	107.58	97.61	83,780	85,880	779	880
Oil palm	30.93	59.72	20.57	49.28	35,843	82,208	1,742	1,668

Source: Land Development Department & Office of Agricultural Economics

3. Past trends and drivers of change

- ✓ Transformation of the Agricultural Sector (reduction in area farmed and in # of families farming/reliance on migrant labour)
- ✓ Securing adequate water supply

The number of farming households and the total area farmed in Rayong have been decreasing over recent years. Between 2003 and 2017 the total farmed area has decreased from just over 1.5 million rai to 1.3 million rai, while in the same period, the number of farming households has decreased from around 55,000 to 44,000 (Figure 10-5). Farming households now account for less than 10% of households in Rayong Province (POAC, 2018).

Economic growth has resulted in conversion of some farmland to other uses such as community and building areas, including industrial estates and factories. As land prices have increased, many farming families have sold their land. Based on land-use information from 2006 and 2018, the “communities and building” land-use category grew to one and a half times its previous area – expanding from 9.8 % to 14.86% of the provincial area. Similarly, “industrial estates and factories” increased by about one-third over that period. On the other hand, “agriculture land” and “forestry” saw slight decreases in their overall extent. Agricultural land decreased from 71.94% to 70.41% of the province, while the forest area decreased from 8.37% to 7.92%. While agriculture in Rayong has approximately doubled in value over the 25-year period from 1995, the value of the non-agricultural sectors of Rayong’s economy have increased 800% over the same period. In 1995 Agriculture represented 7.8% of Rayong’s economy, by 2016 that was only 2.2% (Figure 10-6). Average farming household incomes increased between 2003 and 2011, to a maximum of 670,000 baht/household/year. Since then income has been steadily declining and by 2016 had returned to levels of around 400,000 baht/household/year formerly seen in 2007 (Figure 10-7).

From the mid 2000s onwards the area of rubber expanded considerably. This was largely in response to a huge increase in demand from China and associated attractive market prices during the early part of this period, which encouraged millions of small farmers throughout the country (including in Rayong) to plant rubber. More recently the government has had a national policy directive to reduce the total area of rubber and by 2017, this caused a reduction of about 10%

in the area of rubber in Rayong. In 2018, the harvested area increased again and is expected to increase somewhat in 2019 as well, as trees planted around 2010 start to be tapped.

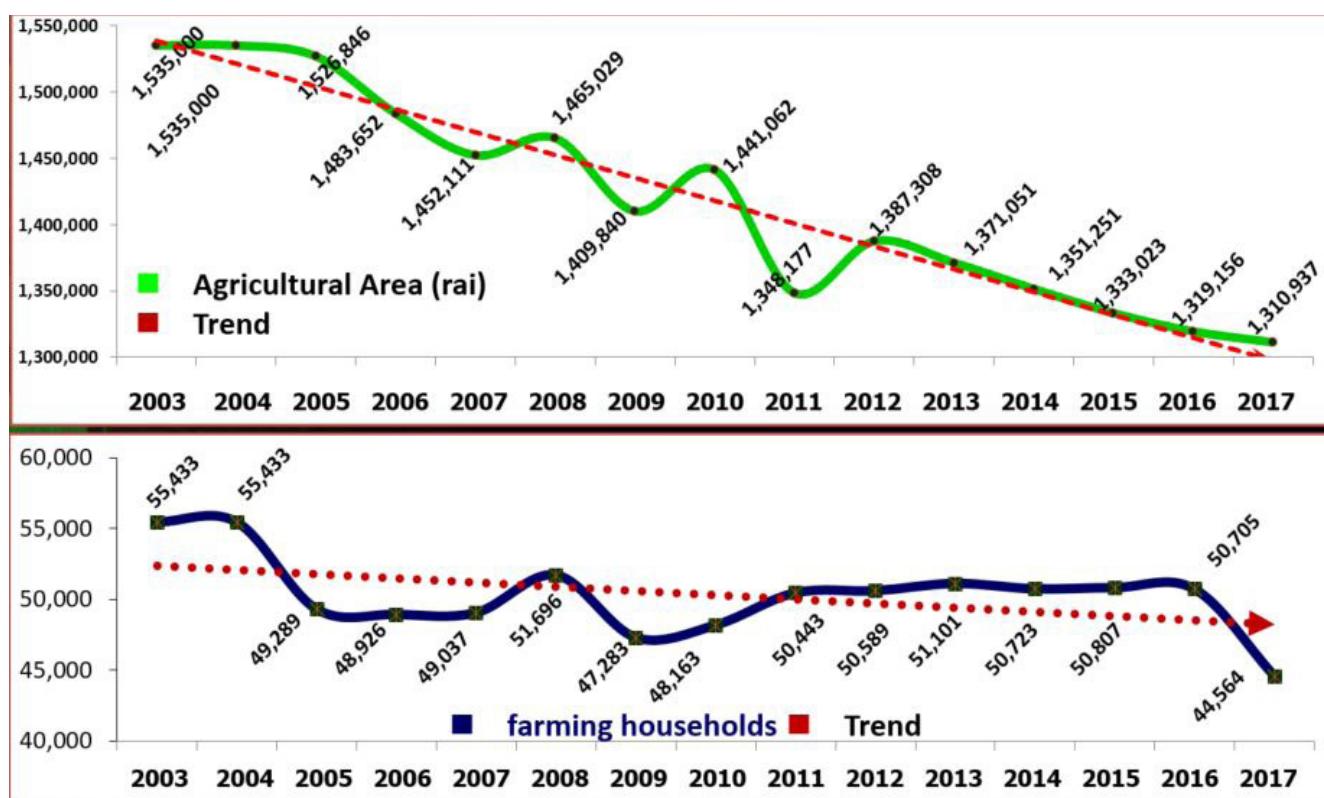
More recently, the Chinese economy has slowed, and demand reduced while supply continued to grow – and prices dropped significantly. There have been repeated calls by rubber farmers across the country for the government to provide assistance to them. Such boom and bust cycles whereby early adopters reap the benefits of initially high market prices, followed by huge increases in production eventually resulting in oversupply and market price collapse have been regular occurrence in the agricultural sector of Thailand. The government is trying to reduce the area of rubber to be more in line with demand and is providing some incentives for farmers to switch to other crops. At the same time, the three main global rubber exporters – Thailand, Malaysia and Indonesia have recently reached an agreement about controlling export amounts in order to help maintain prices at a reasonable level (POAC, 2018)

After expanding in area until 2016, pineapple plantations declined by 29% in 2017 and have continued to decline to 2019. At the same time price has declined from 10,500 baht/ton to 7,500 baht/ton. A slowdown in export orders for canned pineapples has resulted in Thai factories buying less pineapple, and buying it for a cheaper price. As rubber trees have grown in size, it is no longer possible to intercrop them with pineapples, which had been a common practice in many new rubber plantations – accounting for much of the reduction in area of pineapples harvested.

Over recent years there has been a reduction in the area of mixed fruit tree orchards, but an increase in the area of durian orchards. This is in response to the growing market for durian in China attracting high prices (currently around 65,000 baht/ton). Recent production from trees planted in the last decade or so has been very good as the weather in the last couple of years has been favourable for durian production – and this good production coupled with high prices is encouraging more farmers to plant more durian. It is expected that durian plantations will continue to expand to 2020. Abandoning mixed species orchards in favour of durian single-species orchards may create high returns for some, at least initially – but is also riskier due to market fluctuations, disease outbreaks, and in the longer-term, climate change impacts. There is the danger of market over-supply, not only from within Thailand, but also from the Malaysian market, which is competing for the same Chinese market.

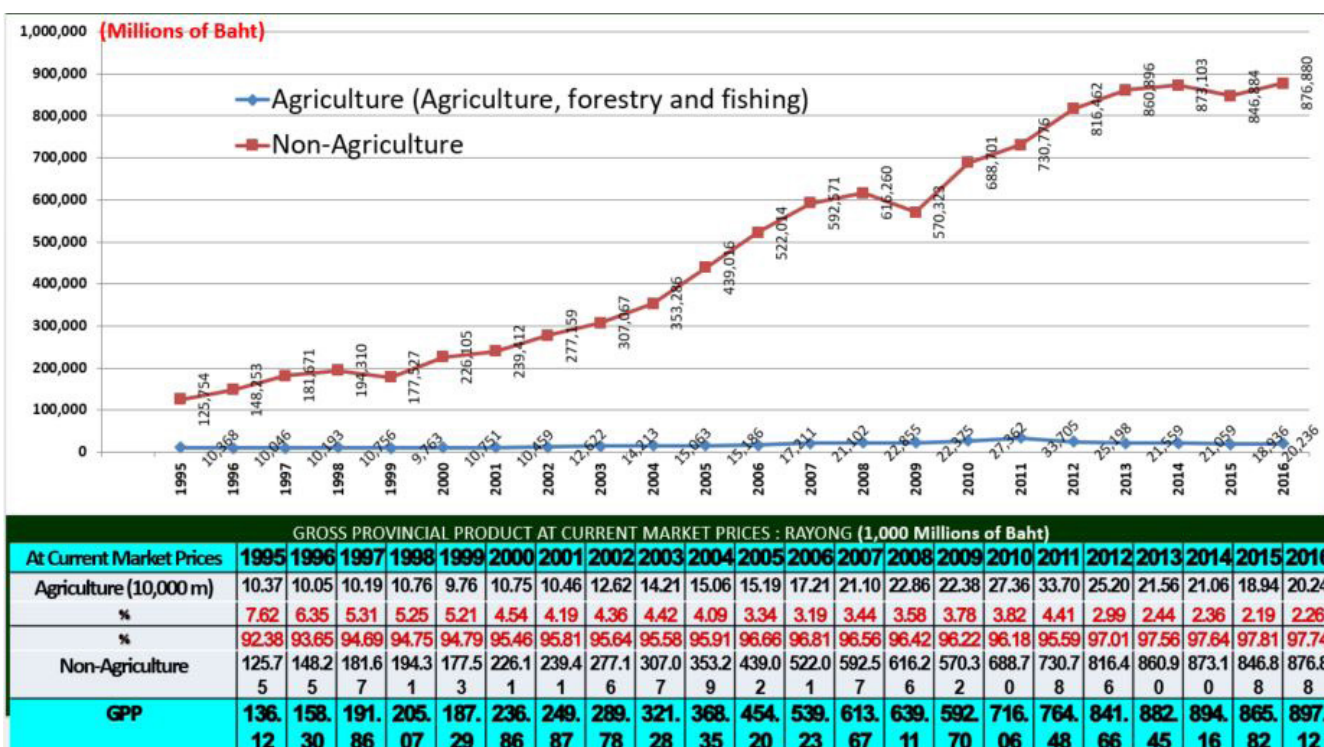
In 2016, the production of cassava fell by almost 12%, and fell again by 3% in 2017. This was partially in response to low prices, but also because the same weather patterns that were

Figure 10-5: Agricultural area (2003 - 2017) (top), farming households (2003 - 2017) (bottom)



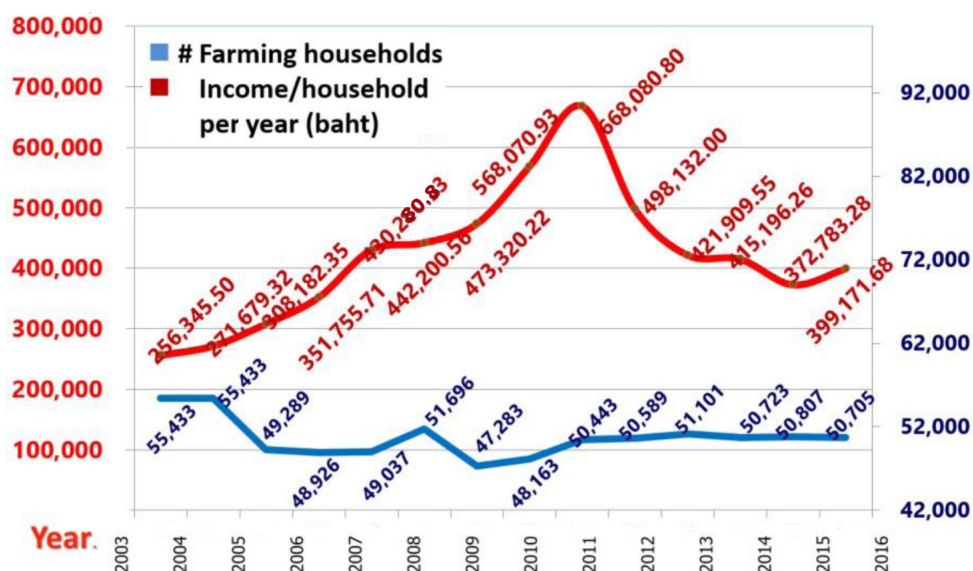
Source: NESDB

Figure 10-6: Contribution of Agriculture and non-agriculture sectors to the economy of Rayong Comparative value of agriculture and non-agriculture sectors (1995-2016)



Source: NESDB

Figure 10-7. Income of farming households in Rayong (2003 - 2016)



Source: NESDB

good for durian production (consistent and abundant rains) were not so good for cassava – resulting in fungal infections and rotten tubers.

In conclusion, agriculture occupies close to three-quarters of the land in Rayong Province. The agricultural landscape is dominated by rubber, pineapple and cassava, while oil palm, durian and other fruits are also economically important. Over the last decade or so there has been more emphasis on rubber and durian in response to Chinese demand and high prices, while field crops and mixed fruit orchards have been reducing in area. The number of farming families, and the area of land farmed are both declining. In the short-medium term, small-holders are highly vulnerable to price fluctuations, and in the medium-longer term they are exposed to significant climate change impacts and competing demands for water. Some farmers have uncertain land tenure, farming inside protected areas and in former National Reserve Forest. In the northern part of Khao Chamao District some farmers also live with the threat of elephant damage to their crops.

4. Future trends/drivers of change without the Rayong Provincial Development Plan

- ✓ Expansion in Industrial and residential areas and increase in land price
- ✓ Market demand and commodity prices
- ✓ Demographic Change
- ✓ Competition for water

The Provincial Office of Agriculture and Cooperatives in its Agriculture Plan for Rayong for 2017-2021, identifies five main areas of problems/challenges:

1. Land availability and quality (some agricultural land is degraded and no new land is available)
2. Limited area under irrigation
3. R&D and innovation (need for increased investment)
4. Agricultural labour (limited supply and dependence on migrant labour)
5. Commodity prices (low prices and dependency on global markets)

Without the Rayong Provincial Development Plan, it is likely that the trend in the number of farmers and the area of land farmed in Rayong will continue to decline. If commodity prices remain low, income from farming will also continue to decline. With falling income and rising land prices, the opportunity for farmers to sell their land and exit from the farming sector will become increasingly attractive, especially for older small-holders whose children have chosen other occupations. While some of this former farming land will be taken up by expanding residential areas and industrial estates, some of it may also be bought up by larger farmers who with economies of scale can invest in increased use of mechanization and technology as well as taking advantage of new trends such as agro-tourism.

Many farmers in Rayong are suffering from a lack of sufficient water, especially in the dry season. Climate change projections suggest that in future there will be more rainy days overall - increasing from an average of 159 rainy days/year between 1980-2009; to an average of 164 rainy days/year during 2030s-2050s. However, a drier dry season and more very hot days are also expected. The number of days with temperatures over 35 degrees could increase from 50/year currently to 80/year in the 2030s, 94/year in the 2040s and 126/year in the 2050s. This temperature increase may be compounded by greater competition for available water

between the agriculture sector, and other sectors in Rayong. While much of the discussion about the impacts of climate change on agriculture is focused on changes in temperature and rainfall patterns, less attention has been given to impacts resulting from changes in winds. But for farmers in Rayong Province relatively close to the coast, this could be of major importance. Climate change projections suggest that the frequency and intensity of storms along the coastline of the Gulf of Thailand may increase. These storms may damage fruit orchards and rubber plantations. In addition, strong winds blowing directly on shore may occur more frequently in the first quarter of the year. This could potentially cause severe losses to durian farmers if flower and young fruit are blown off the trees before they mature and ripen (Bezuijen et al., 2011; SEA-START 2011).

Climate change is therefore likely to have some negative impacts on dry season water availability for all farmers; as well as wind/storm damage impacts to durian orchards, and possibly also rubber plantations. Thailand's Climate Change Master Plan (2014-2050) includes a number of priorities for adaptation in the agriculture sector that would help ameliorate this situation:

- Increase the number of farmers with crop insurance
- Increase the proportion of irrigated areas
- Improve water resource management in non-irrigated areas
- Increase use of soil and water conservation practices in climate change hot-spots
- Reduce open burning of agricultural residue
- Increase application of GAP and Organic Farming (Srinanpaporn, 2015; Arunrat and Pumijumnong, 2017).

Some of Rayong's farmers have already received GAP training and have started to adopt some of the GAP practices. Efforts to provide more GAP training and encourage greater adherence to GAP practices are likely to continue, providing opportunities to add value particularly to fruit production. However, the cost of GAP certification for small-holders is an issue that needs to be addressed. Other initiatives to add value to fruit farming such as promotion of agro-tourism are likely to continue. These are likely to add the most value to the biggest producers who can afford to invest in additional services and facilities such as restaurants, though there may also be some knock-on benefits to smaller farmers.

Suphatthaland is working with the Drug Discovery and Development Centre of Thammasat University, and other partners to create a research and development centre, the Suphatthaland Excellent Agriculture Research Centre Hub (SEARCH), along with the Thailand Equatorial Fruit and Herbal Park. Also involved is the National Centre for Genetic Engineering and Biotechnology (Biotec) which will provide R&D services and set up a health and anti-ageing innovative product centre, as well as social services through a company CSR and Social Enterprise Centre. SEARCH will function as an R&D and innovation network centred in the nation's eastern region. It aims to build on current knowledge and know-how, while linking a network of R&D researchers in the region and nationwide to support both the government and private sector (The Nation, 2018).

A new project of Jülich's Institute of Plant Sciences together with the Thai National Science and Technology Development Agency (NSTDA), King Mongkut's University of Technology Thonburi (KMUTT), and the Department of Agriculture (Thai Ministry of Agriculture and Cooperatives) aims to increase cassava production in Thailand to 60 tons/hectare (Jülich, 2017). With more jobs opening up in the industrial and service sectors that provide stable employment with a fixed and predictable income, it is likely that labour-intensive forms of agriculture in Rayong Province (such as rubber-tapping) will increasingly rely on migrant labour. Regardless of climate change effects, farmers are likely to continue planting the crops they believe will offer the greatest returns. Their choices will continue to be influenced by what their peers are doing; by the advertising and marketing efforts of seed, fertilizer and agri-chemical companies; and by the efforts of agriculture extension offices. Ultimately, farmers will still be at the mercy of global commodity prices, and especially fluctuations in demand from China.

Without the Rayong Provincial Development Plan, the ongoing/future drivers of change in the agriculture sector can be identified as:

- Expansion of industrial and urban/residential areas in Rayong Province
- Demographic change and reliance on migrant labour
- Increasing competition for water (potentially exacerbated by climate change)
- Fluctuations in market demand and global commodity prices

Under the 20-Year National Strategy 2017-2036, the strategy for "competitiveness", includes the following on agriculture: "Build the basis for production to be strong and sustainable, increasing competitiveness and developing quality agricultural and food products. Smallholders should follow sustainable agricultural models that are environmentally friendly, and develop groups and networks for livelihood development"

Under the 12th National Economic and Social Development Plan (2017-2021) the vision for the agriculture sector is that "the agricultural sector is modernized through the use of technology and innovation, with production increasing, farmers leading quality lives, and agricultural land in good condition and used sustainably".

Under the Rayong Provincial Development Plan (2018-2021) the development aim for agriculture in the province is to "Develop the quality of agricultural products to meet international standards through agricultural innovation, together with the development of industrial agriculture and agro-tourism"

Under the Provincial Office of Agriculture and Cooperatives of Rayong Province, Agricultural Development Plan 2017-2021 (revised 2018), the 4th strategy is for balanced and sustainable management of agricultural resources and the environment, with a focus on restoration and conservation of agricultural resources for maintenance of agro-biodiversity, support for conservation agriculture, management of water resources, building resilience to climate change impacts.

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Image: Nikkei Asian Review

STRATEGIC THEME: TOURISM

1. Introduction

Tourism is a major contributor to the Rayong economy. The popularity of Rayong has grown following campaigns supported by the Royal Thai Government and Tourism Authority of Thailand (TAT). Visitors are attracted to the province by its seafood, history, and beaches (Figure 11-1)². Top destinations in the province include the islands of Koh Samet and more recently tours of fruit orchards, particularly those growing durian, mangosteen and rambutan. Other destinations promoted by TAT include the Mun Islands, Khlong Tha Ta Boi Development and Conservation Project, Yom Jinda Road, Floating Pagoda, Khao Laem Ya National Park, Laem Mae Pim Beach, Prasae Estuary, Tung Prong Thong mangrove forest, Khao Chamao-Khao Wong National Park and Rayong Wetland Sanctuary.

Interlinkages with other sector strategic objectives: Strategic objectives in other sectors of the economy (especially industry, agriculture, and transport) potentially influence the tourism sector. Rayong's marine and coastal environment is especially important to the tourist industry, though the latter together with the industrial sector have potential to negatively impact the sustainability of marine and coastal natural resources and environmental quality.

2. Current status

Rayong is the seventh most visited province in terms of the number of visitors in Thailand³ and it is the most visited province by Thais living in Bangkok.⁴ Rayong hosted 390 tourist attractions in 2017, amounting to 2% of Thailand's total number of tourist attractions.³ Total revenue from Rayong's tourism in 2017 was worth 33.8 billion THB, with 86% of that amount coming from domestic tourists.⁵ In 2017, there were 15,245 hotel rooms in Rayong province, and an occupancy rate of 69%.⁵ The most

STRATEGIC ISSUES OF CRITICAL CONCERN FOR SUSTAINABLE DEVELOPMENT IN RAYONG

- ✓ Growth in tourist numbers and facilities
- ✓ Environmental impact of tourism facilities
- ✓ Marine and coastal debris and pollution, especially plastics and petroleum products, threaten tourism

SUSTAINABLE DEVELOPMENT OBJECTIVES:

- ✓ Promote ecological, community and agricultural tourism
- ✓ Ensure that tourism related solid waste and wastewater is treated properly

important locations for accommodation are Klaeng, Koh Samet, and Rayong city center, and along the coast at Mae Rumphueng and Rim Pae Laem Mae Phim (Figure 11-1, left).⁶ In 2017, there was a record number of 7.3 million visitors, the majority of whom were Thai tourists (Figure 11-2, right). Domestic visitors accounted for 92% of all visitors to Rayong in that year.⁵

There is a weekly variation with mainly business visitors during weekdays and more family leisure groups during the weekend. The main foreign nationalities visiting Rayong province were from China, USA, Japan and Korea.⁶ There is a clear seasonality in the revenue coming from the tourism sector. A spike around April is due to the Songkran festival, Thai school holidays and the fruit season. In November

¹ NESDC (2017) The Twelfth National Economic and Social Development Plan (2017-2021)

² <https://www.tourismthailand.org/About-Thailand/Destination/Rayong>

³ MoT (2017) Tourism in Thailand: Statistical Report. Ministry of Tourism and Sports. URL: https://www.mots.go.th/ewt_dl_link.php?nid=11588 (article_20190516131031.pdf)

⁴ Tourism Authority of Thailand (TAT), pers. comm. 2019

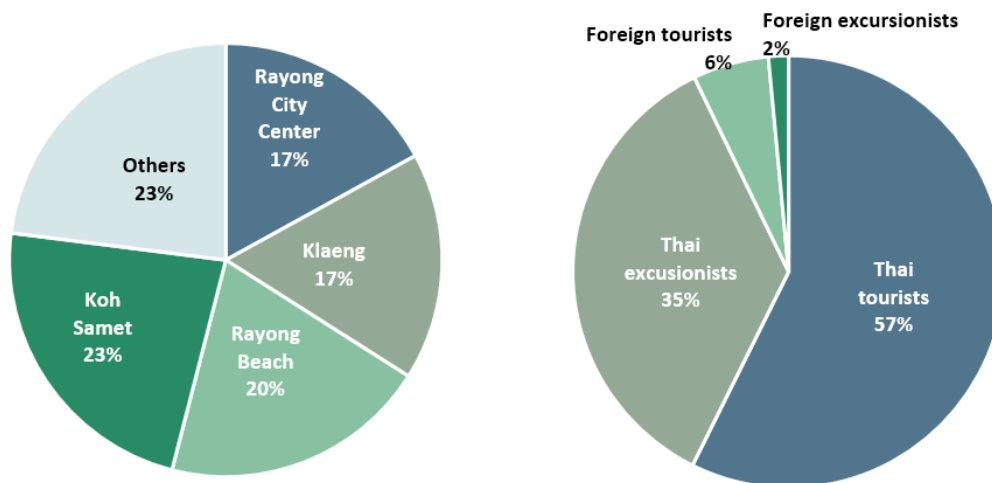
⁵ NSO (2017) Domestic Travellers by Province: 2009 – 2017. National Statistical Office. URL: http://statbbi.nso.go.th/staticreport/Page/sector/EN/report/sector_17_19_EN.xlsx



Figure 11-1: Tourism sites of Rayong



Figure 11-2: Main locations of room supply in Rayong province (left)⁵ and visitor type in 2017 (right)⁶



Source: <https://www.c9hotelworks.com/downloads/rayong-hotel-market-update-2018-04.pdf>

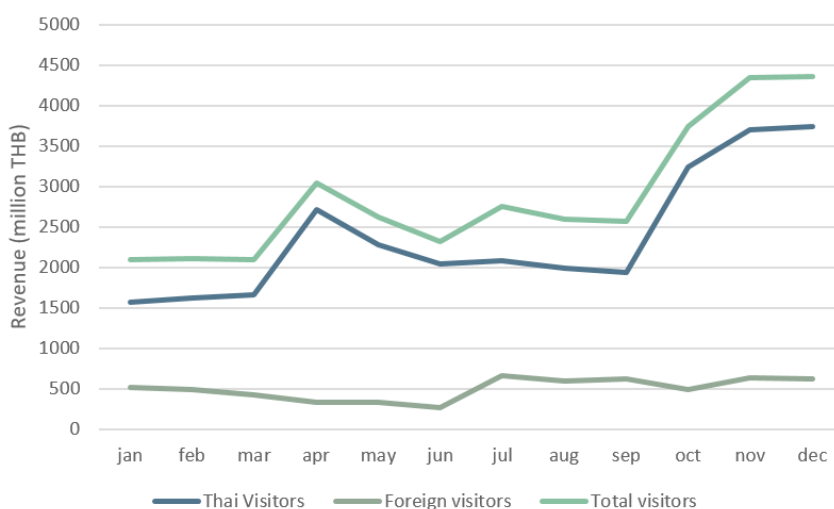
and December, it is high season for coastal tourism to the beaches and islands of Rayong province (Figure 11-3).⁶

Ecotourism is an important part of the tourism sector, offering visitors the opportunity to visit local home stays (e.g., Noen Kho Community Fishing Learning Center);

mangrove forests which have been made accessible for exploration via boardwalks (Pak Nam Prasae, Klaeng District); bird watching; and the Sea Turtle Conservation Center at Koh Mun Nai. There are two national parks which have increasing visitation - Khao Chamao-Khao Wong and Khao Laem Ya-Mu Ko Samed.

⁶ C9 Hotelworks Company Limited (2018) Rayong Hotel Market Update April 2018. URL: <https://www.c9hotelworks.com/downloads/rayong-hotel-market-update-2018-04.pdf>

Figure 11-3: Seasonality in tourism revenue in Rayong Province in 2017⁷



Source: MoT (2018)

3. Past trends and drivers of change

- ✓ Growth in tourist numbers and facilities
- ✓ Environmental impact of tourism facilities
- ✓ Marine and coastal debris and pollution, especially plastics and petroleum products, threaten tourism

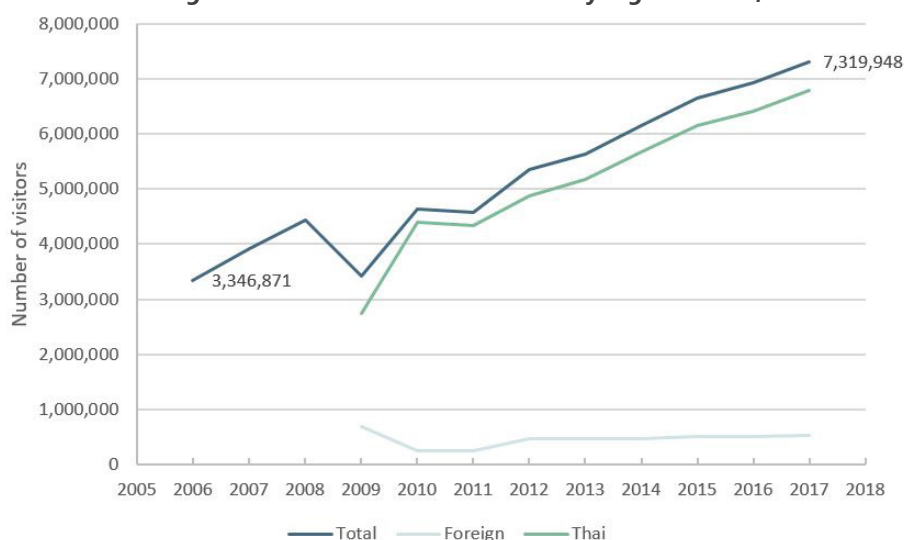
Growth in tourist numbers and facilities

More visitors and residents: Rayong's tourism industry has been steadily growing over the past decade, with visitor numbers more than doubling in 2017 compared to 2006. A dip in the number of visitors in 2009 may be a response to a variety of factors including the global financial crisis,

variable oil prices, political uncertainty, and the flu outbreak in early 2009.⁸ The number of international visitors has been increasing since 2011, with an average increase of 2.3% year-on-year between 2012 and 2017, and a 6.5% year-on-year increase for all visitors (domestic and foreign).⁵ Much of the increase in numbers in the tourism sector comes from domestic visitors, which rose on average 6.9% per year between 2012 and 2017 (Figure 11-4).⁵ The development of new tourist destinations in recent years is noticeable, with an increase from 301 to 390 between 2016 and 2017.⁷

U-Tapao is Rayong's international airport, located in the southwestern corner of the province and close to Pattaya City. Over the last few years, numbers of **international and domestic visitors and flights have increased significantly**, with comparable numbers of international and national users (Figure 5). In total, there were 699,509 international passengers using U-Tapao airport, and a total of 527,216 foreign visitors to Rayong in 2017.⁵ However, there was only a small 6% increase in foreign visitors to Rayong province from 2015 to 2017⁵, compared to a 420% increase at U-Tapao

Figure 11-4: Number of visitors to Rayong Province^{5,9}



⁷ MoT (2018) Tourism indicators: income from Thai and foreign visitors Fiscal Year 2018 Oct 60 - Mar 61 (31 May 2018). Ministry of Tourism and Sports. URL: https://www.mots.go.th/ewt_dl_link.php?nid=10459 (article_20180531114821.xlsx)

⁸ <http://www.traveldailynews.asia/thailand-tourism-overview-for-2009-and-tourism-goals-and-tr>

⁹ NSO (2015) Number of visitors Classified by region and province, 2006–2015. National Statistical Office. URL: http://service.nso.go.th/nso/web/statseries/tables/00000_Whole_Kingdom/16.2.xls

airport over the same time period¹⁰, indicating that most of the visitors using U-Tapao airport do not stay in Rayong, perhaps travelling onward to neighbouring Chonburi province and the city of Pattaya. The limited ground transportation options is considered an ongoing hindrance to encouraging tourism in the province.¹¹

Supply of hotel rooms grew steadily year-on-year (Figure 6). There has been a substantial increase in the occupancy rate since the 2011 low point of 27%. On average, Thai visitors spent 2.3 days in Rayong province, whereas foreign visitors stayed for about 3.4 days in 2017.⁵ There were growing numbers of European visitors coming from Pattaya, who for the most part were citizens of Germany, France and Russia, and an increase in Korean and Japanese visitors working in

the industrial sector⁶. The growth in the industrial sector has also greatly increased the expatriate community in Rayong by 45% from 2016 to 2017, to a total of 45,051 in 2017.⁶

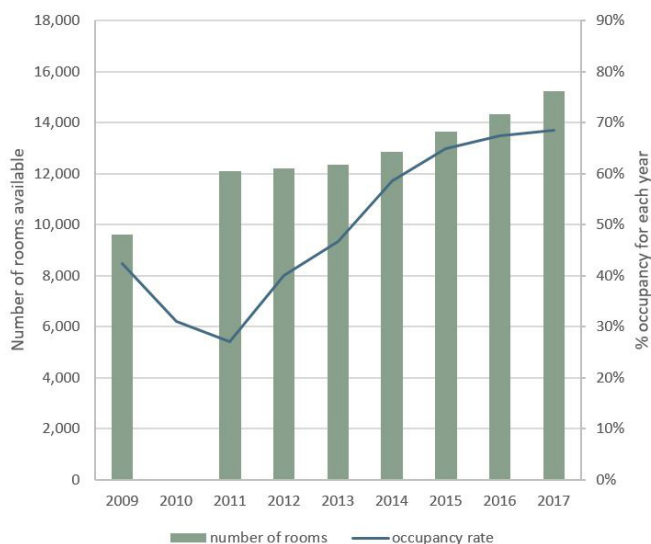
Between 2013–2017, **total revenue from tourism increased** by 6 to 10%, following a similar upward trend in the number of visitors (Figure 11-7). Revenue is increasing faster than the number of visitors, with visitors spending more money per person per day (2,483 THB/person/day in 2017). Business visitors are estimated to spend two to three times as much as leisure tourists.¹³ Growth was highest in 2010, due to the recovery after the low point in 2009. The slight dip in growth in 2016 may reflect the government's control of zero-baht tours.⁶

Figure 11-5: Visitor and flight numbers at U-Tapao Airport in 2015- 2017¹²



Source: EECO

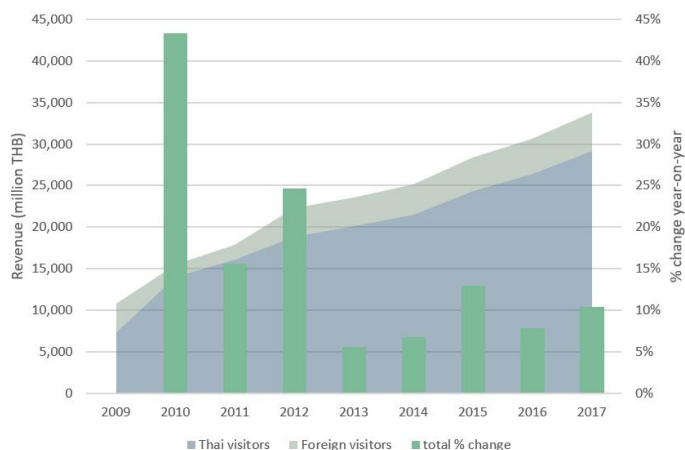
Figure 11-6: Number of rooms available and occupancy rates in Rayong Province from 2009 - 2017⁵



Source: NSO (2017)

*Value for 2010 number of rooms omitted

Figure 11-7: Revenue from tourism in Rayong Province⁵



Source: NSO (2017)

*Percentage change is compared to revenue of the previous year

¹⁰ <https://www.eeco.or.th/sites/default/files/Board.pdf>

¹¹ Tourism Authority of Thailand (TAT) pers. comm. 2019

¹² <https://www.eeco.or.th/sites/default/files/Board.pdf>

¹³ <https://oxfordbusinessgroup.com/overview/tapping-new-sources-visitor-numbers-increase-officials-look-diversify-offering>

Environmental impact of tourism facilities

Waste management, water and air quality are environmental concerns of the tourism industry, with marine litter along the shores of Rayong an especially evident issue for sustaining coastal tourism income. In Thailand, negative social and environmental impacts have been linked to tourism, which in turn can damage the assets on which the sector depends for its sustainability. Often, much of the profits made from tourism activities are made outside the area, the local jobs created are low paid and price rises put services and products beyond reach of local people (ERIC 2007).

Considering visitor numbers and the estimated duration of each visit - municipal solid waste (MSW) linked to tourism is estimated to have increased by some 42% between 2012 (21.65 tonnes/year) and 2017 (30.81 tonnes/year) (Table 11-1). Water usage by tourists over the period from 2012 to 2017 has increased by 36%. This calculation is based on the mean of domestic water use in rural (50 l/day) and urban (250 l/day) areas (World Bank 2011). Of this total amount of

domestic water use, about 80% will likely be discharged to to the environment without treatment (Table 11-2).¹⁴

Untreated wastewater from the tourism sector and plastic wastes have been linked to the degradation of coral reefs in Thailand,¹⁵ and there is concern about algal blooms (caused by nitrate and phosphate pollution from boats, tourism and industry) causing coral mortality (DMCR 2018). With regard to water quality, generally the status of Rayong's coastal waters has been reported as fair or good, though above standard levels of enterococci bacteria have also been recorded at Phayun Beach, Laem Mae Phim Beach and Arboretum (PCD 2015). The baseline report on Rayong's marine and coastal environment highlights further details of the impact of the tourist industry on environmental quality and natural resources.

Increased awareness of the impact of the tourism industry has contributed to an interest in sustainable or eco-tourism in Rayong. The Ban Jum Rung Community is a good example of how ecotourism can support local communities in Rayong (Box 1).

Table 11-1: Municipal solid waste generation by the tourism sector in Rayong

Year	MSW generation (kg/person/day)*	Number of visitors**	Visit duration	Total MSW generated (tonnes/year)****
2012	1.76	5,347,954	2.3 days***	21.65
2013	1.77	5,643,533		22.97
2014	1.79	6,150,336		25.32
2015	1.80	6,650,710		27.53
2016	1.82	6,929,843		29.01
2017	1.83	7,319,948		30.81

*Statistics for Thailand assuming a linear increase of 0.0146 kg/person between 2012 (1.76 kg/person/day) and 2025 (1.95 kg/person/day) (source: World Bank 2012)

**Total number of Thai and foreign visitors

***Based on 2017 statistics for a Thai visitor and assumed to be the same in other years.

****Total MSW generated per year by all tourists (using World Bank statistics for Thailand) = MSW generation (kg/person/day) x no. visitors x visit duration

Table 11-2: Domestic water consumption and waste generation by the tourism sector in Rayong

Year	Domestic water usage (litres)	Number of visitors**	Visit duration	Total volume of water consumed (MCM/year)**	Total volume of domestic wastewater (MCM/year)***
2012	150 l/day*	5,347,954	2.3 days	1.85	1.48
2013		5,643,533		1.95	1.56
2014		6,150,336		2.12	1.70
2015		6,650,710		2.29	1.84
2016		6,929,843		2.39	1.91
2017		7,319,948		2.52	2.02

*Mean of rural (50 l/day) and urban (250 l/day) domestic water consumption (source: World Bank 2011)

** MCM: Million cubic metres

*** Assumed as 80% of domestic water usage

¹⁴ <https://nptel.ac.in/courses/105104102/Lecture%2017.htm>

¹⁵ <https://www.ibtimes.sg/coral-reefs-thailand-decaying-alarming-rate-scientists-blame-it-tourism-23799>

¹⁶ http://www.banjumrung.org/Home/menu_03/banjumrung_eng

¹⁷ DMCR (2017) Department of Marine and Coastal Resources. UTL: <https://www.dmcg.go.th/detailAll/13479/nws/87/>

¹⁸ <http://www.nationthailand.com/national/30344702>

Box 1: Sustainable tourism in the Ban Jum Rung Community

In contrast to the damage that more conventional tourism can do to the environment, the Ban Jum Rung Community in Neon Kho sub-district is considered an example of best practice in ecological, agricultural and educational tourism and community-based development. The community is a traditional agricultural community of more than 500 people growing rubber, durian trees and rice. In 1986, they started to pool together their resources as a community and follow the Thai Sufficiency Economy Philosophy, which emphasizes ethical values, and sharing of resources. In 2008, the community started tourism activities in the form of homestays. Activities for tourists include working with rubber trees, planting vegetation, eating local foods. They also promote a community restaurant and shop which adds value to local produce. Tourism in the Ban Jum Rung community is used as a means of providing additional income to agriculture products in the community.¹⁶



Marine and coastal debris and pollution, especially plastics and petroleum products, threaten tourism

Priority concerns for the tourist industry in Rayong include the prevalence of marine debris (litter) along its coastal shores, and the risk of oil pollution from industry and marine traffic. Annually, an estimated 50,000-60,000 tonnes of solid waste from Thailand finds its way into the marine environment where it is consumed and kills marine animals including endangered species such as turtles.¹⁷ About 30% of the solid waste comprises plastic bags, 30% plastic bottles and 20% Styrofoam. Thailand has been ranked sixth in the world in terms of the amount of mismanaged plastic waste entering the oceans (Jambeck et al. 2015). The amount of plastic waste generation is increasing by 12% annually, which is equivalent to 2 million tonnes of waste.¹⁸ Annually, about 3% or almost 31,000 tonnes of plastic waste generated in Thailand is estimated to find its way into the marine environment.¹⁹ The island of Koh Samed banned the use of plastic bags in November 2018, where an estimated 15,000 bags are disposed of each day by visiting tourists.²⁰

In order to encourage more sustainable tourism and alleviate marine litter in Rayong's coastal islands, tourists are

now being encouraged to keep their rubbish and return it to the mainland for proper disposal. However, the problem of marine litter cannot be solved through local initiatives alone and this is recognized by the Royal Thai Government and reflected in the implementation of two national plans: *The National 3R Strategy and the National Master Plan for Waste Management (2016–2021)* and *Plastic Debris Management Plan 2017–2021* (Wichai-utcha, & Chavalparit 2019).

The coastal and marine environment is at risk from oil spills from the activities of industry, particularly near Map Ta Phut, and marine vessels. Despite increased awareness, oil spills are still frequent in Rayong province and have potential to impact the livelihoods of local fishers²¹ and the tourism sector.^{22 23} The latest major spill in Rayong was in July 2013 when an estimated 50,000 to 100,000 litres of oil was released from a pipeline owned by Petroleum Authority of Thailand, Global Chemical PLC (PTTGC) that is located offshore from the Map Ta Phut facility.^{24 25} Based on remote sensing imagery analysis almost 250,000 litres were leaked into the Gulf (Casarotto et al. 2014). The 2013 incident resulted in the pollution of important tourist beaches, including Ao Prao in Koh Samed, and on the mainland.²⁶ Tourists were evacuated from Koh Samet following the spill.²⁰ According to the latter news report, there were inadequate resources available in Thailand to manage the spill,²¹ though according to the International Tanker Owners Pollution Federation (ITOPF) Thailand is reported to have equipment to tackle a 1000 tonne oil spill, including resources located in nearby Samut Prakarn province.²⁷ Historical large oil spills from the Map Ta Phut area include those in May 2006 (20 tonnes), and in 2001 (30 tonnes).²⁸ In 2015, the Pollution Control Department recorded a total of four oil slick incidents at Mae Rum Phung Beach and Laem Charoen Beach.

Summary

In concert with government-led campaigns over the last decade, Rayong province has grown in popularity with more domestic and overseas visitors. Compared to 2006, the total number of visitors more than doubled by 2017 to greater than 7 million. Tourism in Rayong province primarily caters to a domestic market comprising 93% of all visitors. Numbers of international and domestic visitors and flights using Rayong's U-Tapao airport have increased significantly over the last few years. The number of sites dedicated to tourism has increased (390 sites as of 2017) which offers a way to lessen the impact of tourism activities at current sites of interest and further raise revenue. The supply of hotel rooms has grown steadily, reaching an occupancy rate of almost 70% in 2017, as compared to 27% in 2011. The growth in the industrial sector has substantially increased the expatriate community in Rayong. Negative social and environmental impacts have been linked to tourism, including solid wastes (conspicuously plastics), reduced coastal water quality, and degradation of marine and coastal ecosystems.

¹⁹ <https://asia.nikkei.com/Economy/Thailand-falling-behind-in-global-battle-with-plastic-waste>

²⁰ <https://www.intellasia.net/thailand-island-to-ban-tourists-from-carrying-popular-item-or-be-fined-on-arrival-692025>

²¹ <https://www.bangkokpost.com/news/politics/421276/rayong-oil-spill-fishermen-sue-ptt>

²² <https://www.pttgcgroup.com/en/updates/press-release/627/the-progress-of-oil-spill-in-rayong>

²³ <https://www.bangkokpost.com/learning/learning-news/362033/oil-spill-hits-beach-at-koh-samet-island-update-2>

²⁴ <https://www.bangkokpost.com/thailand/politics/361829/huge-oil-slick-drifts-towards-rayong>

²⁵ <https://edition.cnn.com/2013/07/31/world/asia/thailand-oil-spill-beach>

4. Future trends and drivers of change without the Rayong Provincial Development Plan

- ✓ Growth in tourist numbers and facilities
- ✓ Environmental impact of tourism facilities
- ✓ Marine and coastal debris and pollution, especially plastics and petroleum products, threaten tourism

Growth in tourist numbers and facilities

In the near term, it is anticipated that Rayong will see growing numbers of visitors and rising revenue following government and private sector-led campaigns and an increasing variety of tourist destinations within the province. The numbers of domestic and international travellers using U-Tapao Airport are likely to increase considerably based on the trend over the last few years. Development of high-speed rail and road networks, as promoted in the Eastern Economic Corridor development,²⁹ should improve options for public transportation, but may not in themselves encourage more tourists living outside the province to visit as it is high quality destinations that are important (TAT, pers. comm. 2019). However, an increasing local population boosted by migration given more work opportunities may provide further support to the tourism industry.

Environmental impact of tourism facilities

If the trend of increasing number of visitors continues then it is expected that the amount of municipal solid waste (MSW) will increase, as well as water consumption and wastewater generation. Over a period of 5 years from 2012, the amount of MSW grew by 36%, and if the trend persists, by 2025 the amount of MSW generated by the tourist sector will increase by a conservative 50% compared to 2012 (assuming the same number of visitors as in 2017). Increasing numbers of visitors will generate greater volumes of waste water that will for the most part be discharged untreated into local waters in the vicinity of hotels and sites of interest to visiting tourists, especially at beach resorts along the coast and on offshore islands. These waste streams will add to the current load entering the environment which are already impacting water quality and natural resources. Continued poor waste management, increasing marine debris, and degradation of natural resources by the tourism sector may constrain interest in the province as a tourist destination in the longer-term. For instance, concerns over marine litter along Rayong's shores have been shared widely in social media such as Twitter and media outlets.

It remains to be seen the extent to which the tourism industry can become more sustainable, though The Twelfth National Economic and Social Development Plan (2017-2021) states as Objective 1.3 – *to develop and revive key economic areas to grow ecologically and improve the living standards of their communities* – and section 3.3.3 – *Community-based tourism and conservation tourism should also be promoted in communities with touristic sites* (NESDC 2017).

Marine and coastal debris and pollution, especially plastics and petroleum products, threaten tourism

Marine plastic debris is a well-known and conspicuous problem along the beaches of Rayong and it remains to be seen whether the Thai government's plans to address this problem will prove effective. If the planned rehabilitation and development of water treatment plants proceed, it should go some way to alleviating sewage contamination of inshore waters. The prevalence of solid waste, particularly plastics, is anticipated to continue as a visible problem along Rayong's shores and as a threat to endangered species. A national response to solid waste management has been initiated as it is an issue that cannot be resolved at only provincial and community levels. Private sector initiatives in Rayong have also been launched to raise awareness and address the problem.^{30 31}

Oil pollution will remain a risk to the coastal and marine environment due to the presence of oil installations and increasing marine traffic. Thus an effective oil spill contingency plan and appropriate resources are required to avoid and mitigate the impacts of future spills. PTTGC planned to reevaluate their contingency plan following the 2013 oil spill. According to ITOPF, Thailand has adequate equipment and resources, including located in nearby Samut Prakarn province, to tackle a spill of 1000 tonnes.

Ecological carrying capacity

Pertinent to the all three strategic issues is the concept of ecological carrying capacity. While not specifically highlighted in the Rayong Provincial Development Plan, carrying capacity is mentioned on a number of occasions within the NESD Plan (2017) in relation to the past decline of natural resources and developing a sustainable tourism industry. The NESD Plan (2017) proposes the implementation of a project (between 2017 and 2021) to study the carrying capacity in conservation areas and the possibility of limiting tourist numbers, and also consideration of carrying capacity in another project for developing and rehabilitating top tourist attractions. The NESD Plan's development guidelines further promote 'sustainable tourism by taking the carrying capacity of ecosystems (i.e. tourist destinations) into account'. This concept is further addressed in this Strategic Environmental Assessment's Sustainable Development Pathway.

²⁶ <http://www.nationthailand.com/national/30211475>

²⁷ <http://www.itopf.org/knowledge-resources/countries-territories-regions/countries/thailand/>

²⁸ http://www.mkh.in.th/index.php?option=com_content&view=article&id=351:2544-2554&catid=8&Itemid=361&lang=en

²⁹ <https://www.eeco.or.th/en/project/infrastructure-development/high-speed-train>

³⁰ <http://www.scgsustainability.com/en/sustainability/environment/biodiversity-and-ecosystem/>

³¹ <https://www.bangkokpost.com/business/news/1573350/pttgc-to-recycle-plastic>

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STRATEGIC THEME: COASTAL AND MARINE ENVIRONMENT

1. Introduction

Sustainable development in Thailand is driven at national level by the implementation of **Sustainable Development Goals (SDGs) and the Thai Sufficiency Economy Philosophy (SEP)**.² Sustainable Development Goals and SEP are articulated in the 12th National Economic and Social Development Plan (2017 – 2021) (NESDB 2017) and 20-Year National Strategy Framework of the Royal Thai Government (RTG), which in turn are further reflected in the policy-making and planning processes of government agencies.³ Of the 17 SDGs, SDG 14 aims to 'conserve and sustainably use the oceans, seas and marine resources for sustainable development' and comprises a set of targets that are relevant within the context of economic development in Rayong Province³:

- SDG 14.1: By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution;
- SDG 14.2: By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans;
- SDG 14.4: By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated (IUU) fishing and destructive fishing practices and implement science-based management plans;
- SDG 14.5: By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information.

In Thailand's *Voluntary National Review on the Implementation of the 2030 Agenda*, Koh Mun Islands in Rayong province was declared a marine protected area, and public participation in management of coastal

STRATEGIC ISSUES OF CRITICAL CONCERN FOR SUSTAINABLE DEVELOPMENT IN RAYONG

- ✓ Unsustainable fishing practices
- ✓ Poor management of solid wastes and effluent discharges
- ✓ Limited environmental monitoring and reporting to support effective evidence-based management

SUSTAINABLE DEVELOPMENT OBJECTIVES:

- ✓ Sustainably use marine and coastal resources
- ✓ Restoration, enhancement and protection of marine and coastal ecosystems and resources

and marine resource at local level was encouraged through issuing of new regulations by the Department of Marine and Coastal Resources.⁴ The *2015 Marine and Coastal Resources Management Act* promotes community participation, and permits the establishment of marine protected and mangrove conservation areas.⁵ In Thailand, recent legislation and national plans support fisheries management reforms, including the Royal Ordinance on Fisheries 2558 (2015), the Marine Fisheries Management Plan (FMP) and the National Plan of Action to Prevent, Deter and Eliminate IUU Fishing (NPOA-IUU).⁶ Multiple aims within the Rayong Provincial Development Plan already reflect a range of concerns related to sustainable management of marine and coastal resources. Pollution management in coastal and marine areas is the mandate of the Pollution Control Department under the Ministry of Natural Resources and Environment.

¹ <https://sustainabledevelopment.un.org/content/documents/14375SDG14format-revOD.pdf>

² <https://sustainabledevelopment.un.org/memberstates/thailand>

³ <https://sustainabledevelopment.un.org/sdg14>

⁴ <http://www.mfa.go.th/sep4sdgs/contents/filemanager/images/sep/VNR%202018%20English%2010.07.18.pdf>

⁵ <https://www.iucn.org/content/thailand%E2%80%99s-new-marine-and-coastal-resources-management-act-engaging-coastal-communities>



2. Current state of the marine and coastal environment

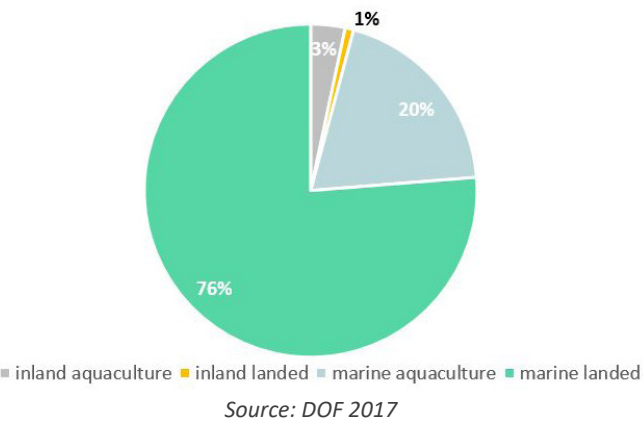
The coastline of Rayong province extends for some 100km including a variety of important mangrove wetland, coral reef and seagrass ecosystems. Endangered species, including dolphins and sea turtles are found in Rayong’s coastal waters (DMCR 2018). The coastal and marine environment, including offshore islands, are important for the tourism sector while fisheries-related employment as well as downstream activities make an important contribution to Rayong’s economy. Small-scale marine fisheries offer a source of employment to coastal communities along the Rayong coast (Tiaye et al 2018) and fish sauce is a major product from the region (Boutson et al 2016).⁷ Revenue generated from fishing and fish processing contribute to the wider local economy.

Fisheries

The fisheries sector of Rayong is dominated by marine capture fisheries.⁸ In 2015, some 76% of Rayong’s fisheries were marine caught species (Figure 12-1).⁹ Food fishes comprise the majority of the total weight landed (Figure 12-2, left). Anchovy fishing grounds are found in nearby coastal waters which are of economic importance for the fish sauce industry and other products.¹⁰ Finfish species commanding good prices in the Rayong market include Indo-Pacific mackerel, Indian mackerel, the king mackerel, tuna and trevallies (DoF, 2017).

Marine aquaculture is the main source of shrimp, accounting for more than 99% of the total shrimp yield in 2015. The main species grown is the white leg shrimp (*Litopenaeus vannamei*) (Figure 12-2, right). Green mussel is also produced but to a much lesser extent, with no yield recorded for blood cockle or oysters in 2015 (DoF 2017). In total, 111 fish farms (pond and cage) were producing marine fish in 2015 (DoF 2017). In comparison to marine fisheries, the total yield from

Figure 12-1: Relative importance of inland and marine fisheries and aquaculture (finfish, shellfish and others) by weight in 2015

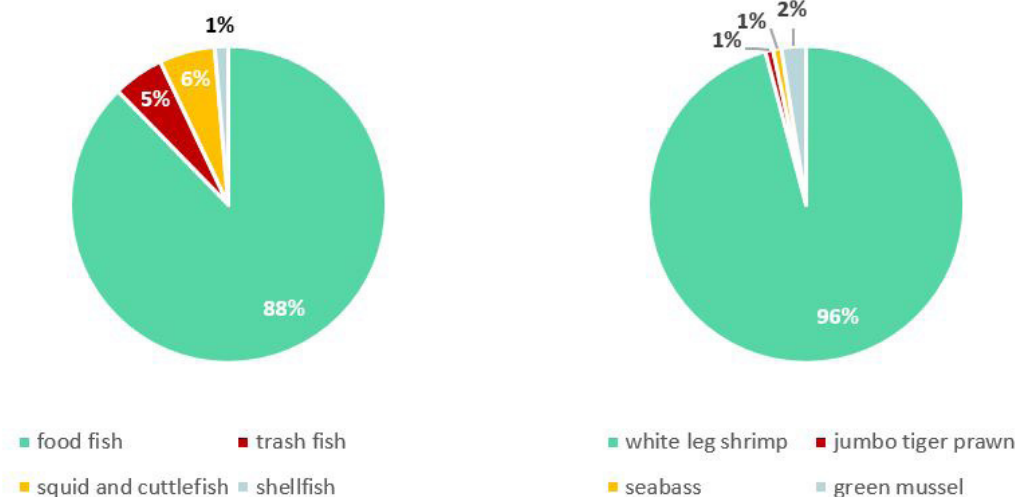


freshwater fisheries was much less (Figure 12-1) though still an important source of household income: in 2015, there were 439 freshwater fish farms, mainly employing fish ponds. Reservoirs in Rayong also support freshwater fisheries (RPDP 2018).

Coastal ecosystems

Mangroves, seagrasses and coral reefs provide a foundation for the fisheries sector productivity in Rayong. Mangrove wetlands are nowadays viewed as an important natural resource and of value for recreation and tourism, as well as functioning as an important natural buffer to storm surge, and as breeding and nursery grounds for fisheries. Mangroves are mainly concentrated in the eastern part of the province (Figure 12-3). Dominant mangrove species include *Rhizophora apiculata*, *Avicennia marina* (grey/white mangrove), and *Lumnitzera racemosa* (black mangrove). Mangrove wetlands contain a variety of fauna and flora

Figure 12-2: Fisheries yield in Rayong Province in 2015: marine capture fisheries (left) and aquaculture (right)



Source: Department of Fisheries, 2017

⁶ <https://thaiembdc.org/2016/03/07/thailands-fisheries-reform/>

⁷ http://www.chikyu.ac.jp/CAPABILITY/img/books/FieldGuidesOnSmall_Cover.pdf

⁸ In this report inland (freshwater) fisheries and aquaculture are also included for completeness.

⁹ According to statistics compiled by the Department of Fisheries (2017)

¹⁰ http://www.seafdec.org/documents/2017/03/49cm_wp06-3.pdf

which are included on the IUCN Red List including species categorised as near threatened such as the red-necked stint (*Calidris ruficollis*) and the grey-tailed tattler (*Tringa brevipes*).

Coral reefs in Rayong province span an area of 3058 rai and are mainly found around the islands off the coast: near Koh Samet and the islands of Ko Man Nai, Ko Man Klang and Koh Mun Nok. Coral species found in these areas include *Porites lutea* (stony coral), the near threatened (IUCN) *Fungia fungites* and the vulnerable (IUCN) cactus coral (*Pavona decussata*). The current status of coral reefs in Rayong province is quite poor and degrading, with none of the main locations in Rayong having more than 50% live coral (DMCR 2018). Coral reefs at Koh Saket near Map Ta Phut are now severely degraded due to sedimentation (DMCR, 2019, pers. comm.). Most coral reefs around Koh Samet are damaged, and those around Koh Man Klang and Ko Man Nai islands are partly damaged or dead (Figure 12-4).

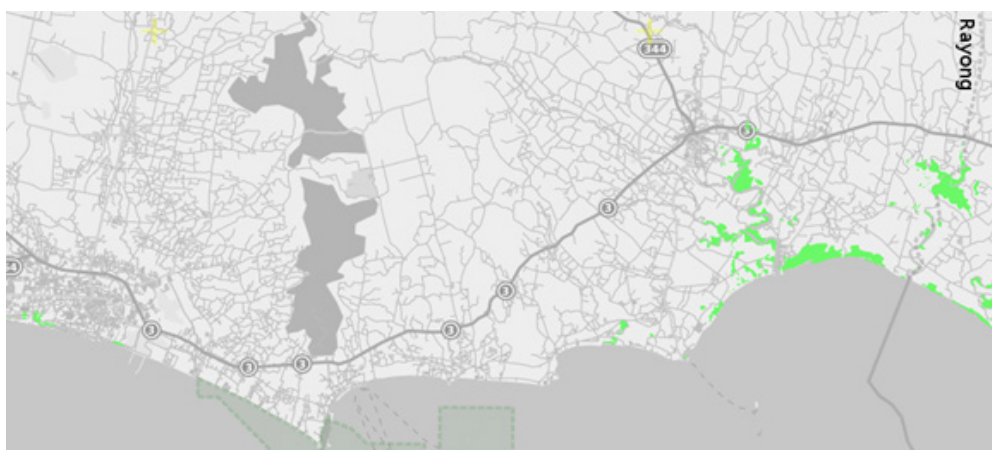
Seagrass beds are critically important ecosystems for supporting marine life including fisheries. Based on a survey

conducted during February–March 2014, a seagrass area of 732 rai was delineated, which was primarily found in a handful of locations, including Koh Mun (Koh Man Nai) Islands, Rock Village Beach, Ao Makham-pom, Ban Noen Kho, Pak Khlong Klang and Pak Nam Prasae (Figure 12-5). Most seagrass beds were in moderate condition, usually with less than 50% average cover. Two main species of sea grass, namely *Halophila ovalis* (spoon grass) and *Halodule pinifolia* were found: *H. pinifolia* was of widespread occurrence whereas spoon grass was only encountered at two locations (DMCR 2018).

Endangered species

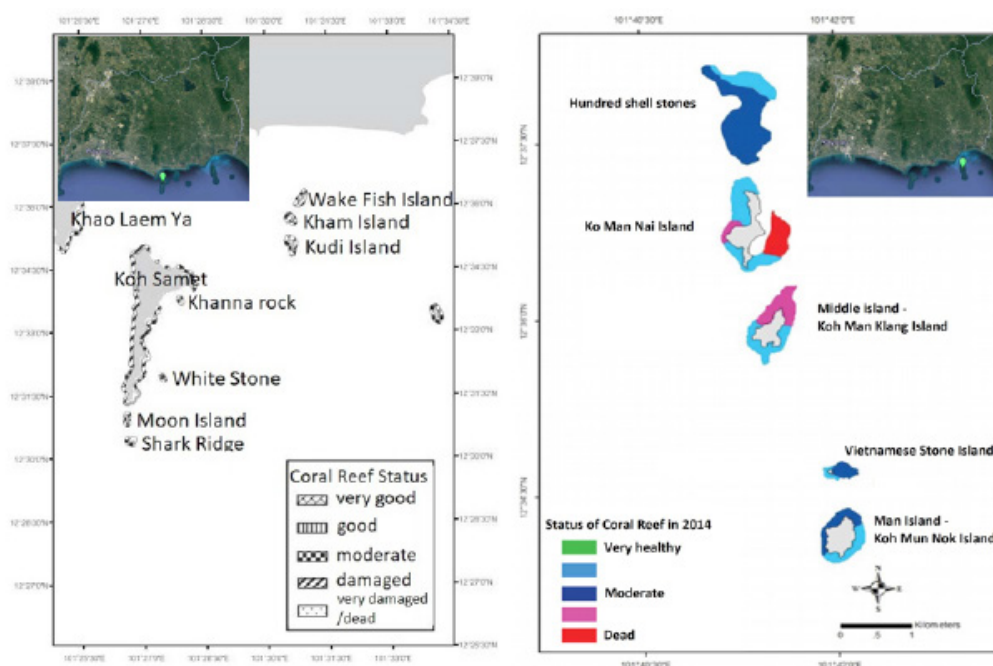
Based on interviews with local fishermen and identification of photographs by the Department of Coastal Resources in 2015, endangered marine mammals and turtles were sighted in the waters of the Rayong province. Four species of dolphin and whale were sighted, namely the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*), Indo-Pacific finless porpoise (*Neophocaena phocaenoides*), the Indo-Pacific humpback dolphin (*Sousa chinensis*) and the Irrawaddy dolphin (*Orcaella*

Figure 12-3: Location of mangroves (green shading) in Rayong Province in 2014



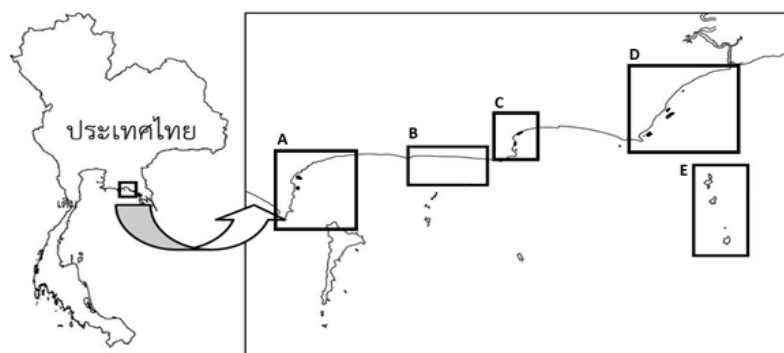
Source: <http://marinegiscenter.dmcrc.go.th/gis/gis.php>

Figure 12-4: Status of coral reefs around Koh Samet (left) and Ko Man Nai Island (right)



Source: DMCR 2018

Figure 12-5: Location of Rayong seagrass beds: Khao Laem Ya (a), mouth of Klaeng canal (Pak Khlong Klaeng) (b), near Thap Samet Village (c), Pak Nam Prasae, Ao Makham Pom and Rock Village beach (d) and around Ko Man Nai



Source: Adapted from DMCR 2018

brevirostris). Most sightings were of the Indo-Pacific finless porpoise (15 out of 51) and the Irrawaddy dolphin (20 out of 51). Two species of sea turtles were found, namely the green sea turtle (*Chelonia mydas*) and the hawksbill sea turtle (*Eretmochelys imbricata*), as well as one species of sirenian, the dugong (*Dugong dugon*) (Figure 12-6). Also thought to be in the region are the olive ridley turtle (*Lepidochelys olivacea*), leatherback turtle (*Demochelys coriacea*) and loggerhead turtle (*Caretta caretta*), as well as two species of whale, the Bryde's whale (*Balaenoptera edeni*) and Omura's whale (*Balaenoptera omurai*) (DMCR 2018).

Coastal pollution and erosion

Regular (although infrequent) monitoring of the environmental quality of coastal waters along Rayong's coastline and derivation of a water index indicates that water quality is for the most part reasonable or good, though some areas have been reported with high nitrate and coliform levels (DMCR pers. comm. 2019). According to the Pollution Control Department (2015) coastal water quality is defined mostly as good to fair. Water

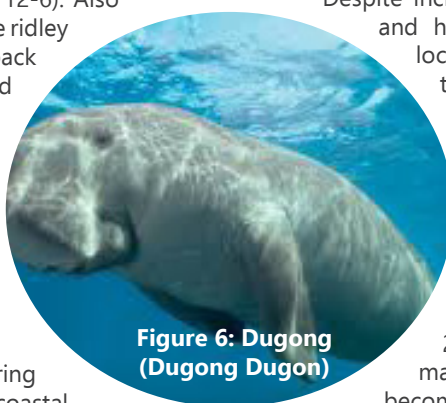


Figure 6: Dugong (Dugong Dugon)

quality monitoring is however only conducted by DMCR and PCD twice a year at each recording station.

Oil pollution poses a threat to the marine environment from industrial installations and release from marine vessels.

Despite increased awareness, oil spills are still frequent and have potential to impact the livelihoods of local fishers¹¹ and tourism sector^{12,13}. In 2015, the Pollution Control Department recorded a total of four oil slick incidents at Mae Rum Phung Beach and/or Laem Charoen Beach. The occurrence of algal blooms is related to nutrient levels, and high nutrient levels may result from sewerage discharges, agricultural runoff, and aquaculture. A single incidence of an algal bloom was reported along the Rayong coast by the DMCR in 2015, though they have been observed at many locations in the Gulf of Thailand and are becoming more common (PCD 2015).

Coastal erosion, although currently not considered a high priority issue, occurred substantially along the Rayong coast following construction of Map Ta Phut (Saengsupavanich et al. 2008). Sections of the Rayong coast that currently have unresolved erosion problems are indicated in Figure 12-7.

Figure 12-7: Areas experiencing coastal erosion (yellow shading) that have not been resolved



Source: <http://marinegiscenter.dmcg.go.th/gis/gis.php>

¹¹ <https://www.bangkokpost.com/news/politics/421276/rayong-oil-spill-fishermen-sue-ptt>

¹² <https://www.pttgcgroup.com/en/updates/press-release/627/the-progress-of-oil-spill-in-rayong>

¹³ <https://www.bangkokpost.com/learning/learning-news/362033/oil-spill-hits-beach-at-koh-samet-island-update-2>

3. Past trends and drivers of change

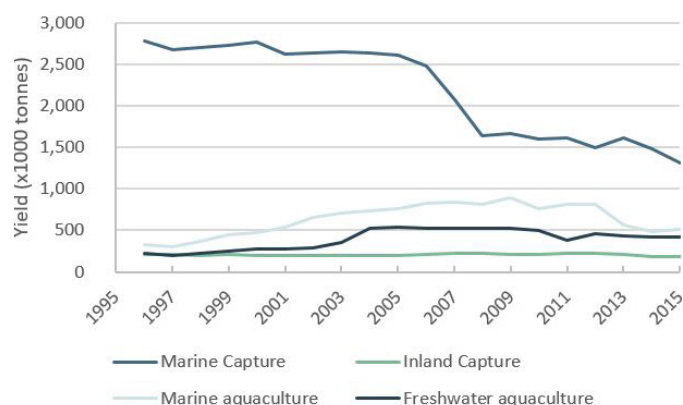
- ✓ Unsustainable fishing practices
- ✓ Poor management of solid wastes and effluent discharges
- ✓ Limited environmental monitoring and reporting to support effective evidence-based management¹⁴

Three strategic issues of concern were identified by stakeholders with regard to the marine and coastal environment of Rayong. Those issues were confirmed through a review of available data and information supplied by government agencies, findings published in the scientific literature, and expert judgement. Each issue is discussed in relation to past trends and drivers of change, and then future trends and drivers of change without the Rayong Provincial Development Plan are presented.

Unsustainable fishing practices

Since the mid- 1990s, at the national level, there has been a noticeable decrease of approximately 50% in marine caught fish since the mid-1990s (Figure 12-8), which reflects overexploitation of fishery stocks (Derrick et al. 2017). In Rayong, a similar downward trend in yield from marine fisheries has been observed (Figure 12-9).¹⁴ However, the total production of marine fish indicated in Figures 12-8 and 12-9 may be underestimations given the potential for unreported catches (Derrick et al. 2017).

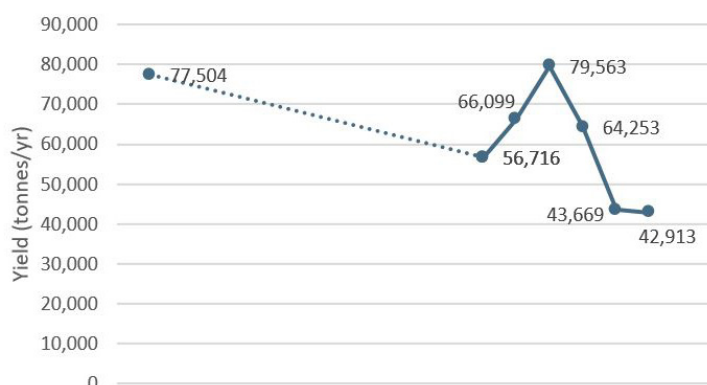
Figure 12-8: National yields of marine and freshwater fisheries (1996 - 2015)



Source: DoF 2017

In 2015, the majority of fish caught in the Gulf of Thailand was through trawling (49 %), followed by purse seining (37%) (DoF, 2017). Gill nets and other types of fishing gear were employed for 14% of the total catch (DoF, 2017). The type of fishing gear selected by fishers depends on target fish species, and each type can have negative impacts on natural ecosystems. Trawling is especially destructive to coastal ecosystems, such as seagrasses, coral reefs and other seafloor habitats, since fishing gear is dragged along the ocean floor. The risk from using purse seining is the capture

Figure 12-9: Marine fishes landed in Rayong Province



Source: DoF 2013-2018; ICEM 2004

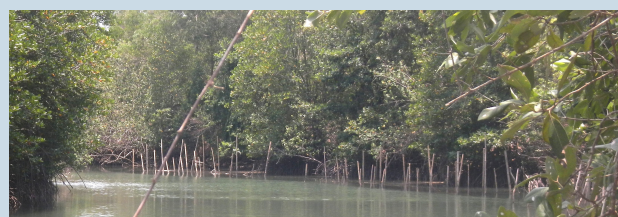
*Note: provincial data difficult to source between 2002 and 2010

of dolphins. Some 5% of all marine fish caught in Rayong are categorized as trash fish (Figure 12-2, left). The depletion of inshore fisheries is driving fishers to exploit fisheries further offshore, although labour shortages currently pose a problem for offshore fishing (i.e., more than 3 km from the coast) by local Rayong communities.

Coastal aquaculture is dominated by the production of shrimp, of which 99% comprises white leg shrimp (DoF 2017). Shrimp aquaculture production is currently threatened by disease, such as white spot disease which first was reported in 1995 and can cause mortality within 3 to 10 days (Piamsomboon et al. 2016). To combat the disease, shrimp aquaculturalists have avoided stocking shrimp during the cooler monsoon season or shifted culture to the non-native *Litopenaeus vannamei* (white leg shrimp). Despite these changes, the disease is still causing considerable losses (Piamsomboon et al. 2016). Aquaculture of oysters and mussels is being encouraged in Rayong, however the sustainability of the industry is hampered by the lack of appropriate zoning of coastal resources and coordination between government departments, such as the Department of Fisheries and Marine Survey Department (Box 1).

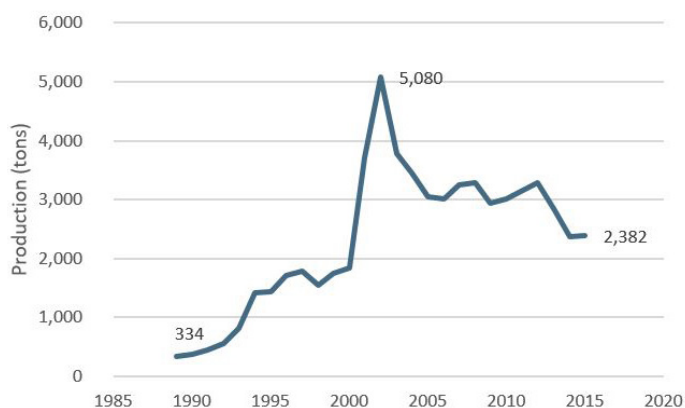
Box 1: Sustainability of Lawson Creek mangrove ecosystem and local livelihoods

For over 70 years oysters have been cultured by the local community of Lawson Creek with permission from the Department of Fisheries. However, the Marine Survey Department now considers that aquaculture should be curtailed in the creek. Recent development has also seen infilling of mangrove wetlands adjacent to the waterway. The sustainability of the mangrove ecosystem and livelihoods of local people are now at risk. Appropriate zoning of coastal and marine resources could ensure sustainability of the mangrove ecosystem and support the livelihoods of local people.



¹⁴ Annual catch data were not readily available for the full period before 2011.

Figure 12-10: Production of freshwater fisheries and aquaculture 1989 - 2015



Source: DoF, 2017, *Fisheries Statistics of Thailand for 2015*.
Technical Paper No. 5 / 2017. Information Technology Center,
Department of Fisheries, Bangkok.

Production from inland fisheries and freshwater aquaculture has increased rapidly over the 1990s, but has since dropped to less than half the peak production of 2002 (Figure 12-10). The causes of the recent drop include collapse of wild freshwater fish populations.

Mangrove wetland has experienced considerable loss in coverage over the last 50 years due mainly to the coastal aquaculture industry. Expansion of nearby communities and encroachment by agriculture puts additional pressures on mangrove ecosystems (DMCR 2018). There was extensive mangrove deforestation in the 1980s, and by the mid-1990s only a fraction of Rayong's mangroves remained intact. Since the low point in the 1990's, the area of mangrove wetland had recovered to about one third of its original coverage in the 1970s (Figure 12-11). However, the expansion appears to have stalled since the early 2000s (Figure 12-11), despite growing local awareness of the ecological importance of mangroves. It should also be noted that, while Figure 12-11 shows areal coverage, it does not indicate biodiversity and ecosystem health (e.g., extent of disturbance) of the mangrove ecosystems. There have been recent efforts to better protect mangroves in the province. For example, in 2018, 500 rai of urban mangrove forest was established

Figure 12-11: Change in remaining mangrove forest coverage



Source: DMCR 2018

with support from Rayong government authorities, private sector and local communities. Rayong's Chedi Klang Nam Mangrove Forest is part of the Thai government's City Forest scheme to encourage development of forests in urban areas.

Poor management of coastal ecosystems (including solid waste and effluents)

Marine and coastal ecosystems are threatened by poor management of solid wastes and effluent discharges from domestic and industrial sources. Human pressures on coral reefs include physical damage caused by fishing, and impacts associated with the growth of the tourist sector over the last decade or so, including those arising from waste water discharges, and sedimentation from land based coastal development.

In Thailand, tourism has been reported as the main cause of coral degradation, and solid wastes such as plastics are believed to increase the rate of coral infection.¹⁵ Algal blooms, caused by nitrate and phosphate pollution from boats, tourism and industry, can also cause coral mortality (DMCR 2018). Coral reefs are also at risk from increasing surface water temperatures, as well as from freshwater runoff and sedimentation. Coral bleaching is caused by increased surface water temperatures, and bleaching events have increased in frequency since the 1990s (DMCR, 2019, pers. comm.).

Seagrasses are critically important ecosystems for supporting marine life including fisheries. Surveys on the status of seagrass beds between 2003 and 2013 found some areas had been degraded as a result of sedimentation (in Ao Makhamom) or by physical disturbance (near Thap Samet village) (DMCR 2018). Seagrass beds may be degraded though direct physical impacts from vessels' anchors, and from sediment deposition due to development of coastal communities and industry. Other threats include shellfish dredging and the construction of piers and ports (DMCR 2018).

Marine debris, especially plastics, has become more widespread in Rayong's coastal environment. There are various routes for debris to enter the marine ecosystem, including from rivers, boats, sewerage systems, and overtopping of flooded landfills. Thailand has been ranked sixth in the world in terms of the amount of mismanaged plastic waste entering the oceans according to a study by Jambeck et al. (2015). Plastic waste in Thailand has been reported as increasing by 12% each year. Two national plans are being implemented to address Thailand's growing generation of solid waste, including the *National 3R Strategy* and the *National Master Plan for Waste Management (2016–2021)* and *Plastic Debris Management Plan 2017–2021* (Wichai-utcha, & Chavalparit 2019).

Solid waste threatens endangered species in the coastal waters of Rayong. Autopsy results from 271 endangered marine animals that were beached between 2004 and 2015 demonstrate the scale of impact of solid waste (DMCR 2018) (Figure 12-12). While most dolphins and whales had unknown causes of death, for 53% of stranded sea turtles the

¹⁵ <https://www.ibtimes.sg/coral-reefs-thailand-decaying-alarming-rate-scientists-blame-it-tourism-23799>

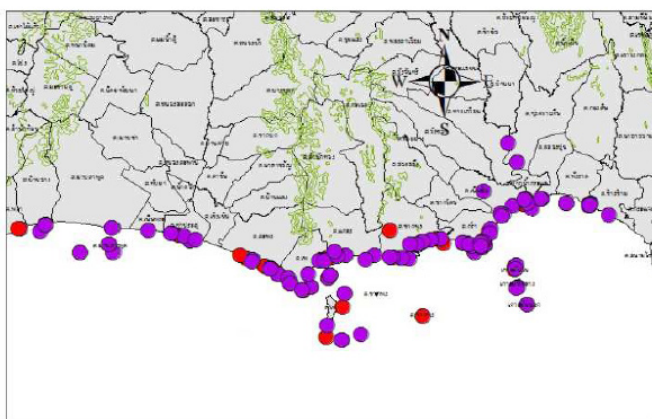
cause of death was directly related to fishing gear such as crab gill nets, fishing hooks and trawling, as well as garbage. The presence of solid waste such as bottle caps, plastic water bottles, nets and hooks have been extensively recorded in beached endangered animals of Rayong province. Other key impacts on endangered animals include the loss of habitat and food sources, and consumption of turtles, dugongs and dolphins or their use to make talismans or jewelry, as well as the linked production and trafficking of illegal wildlife products. Trafficking of illegal marine wildlife products continues in Thailand (DMCR 2018).

Limited environmental monitoring and reporting

Effective marine and coastal management requires appropriate monitoring and reporting. Monitoring and reporting on environmental quality of coastal waters is inadequate. Potential sources of coastal pollution include untreated household discharges and wastewater from boats and tourist attractions and industrial discharges. Coastal water quality was found to be mostly 'fair' or 'good' along much of the Rayong coast in 2014, although enterococci (sewage indicator bacteria) levels have been reported to exceed standards at Phayun Beach, Laem Mae Phim Beach and Arboretum (PCD 2015). Monitoring of coastal water is only conducted by DMCR and PCD twice a year and thus it is difficult to determine the state of water quality during the whole year, for hot spots or over longer time periods.

Concerns over the lack of information on water quality have been expressed by local fishers, especially with regard to industrial wastes and potential contamination of marine life. For example, as detailed in the social and demographic baseline, Rayong's Artisanal Fishermen's Association have protested in the past about pollutant loading in coastal waters because of industrial waste water. Red algae blooms have been reported to occur regularly along the coast and oil spills pose a risk to coastal natural resources (DMCR 2018). In relation to reporting of fisheries catch, the total production of marine fish reported in the past may be underestimated given the potential for unregistered catches.

Figure 12-12: Location of strandings between 2004 - 2015: turtle (purple), dolphin/whale (red)



Source: DMCR 2018

4. Future trends and drivers of change without the Rayong Provincial Development Plan

- ✓ Unsustainable fishing practices
- ✓ Poor management of solid wastes and effluent discharges
- ✓ Limited environmental monitoring and reporting to support effective evidence-based management

Unsustainable fishing practices

Marine fisheries yield is likely to continue falling, though official figures may under report yields. Future productivity of the industry in Thai waters will depend on implementing sustainable practices. A further threat comes from climate change with total catch from the tropics projected to decline by up to 40% from 2005 to 2055 (Cheung et al. 2009). The yield from Rayong's inland fisheries and aquaculture has dropped by over 50% from the peak of 2002, though the cause(s) are unclear. Coastal shrimp aquaculture is threatened by disease outbreaks, and white spot disease in particular has potential to challenge the future viability of local businesses.

Conflict over the use of natural resources will likely continue given no clear policy on zoning and marine spatial planning. Zoning would help reduce conflicts between fishers (e.g. zoning areas for either crab or fish capture), and between the local community and government (see Box 1), and also promote sustainable management and conservation of resources and ecosystems, for instance by delineating marine protected areas, seasonal "no go" areas and areas that permit tourism or industrial activities under a framework of zone standards and safeguards. The DMCR is currently working on a marine spatial plan for Koh Man Nai (DMCR, 2019, pers. comm.). Increased participation by communities in natural resources management could help address environmental issues and improve management outcomes.

Poor management of solid wastes and effluent discharges

It is likely that coral reefs and seagrass beds will continue to be further degraded and diminish in their coverage unless sedimentation, and inland and coastal waste discharges are reduced. The planned construction of three wastewater treatment plans in Rayong province should alleviate pollution from household waste discharges. The prevalence of solid waste, particularly plastics, is anticipated to continue as a visible problem along Rayong's shores and a threat to endangered species. A clear national response to solid waste management has been initiated as it is an issue that cannot be resolved at provincial and community levels. Private sector initiatives in Rayong have also been launched to raise awareness and address the problem.^{16,17}

¹⁶ <http://www.scgsustainability.com/en/sustainability/environment/biodiversity-and-ecosystem/>

¹⁷ <https://www.bangkokpost.com/business/news/1573350/pttgc-to-recycle-plastic>

Limited environmental monitoring and reporting

Sustainable management of coastal and marine resources is constrained by limited environmental monitoring and reporting. Gaps in data and information challenges the implementation of evidence-based management of the environment and the capacity to demonstrate whether or not SDG 14, national or provincial sustainability objectives are being delivered. In the fisheries sector, improved enforcement and monitoring is needed to decrease unsustainable fishing. Progress is reportedly being made in

reducing illegal, unregulated and unreported (IUU) fishing at the national level, though in Rayong fishers have expressed difficulties in addressing new reporting requirements.

Past limited monitoring of the environmental quality of coastal waters along Rayong's coastline and derivation of a water index indicates that water quality is for the most part fair or good, though with higher than standard levels of enterococci bacteria reported in some localities. Concerns over the lack of information on water quality have been expressed by local fishers, especially with regard to industrial wastes and potential contamination of marine life and human consumption.

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STRATEGIC THEME: TERRESTRIAL BIODIVERSITY

1. Introduction

Under the scope of the strategic theme of terrestrial biodiversity we are concerned primarily with natural forest cover in Rayong Province, as well as its connectivity with forests in neighbouring provinces, as part of the “forest that connects five provinces” or the Eastern Forest Complex (EFCOM) and the biodiversity contained within those forests. A more detailed assessment would consider agrobiodiversity, and the extent to which the agricultural systems of Rayong support the persistence of some biodiversity, but while important, this is beyond the scope of the SEA.

The vast majority of remaining forest within Rayong Province is contained within National Parks and Wildlife Sanctuaries, while some smaller patches of National Reserve Forest still persist. Geographically, the largest remaining forests in Rayong Province lie in Khao Chamao District, while some dry evergreen forest on Koh Samet and other islands are part of Meuang District and Prasae District, the latter of which also has the largest mangrove forests. Khao Chamao-Khao Wong National Park (in Khao Chamao District) and Khao Ang Rue Nai Wildlife Sanctuary (with a small part found in Khao Chamao District and bigger portions in neighbouring provinces) are home to relatively complete assemblages of fauna and flora that would be expected to be found in this part of Thailand. Important mammal species include elephants, gaur, banteng, serow, sambar deer, muntjac, wild boar, pileated gibbons, sun bear, Asiatic black bear, dhole, leopards and tiger. Important birds include Siamese fire back, silver pheasant, red jungle-fowl, great, wreathed, and pied hornbills, and blue-winged pitta.

Large mammals in particular require large areas of forest for their continued survival. A single male tiger for example may require a home range of 100 km² in order to find enough food to survive (this will depend on density of available prey).

When forests are fragmented – often by construction of roads and reservoirs, or by the encroachment of farmland, and divided into smaller patches that are no longer connected, then this reduces the chances of long-term survival for many species. It is therefore imperative that no further fragmentation is allowed to happen in Rayong Province and its neighbours – rather efforts should be made to restore connectivity



STRATEGIC ISSUES OF CRITICAL CONCERN FOR SUSTAINABLE DEVELOPMENT IN RAYONG

- ✓ Fragmentation of forests
- ✓ Very low forest cover

SUSTAINABLE DEVELOPMENT OBJECTIVE:

- ✓ Conserve, restore and enhance biodiversity in Rayong
- ✓ Increased forest cover throughout the province with a target to contribute to the national goal of 40% forest cover

between patches wherever possible. Forest fragmentation and connectivity has been identified by stakeholders as a strategic issue of concern to Rayong's development.

Total forest cover in Rayong is already very low, currently less than 8%, compared with a national target of 40% forest cover across the country. This low forest cover limits the availability of ecological services to support the development of the province – especially in terms of watershed functions which ultimately underpin industrial development, and offer both mitigation of and adaptation to climate changes. Forest cover is therefore a second key issue of concern.

The two key issues selected are clearly related to issues in the water sector, the transport sector, the agriculture sector, and the public health sector. The increasing demand for water that is projected for Rayong Province over the next two decades may result in construction of a number of new reservoirs. It is possible that the construction of some of these reservoirs may result in further destruction or degradation of Rayong's limited forest estate. Widening and upgrading roads that surround Khao Chamao will impact its connectivity with other forests. Heavier and faster moving traffic is likely to result in an increased number of collisions with wildlife. Promotion of agricultural crops that are attractive to elephants into the areas immediately adjacent to remaining forests will likely lead to an increase in human-elephant conflict in these areas. Forests also provide important opportunities for outdoor

recreation and education, medically proven to promote both good mental and physical health. Availability and accessibility of forests therefore has important links to the public health sector and to community well being.

2. Description of current status of the strategic theme

Forest cover and terrestrial biodiversity

Forest types found in Rayong include both evergreen (moist evergreen, dry evergreen, and hill evergreen); and deciduous (mixed deciduous and dry deciduous) types, as well as forest over limestone, mangrove forest, beach forest and swamp forest (cajaput or melaleuca forest). Evergreen and deciduous forest each account for about 3.6% of the land area of Rayong Province, while mangrove and swamp forest account for about 0.7%.

Forest Land Categories

Three main legal categories of forest land are found in Rayong Province. These are national parks, wildlife sanctuaries and national forest reserve. Rayong includes all or some parts of: two National Parks, one Wildlife Sanctuary and eight National Reserve Forests, as follows:

- Khao Laem Ya-Mu Koh Samet National Park is contained entirely within Rayong Province, in Muang and Klaeng Districts.
- Khao Chamao-Khao Wong is located mostly within Khao Chamao District of Rayong Province and also partially within neighbouring Chanthaburi Province.
- A small part of Khao Ang Rue Nai Wildlife Sanctuary is also found within Khao Chamao District, while the majority of the sanctuary is located within neighbouring provinces.

Table 13-1: National Parks and Wildlife Sanctuaries in Rayong Province

Name	Year of Establishment	District	Total Area (km ²)	Area within Rayong (km ²)
Khao Laem Ya – Mu Koh Samet Nation Park	1984	Klaeng and Muang District	131.00	131.00
Khao Chamao – Khao Wong Nation Park	1975	Klaeng and City District, Ta Mai District, Chantaburi	83.68	67.84 (estimate)
Khao Aung Rue Nai Wildlife Sanctuary	1977	• Tha Takiap District, • Sanamchai Ket District, • Chachoengsao Province, • Wangnamyen District, • Wangsomboon District, • Sa Kaeo Province, • Khao Chamao, Rayong Province, • Kaeng Hang Maeo District, Chantaburi Province • Bothong District, Chonburi Province	1,030	52.60
Total			1,460.36	251.44

Source: Department of National Parks, Wildlife and Plant Conservation (DNP)

Information about the eight National Reserve Forests which originally had a total area of 822 km² is provided in Table 13-2 below:

Table 13-2: National Reserve Forest in Rayong province

Name	Year of Establishment	District	Original area (km ²)	ALRO area (km ²)	Remaining area (km ²)
Kachet Forest, Pae Forest and Klang Forest	1964	Muang and Ban Kai District	46.30	1.80	44.50
Khao Huai Ma Had Forest, Khao Nang Yong Forest, Khao Krok Forest	1983	Muang District	28.50	10.70	17.80
Rawoeng – Khao Somset Forest	1986	Ban Kai and Pluakdaeng District	220.00	178	42.00
Banna Forest, Tung Kwai Kin Forest	1964	Klang District	501.60	37	463.60
Ban Pae Forest	1959	Muang District	1.00	0.00	1.00
Khao Hin Tang Forest	1979	Klang and Muang District	9.12	2.10	7.02
Lenprasae Forest and Pangrad Forest	1958	Klang District	14.54	0.00	14.54
Nongsanom Forest	1962	Muang District	0.93	0.00	0.93
Total forest land area			821.99	229.60	592.39

Source: Department of National Parks, Wildlife and Plant Conservation (DNP)

While vegetation cover of Khao Ang Rue Nai, Khao Chamao-Khao Wong and Khao Laem Ya-Mu Koh Samet is mostly intact (the latter includes areas of sea as well as land), that is *not* the case for National Reserve Forests, most of which have been destroyed or degraded, with only a fraction of their initial area remaining.

Khao Chamao District

Khao Chamao District is the most important district for forest cover in Rayong Province. The District includes most of Khao Chamao Khao Wong National Park, and part of Khao Ang Rue Nai Wildlife Sanctuary. Lying in the north-east corner of Rayong Province 12°58'30"N 101°41'6"E Khao Chamao District covers 269.95 km². Initially it was created as a minor district (*king amphoe*) split off from neighbouring Klaeng District on 31 May 1993. On 15 May 2007, it was upgraded to a full district. The district is divided into four sub-districts (*tambons*) each with a tambon administrative organization (TAO), which are further subdivided into 21 villages (*mubans*) with a total population of over 24,000 people (2005).

Khao Chamao District location in Rayong Province



Source: Wikipedia

Klaeng District

Klaeng District, 12°46'42"N 101°39'12"E, covering 788.463 km² of Rayong Province, and with a population of 126,289 (2009), is the most important for mangrove forests. Klaeng district is divided into 15 sub-districts (*tambons*), which are further subdivided into 146 villages (*mubans*). Around 11 km² of mangroves are found on the estuary of the Prasae River in Klaeng, in Tambo Pak Nam Krasae.

Klaeng District location in Rayong Province



Source: Wikipedia

Mueang District

Mueang District, 12°40'6"N 101°16'30"E covering an area of 514.5 km² with a population of 229,657 (2008) is the capital district of Rayong Province. The district is divided into 15 sub-districts (*tambons*) which are further subdivided into 86 villages (*mubans*). Rayong is also a city (*thesaban Nakhon*) which covers tambons Tha Pradu and Pak Nam and parts of tambons Choeng Noen and Noen Phra. The provincial administration is in *tambon* Map Ta Phut in the western part of Mueang Rayong District, also the site of the Map Ta Phut Industrial estate, Thailand's largest petrochemical and heavy industry park.

Mueang District, in particular Phe Sub-district, in the southeast, is the location of Khao Laem Ya-Mo Koh Samet National Park. The park covers an area of 131 square kilometres of land and sea. The main island of Koh Samet is a well developed tourist destination, but still maintains some good forest cover in the centre of the island. Samet island together with 8 other main islands making up the archipelago, are also important for their marine biodiversity.

Mueang District location in Rayong Province



Source: Wikipedia

3. Protected Areas

Khao Chamao-Khao Wong National Park

Khao Chamao-Khao Wong was designated a park in 1975, becoming Thailand's 13th National Park, and covering an area of 83.68 km². Named after 2 mountains in Rayong and Chantaburi provinces, with elevations up to 1,000m it provides an important watershed area for the agriculture of the region, and is partially the source of the Prasae River. Most of Khao Chamao consists of moist evergreen forests, followed by hill evergreen forest and dry evergreen forest, whereas Khao Wong consists mostly of moist evergreen forest and limestone forest, with some dry evergreen forest. It receives around 3,000mm of rainfall each year – much higher than the average of the province. Endemic species are include a species of Curve-toed gecko (*Cyrtodactylus sumonthai*) found in Khao Wong cave. In deep pools of the Khao Chamao waterfall is a species of carp which makes people light-headed if they eat it – hence the name of the park (Chamao means getting drunk). The fish feeds on ripe fruit that falls in the water – apparently doesn't affect the fish but intoxicates people. The same fruit has also been used as a traditional cure for leprosy. That the list of known amphibians and reptiles from Khao Chamao-Khao Wong

only numbers 10 and 24 respectively, reflects more on the lack on biodiversity inventory work that has been done there. Around 80% of the park's annual budget of 10 million baht is spent on the salaries of its 88 staff found at the headquarters area and 7 ranger stations spread around the park. The park receives around 100,000 visitors each year, mostly local tourists visiting Khao Chamao Waterfall; Klong Pla Kang Waterfall; and Khao Wong Cave, especially at week-ends and on public holidays. The park has overnight accommodation and a campground which recently have been renovated and improved. Around 8 million baht income is generated from entrance fees and other fees.

Khao Ang Rue Nai Wildlife Sanctuary

Khao Ang Rue Nai Wildlife Sanctuary is a protected area at the western end of the Cardamom Mountain Range. It was gazetted in 1977, and covers over 1,000 km² (643,500 rai) of mostly low elevation, dry evergreen forest with additional areas of moist evergreen, mixed deciduous and dry deciduous (dry dipterocarp) forests. Maximum elevation at Khao Sip-Ha Chan is 802m above sea level. It lies mostly within Chachoengsao Province, but a small part is in Rayong Province, lying just to the north of Khao Chamao – Khao Wong National Park. The two protected areas are almost contiguous forest in some places separated only by the minor road #4060. Khao Ang Rue Nai is the source of the Bang Pakong River in Chachoengsao, the Tanot Canal in Chanthaburi, and (together with Khao Chamao-Khao Wong), the Prasae River in Rayong. Khao Ang Rue Nai and Khao Chamao-Khao Wong, are both part of what has been traditionally known as “the forest connecting five provinces” (Chachoengsao, Chonburi, Rayong, Chanthaburi and Sa Kaeo), and has more recently been designated by the Department of National Parks (DNP) as the “Eastern Forest Complex” (EFCOM).

Khao Laem Ya–Mu Ko Samet National Park

In 1981, Koh Samet (Cajeput Island), along with eight other small islands, the headland of Khao Laem Ya, and the 11km long Mae Rampeung Beach was declared as a national park covering an area of 131 km². Khao Laem Ya is a granite promontory and laterite hill with some forest and grassland. Koh Samet is an island of about 13.1km² shaped somewhat like a “t” lying 2.6km offshore at its closest point. It is about 80% covered with dry evergreen and some beach forest.

Koh Samet is very popular with both foreign tourists and Bangkok residents. However, Koh Samet is one of the driest archipelagos in Thailand, receiving much less rainfall than Rayong mainland and consequently needing to import large amount of potable water. Just off the southern tip of the island are three small rock-islands, Ko Chan (Moon Island), Ko San Chalam (Shark Fin Island), and Hin Khao (White Rock). The other 8 islands making up the park are:

- Ko Kudi (Monk's Chamber Island)
- Ko Kruai (Cone Island)
- Ko Makham (Tamarind Island, also called Ko Kham)
- Ko Plai Teen (Foot Tip Island)
- Ko Chan (Moon Island)
- Ko Talu (Hole Island)
- Ko Klet Chalam (Shark Scale Island)
- Ko Thai Khang Kao (Bat's Bottom Island)

In August 2013 more than 500 national park officials were deployed to destroy three resorts—Muk Samet, Unseen, and Ploy Samet—which had been built illegally in the park. In September 2016, the park chief and 79 other officials were removed from their posts for corruption. Initial investigations found that 200,000 baht per month was paid to park officials as kick-backs. The Department of National Parks (DNP) found that all businesses on Ko Samet “valued at over 100 million baht per month” were operated by “mafia groups”, some linked to police officers. Since the removal of corrupt officials, revenues at the park have increased, rising to 4.8 million baht in October 2016, compared with 1.2 million baht in October 2015.

4. Past trends and drivers of change

- ✓ Forest fragmentation/connectivity
- ✓ Amount of forest cover

Forest fragmentation/connectivity

The major destruction of forests in Thailand occurred mostly between the 1960s and 1980s. During this period, large areas of forest were designated as logging concessions, Thailand's then still largely rural farming population increased significantly in number requiring large areas of former forests to be converted to agriculture, and many development projects including roads and reservoirs also led to the destruction and fragmentation of forests. This same period also saw the establishment of many of Thailand's most important protected areas, as conservationists tried to save as much forest as they could. Khao Chamao-Khao Wong was established in 1975, and Khao Ang Rue Nai was established in 1977.

In 1989 Thailand banned any further commercial logging in its forests, and throughout the 1990s the population growth rate continued to decline. At the same time as the economy expanded and urbanization increased, more young people started moving from the countryside to the towns and cities. These changes, combined with improved protection and management of protected areas led to a stabilization of the forest estate in Thailand starting in the 1990s. Although there was a significant (but ultimately temporary) return to the countryside during 1998-2000 (and an uptick in pressure on forests) as a result of the Asian financial crisis. In the last 20 years additional forest loss in the country has been relatively small.

The most important forests remaining in the Eastern Region of Thailand are within the Eastern Forest Complex (EFCOM). This includes a largely contiguous group of protected areas covering parts of Chonburi, Chachoengsao, Rayong, Chanthaburi and Sa Kaeo provinces with a combined area of 3,024 km². Khao Chamao is the largest intact forest in Rayong Province and is also an important part of EFCOM. Its situation as part of this larger forest block enables Khao Chamao to maintain a diversity of species and populations

of large mammals much greater than if it was an isolated forest patch surrounded by developed areas. This elevates its value from the national level to be part of a regionally and internationally important conservation area. The EFCOM forests are also connected to an even larger forest block in the Cambodia Cardamom mountain range making this a globally significant area for transboundary protected area management (Figure 13-1). Rayong's development and water supply benefits from this broad forest complex. Rayong's two key rivers - the Rayong River or Khlong Yai and the Prasae River, have most of their forested watershed in neighbouring Chonburi, Chachoengsao and Chanthaburi provinces.

Khao Chamao is bounded by minor roads including road # 4023 to the south and southeast of Khao Chamao-Khao Wong National Park; road # 3377 to the west and northwest of the park; and road # 4060 running from west to east between Khao Chamao and Khao Ang Rue Nai. Most important of these from the context of forest connectivity is road # 4060. Presently the forests of Khao Chamao and Khao Ang Rue Nai are nearly contiguous in some places, and the landscape between them is largely a mixture of some forest patches and interspersed farmland. Along significant stretches of the road there is little habitation, and the vegetation on both sides of the road comes right up to the edge of the road. Any improvement or widening of this road could have very negative consequences for connectivity between these important protected areas, which would be detrimental to its ecosystem and biodiversity conservation value.

Due to successful conservation measures and improved management of protected areas, elephant populations have been growing in EFCOM as they have been in other parts of Thailand. Currently there are 3-4,000 wild elephants in Thailand, and EFCOM is home to 400 of these. While this significant recovery of elephant numbers is a great conservation success for Thailand, the incidence of human-elephant conflict is steadily increasing.

A study conducted in 2010 by the Economy and Environment Program for Southeast Asia (EPPSA) found that the average number of crop-raiding incidents in villages near Khao Ang Rue Nai Wildlife Sanctuary was 25/month. Households in the area had to spend an average of 212 nights per year guarding crops. The average crop area damaged by elephants was

approximately six rai (0.96 hectares) per household, and the average cost of damage due to elephants was 34,825 baht per household per year, which accounted for 19% of average household income.

In the area between Chao Chamao and Khao Ang Rue Nai, 17% of farmers surveyed used land inside the protected area, and had no land title; while 83 had land outside the protected area with basic land tenure certificates. Rubber, durian and other fruits were their main source of income. 76% stated that water shortage and drought was the main factor impacting their production, while 24% said that damage to their crops by elephants was the main factor (Puwphiromkhan, 2016).

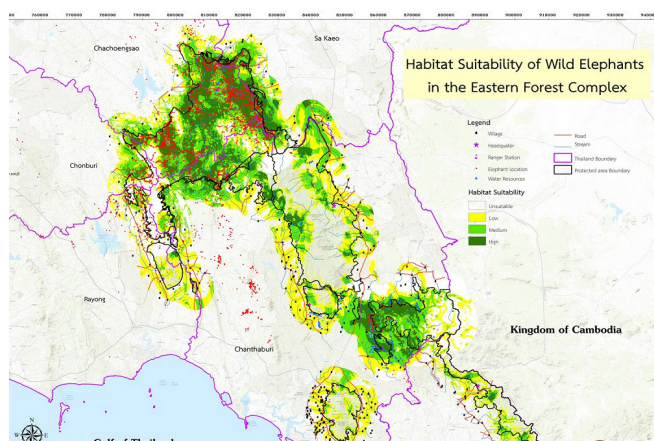
Forest Cover in Rayong Province

Rayong province covers an area of 3,552.00 km². Land use is categorized into 5 categories: communities and buildings; agricultural land; forest land; water resources and miscellaneous. Land use areas for 2006, 2011, 2016 and 2018 (repeated from the agriculture baseline chapter) are shown in Figure 13-3. Overall, the forest cover of Rayong Province currently accounts for about 8.0% of total provincial area, for about 4% of the total area of EFCOM and about 0.5% of the total forest cover of Thailand.

Forest area for 2018 compared to 2006 shows a loss of around 0.90 km² per year over the 12-year period (or about 0.3% of the remaining forest cover each year). Given Rayong's small forest area, this rate of loss is significant. In addition, information on changes in the areas of different types of forest area (Table 13-3) shows that over the last 12 years while some degraded evergreen and deciduous forests have been lost, some of these degraded forests, including mangroves, have been restored. The total forest area has slightly decreased, but a higher proportion of what remains is considered of better quality.

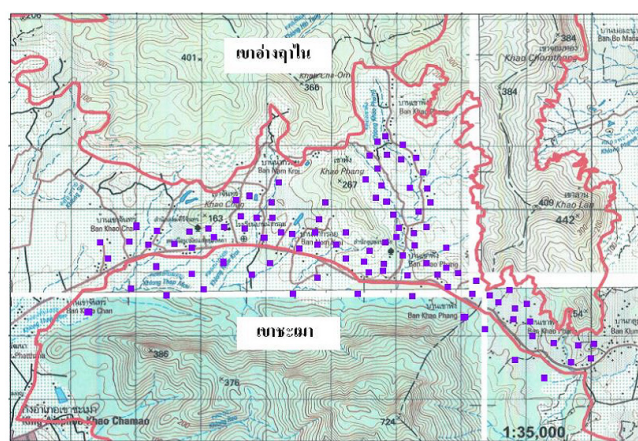
Around 28% of degraded National Reserve Forests in Rayong have already been legally transferred to the Agricultural Land Reform Office (ALRO) which issues land tenure certificates to farmers for this land (POAC, 2018). By 2004, the National Reserve Forest cover had already declined from 822 km² to 313 km², and then over the next decade continued to decline much more gradually to 282 km² by 2014, after which there

Figure 13-1: The Eastern Forest Complex and its suitability for elephants



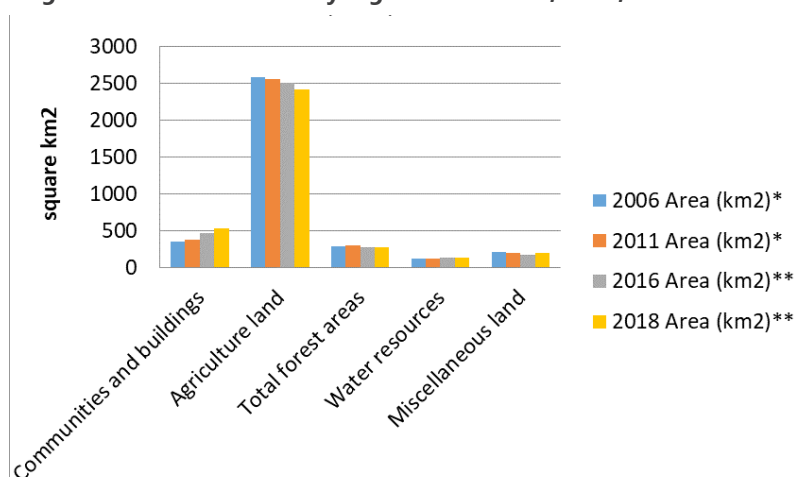
Source: DNP

Figure 13-2 – survey household location in the area between Khao Chamao and Khao Ang Rue Nai



Source: Puwphiromkhan, 2016

Figure 13-3: Land use in Rayong Province 2006, 2011, 2016 and 2018



Source: Land Development Department & Office of Agricultural Economics

Table 13-3: Type of Forest of Rayong Province 2006 and 2018

Type of forest	2006		2018	
	Area (km ²)	% of total provincial area	Area (km ²)	% of total provincial area
Evergreen forest awaiting restoration	7.51	0.49%	4.37	0.12%
Evergreen forest	116.67	3.28%	126.84	3.57%
Deciduous forest awaiting restoration	41.18	1.16%	20.8	0.59%
Deciduous forest	94.32	2.66%	107.52	3.02%
Mangrove forest awaiting restoration	0.024	0.00%	0.08	0.00%
Mangrove forest	12.46	0.35%	17.06	0.47%
Planted forest awaiting restoration	-	-	0.84	0.02
Swamp forest	7.97	0.22%	-	-

Source: Land Development Department & Office of Agricultural Economics

was a slight increase by about 10 km² in 2015 (RFD, 2016). Disappearance of forest and other terrestrial vegetation includes the removal of riverine forest cover along most of Rayong's watercourses, and similarly coastal forests have historically decreased.

The remaining forest cover in National Forest Reserve (NFR) land only accounts for about half of the land that is still designated as National Forest Reserve. It may be possible for some of the non-forested NFR area to be made available for reforestation. A higher resolution analysis of each of the eight individual National Reserve Forests would be necessary to assess how realistic this might be in each case. Some remaining small forest areas are now managed as community forests, which allows the community surrounding the forest area to manage and to use the area with support from the government. The Royal Forest Department retains the rights to withdraw the projects at any time if the management has been found unsuitable.

There are 34 community forests in Rayong, covering a combined area of only 8.85 km². The largest active community forest is Ban Thrai En Community forest located at Song Salueng Subdistrict, Klaeng District, covering 1.32 km². The smallest community forest is Ban Mhuang Rae

Community Forest located at Nam Pen Sub-district, Khao Chamao District, covering only 0.01 km². These community forests may provide some additional opportunities for further reforestation activities.¹

Summary

There has been limited forest cover change in Rayong over the last two decades, with forest loss at less than 0.3% per annum. Remaining forest is concentrated in national parks and wildlife sanctuaries which are well-managed. Most of the remaining forest is in Khao Chamao District and the islands off Meuang and Klaeng Districts. Known endangered and endemic species of Rayong Province are found in these protected areas, where they have the best chances of survival. Wildlife poaching and illegal logging do not appear to be major issues, and forest encroachment is negligible. In addition, small patches of National Reserve Forest scattered in other parts of the province are being managed as community forest. Some reforestation activities are being conducted. Connectivity between Khao Chamao National Park and the rest of the large Eastern Forest Complex spread across parts of five provinces, is critical for maintaining large-scale ecosystem processes, and populations of large wide-ranging species including

¹ <http://forestinfo.forest.go.th/fCom.aspx?prov=21&zone=20&year=-1&eyear=-1&type=-1>

elephants and other large mammals. Human-elephant conflict is a growing issue, especially in the area of mixed patches of forest and agricultural land in the landscape connecting Khao Chamao with Khao Ang Rue Nai, and traffic accidents involving elephants are also increasing.

5. Future trends and drivers of change without the Rayong Provincial Development Plan

- ✓ Expansion of roads in forest landscapes
- ✓ Expansion of water infrastructure in forest landscapes

Without the RPDP, no further significant loss of forest would be expected in Rayong, but few gains in cover. Forest cover will continue to be most important in Khao Chamao District, as well as on the islands that constitute the Khao Laem Ya-Koh Samet National Park.

Small patches of National Reserve Forest scattered in other parts of the province are being managed as community forests. There is increasingly interest in restoration planting/enrichment planting in these small forest patches, sometimes supported by private sector CSR initiatives, and these community forest areas could see increases in both area and quality of forest over time. Most of them are too small to be of significant biodiversity value, although they may be important for local ecosystem services.

Connectivity of Khao Chamao-Khao Wong National Park with Khao Ang Rue Nai Wildlife Sanctuary and the rest of EFCOM has been recognized as a priority by DNP. A DNP research team has identified suitable corridor areas between Khao Chamao and Khao Ang Rue Nai, where there is habitat fragmentation and patchy forests are interspersed with small-holder farmlands. The delineation of the corridor was determined by line transect studies (using a series of 6km long transects spaced 1km apart), regression analysis and GIS mapping. These are the areas where many animal signs were found. Four new water sources, check dams and plantations of elephant food species have been developed in the corridor, to encourage elephants to move through this part of the landscape, where they will create less conflict and have less chance of being injured. Salt-lick areas have also been enhanced. Much of this work is being funded as a CSR initiative by Kubota farm machinery company. There is a plot of land at the elephant conflict area in the north that was purchased from villagers with money raised by monks through merit-making events. This is now being used for revegetation and protection of the elephants. This land will not be used for any development.

In the broader EFCOM landscape, DNP and the Highways Department are working on approaches to re-establishing connectivity through tunnels and fly-overs. A model for this already exist in Thailand between Khao Yai and Thaplan National Parks. A further initiative is under way to reconnect

forests on either side of the highway running through EFCOM linking Chantaburi to Sa Kaeo. Without the Rayong plan, all these activities are likely to continue, with remaining and some additional connectivity likely to be restored.

6. Definition of sustainability objective and parameters

Effective management of Rayong's protected areas ensures no further loss of forest or terrestrial biodiversity, and together with ecosystem restoration across the province, enhances the availability of natural capital and provision of ecosystem services to support economic development; contributes to climate change adaptation and mitigation; and provides nature education and recreation opportunities that support the mental and physical well-being of Rayong's population.

Parameters:

- Management Effectiveness of Protected Areas in Rayong
- Total forest cover of Rayong Province
- #/size of areas where forest connectivity has been restored
- # of visitors to national parks and their satisfaction rating

Explanation/Source:

From the 20-year National Development Strategy (2017-2036): From the specific strategy on improved quality of life that is environmentally friendly, "develop a systematic approach to conservation, protection and restoration of natural resources"

From the 12th National Economic and Social Development Plan (2017-2021): The 4th strategy is "growth that is environmentally friendly for sustainable development" and includes driving improved conservation and restoration of natural resources with a target to achieve 40% forest cover nationally.

From the Master Plan for Integrated Biodiversity Management B.E. 2558-2564 (2015-2021): The strategies for integrated biodiversity management comprises 4 strategies and 11 measures, including Strategy 2 Conserve and restore biodiversity:

Measure 1 Conserve, restore and protect ecosystems, species and genetic diversity.

1.1) Strengthen and increase efficiency in management of protected areas and conservation areas according to law.

1.2) Reduce habitat loss rate and restore degraded ecosystems so as to maintain their ecological services for climate change mitigation and combating desertification.

1.3) Develop mechanisms for protecting and restoring endemic and threatened species according to Thailand's Red Lists.

1.4) Conserve and protect genetic diversity of agricultural plants, livestock, aquatic and domesticated animals, wild and native varieties, microorganisms, including other species that have economic, cultural, social and ecological values.

1.5) Enhance and urge all relevant sectors to implement targets and guidelines on biodiversity conservation of flora

and fauna in line with global targets and strategies.

1.6) Promote integrating management of ecosystems into the wider landscape and seascape in order to promote conservation and sustainable utilization and maintain ecosystem services.

7. References and sources of information

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Provincial Office of Agriculture and Cooperatives, Rayong (2018) Agriculture Development Plan Rayong Province 2017-2021

Puwphiromkhwan (2016) Valuation of ecosystem services of the Eastern Forest Complex, for water use in industry, agriculture and commerce.

Unpublished Report, CATSPA Project 221pp (Thai language only).

RFD (2016) Forest area information for Rayong Province

Meeting at region 2 Forestry Office, Chonburi (8 March 2019), with:

1. Mr. You Senatham, Director of PARO2
2. Mr. Weera Khunchairak, Director of National Parks Division, PARO2
3. Mr. Kittisak Sripadtha, Technical Officer, Wildlife Conservation Division, PARO2
4. Mr. Pornchai Vanassarut, Superintendent of Khao Chamao – Khao Wong National Park

Meeting at Khao Chamao – Khao Wong National Park (8 March 2019) with:

1. Mr. Pornchai Vanassarut, Superintendent of Khao Chamao – Khao Wong National Park
2. Mr. Thammanoon Temchai, Head of National Parks Research Centre (Petchburi)
3. Mrs. Supannida Phasuktanakan, Staff of Khao Chamao – Khao Wong National Park
4. Ms. Kuakoon Kukkong, Staff of Khao Chamao – Khao Wong National Park
5. Ms. Artcharee Wongprom, Technical Officer, DNP HQ
6. Ms. Natthaya Sribunrueang, Technical Officer, DNP HQ
7. Ms. Waewmanee Patsoongnarn, Technical Officer, DNP HQ





STRATEGIC THEME: ENVIRONMENTAL QUALITY

1. Introduction

Rayong's environment is heavily affected by human activities. The province is a major and growing energy and industrial hub. It is also a growing centre for domestic tourism. The industry, energy and transport sectors all emit pollution to air, water and land. Domestic, industry, tourism and agricultural activities all consume and contaminate water. Poorly planned and managed development of the coastal zone has resulted in multiple point source pollution and localised water quality problems.

The Regional Environment Office reports that pollution in the Rayong River has now reached critical levels due to inflows from domestic, agriculture aquaculture and localised industrial sources (interview with REO 31 May 2019). Reservoirs have been built to supply water to industry, to urban centres and to agriculture and some suffer algal blooms and problems with upstream pollution from factories and sedimentation. Landfill sites have reached capacity and an increasing accumulation of hazardous wastes remain untreated. Some sources of pollution remain largely unrecognised and unmanaged such as expanding shipping, thermal discharges and decommissioned factories.

2. Scope

This theme deals with environmental quality. The main issues for environmental quality in Rayong have been identified during the consultation process as:

- hazardous waste
- solid waste
- water quality
- air quality



The limited traction of environmental management plans for Rayong Province has not been included in the list of strategic issues but it is an underlying impediment to all forms of pollution control.

Past trends and drivers of change in the four strategic issues are examined with a brief analysis of how the trends are likely to project into the future.

STRATEGIC ISSUES OF CRITICAL CONCERN FOR SUSTAINABLE DEVELOPMENT IN RAYONG

- ✓ Hazardous waste
- ✓ Solid waste
- ✓ Water quality
- ✓ Air Quality (emissions from transport and industry)

SUSTAINABLE DEVELOPMENT OBJECTIVES:*

- ✓ Establish effective measures for the prevention, control and abatement of water pollution;
- ✓ Hazardous wastes from industry, domestic and agricultural sources are identified, minimised and disposed without negative environmental impacts;
- ✓ Replace open dumping sites by sanitary landfills, green space, incineration and waste to energy and recycling schemes;
- ✓ Establish and enforce point source air pollution standards, especially relating to the industry, energy and transport sectors.

* Summarised from Thailand's Environmental Quality Management Plan 2017-2021, the National Master Plan for Waste Management 2016-2021 and MONRE's EEC environment plan 2018-2021:

3. Links to other sectors and themes

Industry: Map Ta Phut is Thailand's largest industrial estate and the world's 8th largest petrochemical industrial complex. Past sampling of sediments show increased concentration of arsenic, mercury, zinc, copper, nickel and chromium compared to the upstream sources. Sampling from the Map Ta Phut area shows elevated levels of mercury and methylmercury in tissues of fish. Methylmercury accumulates in the environment and is highly toxic. Mercury undergoes bioaccumulation and biomagnification on site and further

away from the original sources of contamination.¹

Industry throughout Rayong Province is a source of air pollution including volatile organic compounds (VOCs), particulate matter (PM), as well as greenhouse gases (GHGs). Industrial waste-water is becoming increasingly hazardous as a proportion of total pollution load, and old, improperly decommissioned factories are becoming a problem with leakages and accidents releasing untreated hazardous waste to the environment. For example, in July 2013, a pipeline owned by the Petroleum Authority of Thailand, Global Chemical Plc. (PTTGC) ruptured while transferring oil from an undersea reservoir to a tanker, leaking crude oil into the Gulf of Thailand off the coast of Koh Samet, a popular tourist island in Mueang Rayong District of Rayong Province. The organic compounds in crude oil are harmful and can work their way through the food chain with the potential to reach humans. The oil dispersants used in the accident are harmful to marine and coastal systems such as sea grass, mangroves, coral reefs and fish spawning areas.

Transport: The transportation sector emits harmful pollutants including PM, nitrogen and sulfur oxides (NO_x and SO_x), carbon monoxide, as well as Green House Gases. The sector also is the focus of expanding servicing facilities such as garages, terminals and ports which produce petroleum and bilge wastes much of it released untreated to the environment.

Energy: Rayong generates around 20% of Thailand's electricity. The power plants emit various pollutants and GHGs into the air. The main fuel for the sector is gas from the Gulf of Thailand. This source is high in mercury, which poses a number of environmental concerns including emissions to air and mercury content in seafood in Rayong.

Urban development: Expanding urban development in Rayong has been linked to raised air and water temperatures and waste-water contamination and concentration, with most sewage released to the environment untreated. Most solid waste in the Province is sourced from urban and industrial areas.

Water resources: Water management and demand has resulted in fundamental hydrological changes in Rayong. These include the construction of four water reservoirs, which alter natural water flows, and involve inter-basin pumping of water between reservoirs in Rayong as well as north-west up to Chonburi. The quality of water provided from reservoirs to industry and domestic consumers is reported to be good (interviews with East Water May 2019).

Agriculture: Agricultural chemicals including pesticides and fertilisers, and increasing sediment loads have been identified by the Regional Environment Office as increasing problems for rivers, canals, wells and other water bodies including coastal waters. The concentrations and dispersal of agricultural chemicals in water is not well monitored or studied.

3. Overall context

Until the early 1980s, agriculture was the mainstay of the Rayong economy. The discovery of abundant natural gas deposits in the Gulf of Thailand, combined with Thailand's pursuit of economic growth, led to industrialisation in eastern seaboard provinces, especially in Rayong. That change in economic activity signalled a steady deterioration of environmental quality in the province. According to the Eastern Economic Corridor (EEC) Environmental Management Plan (MONRE, 2019), coastal and riverine waters are heavily polluted, with increasing air pollution associated with industrial areas. For example, monitoring in the Map Ta Phut area showed 3 types of benzene 1,3 n associate and 1,2 - chloromethane exceeded the standards as did ozone and dust. This reporting is not consistent with advice from the Department of Marine and Coastal Resources which emphasized that coastal waters were of good quality.

Trends in solid waste management are showing some improvement. For example, MONRE found that 61% of solid waste generated in Rayong is now reused or disposed of in the correct way, reflecting the national government emphasis on effective solid waste management through the 3 "R" approach – reduce, reuse, recycle. Even so Rayong is approaching its landfill and storage capacity for solid and hazardous wastes requiring a major investment and innovation in its management strategy. The national Power Development Plan (PDP) for 2018-37 calls for investor participation in waste-to-energy power projects, setting a goal of 500 megawatts, representing 30% of total renewable resources by 2037.

4. Environmental quality projects

- A feasibility study and detailed wastewater collection and treatment system design for Pluak Daeng (960 Million Baht). This was rejected for the 2021 budget year because documentation was incomplete. It is under consideration for the 2022 budget year (interviews, Regional Environment Office, Chonburi)
- A feasibility study and detailed wastewater collection and treatment system design for eight sub-districts in Rayong district (1,400 Million Baht). Because of incomplete documentation, this project was rejected for the 2021 budget year, and is under consideration for the 2022 budget year (interviews, Regional Environment Office, Chonburi).
- Promotion project for coastal tourism in Rayong, Klaeng and Ban Chan districts (256 Million Baht)

5. Key stakeholders

- Provincial Environment Office
- Regional Environment Office
- Town and Country Planning

¹ Jana Tremlová, 2017, Mercury in Fish from Industrial Sites in Thailand, creating Transparency in Industrial Pollution Management through Citizen Science Project, European Union (EU)

² EECO, 2018

- Provincial administration
- Industrial estates and the businesses within them;
- Small power producers, (and maybe Very Small Power Producers) in Rayong
- Rayong Provincial Energy Office
- Provincial Electricity Authority / Electricity Generating Authority of Thailand
- Ministry of Energy and Energy Policy and Planning Office
- Map Ta Phut port

6. Key government targets that influence the environmental sector in Rayong

EEC Environmental Management Plan (2018 – 2021): In November 2017, Thailand's Minister for Natural Resources and Environment (General Surasak Kanchanarat) appointed a committee with representation from various ministries to create an environmental plan for the three provinces in the EEC special economic zone. The focus of the plan is to address potential environment issues associated with the EEC prior to the full implementation of the EEC in 2023 (MONRE, 2019).

The Eastern Economic Corridor (EEC) development plan for Chonburi, Chachoengsao and Rayong provinces:

The plan envisages the expansion of the Map Ta Phut port facilities from 160 hectares to 320 hectares which will include 56 hectares for gas terminals and gas-related warehousing and businesses.² The plan also targets high-tech industries for Rayong, which are less polluting than the existing heavy industry (e.g. oil refineries, petro-chemical factories and gas separation facilities) that currently predominate in Rayong.

Small power producer (SPP) programme: First adopted in 1992 to encourage the development of private small fossil fuel (up to 90 MW) and renewables plants. Fossil fuel plants were restricted to those meeting conditions on cogeneration (at least 10% of waste steam energy used) and efficiency (greater than 45%), which were later relaxed. New legislation developed in 2007 to support smaller scale has also further promoted cogeneration plants.³

Power development plan 2018-2037: The share of renewables is targeted to increase from the current 8% of generation capacity up to 15 – 20% of generation capacity in 2036.⁴

Very Small Power Producer Programme: Regulations adopted in 2002 to allow renewables generators to export up to 1 MW to the grid and to offset their consumption at retail rates.⁵

7. Past trends and current situation

- ✓ Hazardous waste (increasing load, accumulating at central transfer centre, lack of proper decommissioning of factories and management of hazardous sites)
- ✓ Solid waste (limited landfill + importing of waste from neighbouring areas, illegal dumping)
- ✓ Water quality (lack of sewerage treatment, Rayong river water quality is at critical level)
- ✓ Air Quality (emissions from transport and industry)

Lack of traction for environmental plans

According to the Regional Environment Office in Chonburi, there are reporting line problems that have impacted on the uptake of their recommendations to improve environmental outcomes in Rayong. First, provincial environment offices report to the same permanent secretary as the Regional Environment Office, but the reporting lines are separate, which hampers coordination and cooperation between the regional and provincial levels. Second, provincial administration offices view regional environment offices as problem solvers – an office to call when there is an environmental crisis, rather than as agencies that have a key role in planning processes and management priorities. Thus, provincial governments tend to deal with the provincial level offices limiting the potential for coordinated technical support in environment management plan preparation and implementation.

The result is that, although the Regional Environment Office in Chonburi prepares environmental plans to remedy environmental problems, provincial administrations tend not take them on board in their provincial development plans. In part, this may be due to a lack of involvement in the preparation of the plans – but also it relates to the challenges provincial governments face in accessing funding from MONRE in support of environmental plan implementation. In order for a provincial administration to implement the plans, they need to prepare funding proposals for submission to MONRE. However, capacities are not always in place to develop and follow through on these proposals (interviews, Regional Environment Office, 2019).

³ Greacen, C., 2007, An emerging light - Thailand gives the go-ahead to distributed energy. Power Engineering International website. Retrieved from <https://www.powerengineeringint.com/articles/decentralized-energy/print/volume-8/issue-2/features/an-emerging-light-thailand-gives-the-go-ahead-to-distributed-energy.html>

⁴ Bangkok Post, 25 January 2019, National power plan expands private output. Website retrieved from <https://www.bangkokpost.com/business/news/1617382/national-power-plan-expands-private-output>

⁵ Footnote 6.

Table 14-1: Percentage of Map Ta Phut coastal water samples outside standards

Water quality parameter	2015	2016
Dissolved oxygen (DO)	35%	53%
Biochemical oxygen demand (BOD)	81%	98%
Total coliform bacteria (TCB)	74%	80%
Faecal coliform bacteria (FCB)	85%	76%
Nitrate (NO ₃ -)	3%	3%
Ammonia (NH ₄ +))	33%	37%
Arsenic (As)	36%	39%
Manganese (Mn)	4%	4%
Lead (Pb)	3%	

Source: PCD

Table 14-2: Percentage of Map Ta Phut coastal water samples outside standards

Sea water quality parameter	2015	2016
Phosphate (PO ₄ ³⁻)	10%	38%
Nitrate (NO ₃ ⁻)	21%	
Total coliform bacteria (TCB)	2%	24%
Fecal coliform bacteria (FCB)		5%
Manganese (Mn)	2%	
Iron (Fe)	2%	

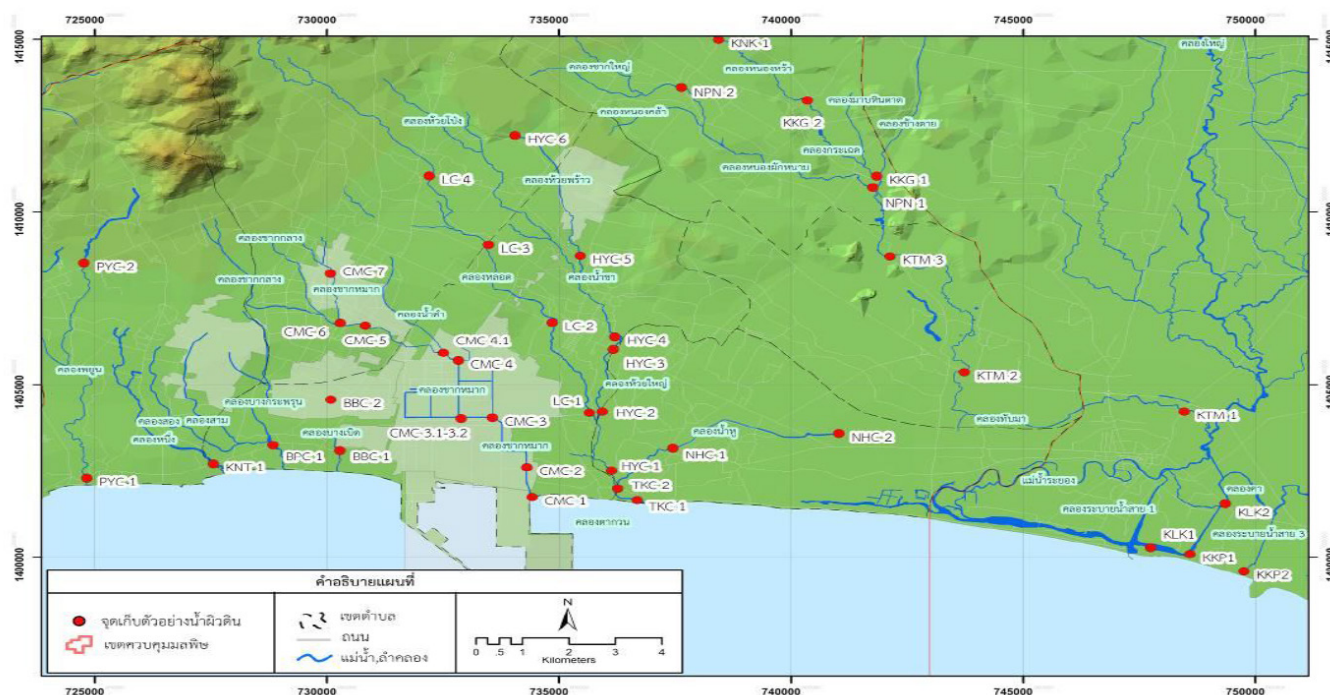
Source: PCD

Water Quality

The Pollution Control Department (PCD) monitors surface water quality across the province (Figure 14-1). Time series data is not available on surface water quality, however data from 2015 to 2016 from 79 sampling points monitored by PCD shows there was a general decrease in water quality across a broad range of parameters (Table 14-1). Organic pollutants exceed permitted standards in surface water. Untreated domestic waste-water is the main cause of poor water quality in the Rayong River and canals (interviews, Regional Environment Office).

Untreated domestic waste-water is a critical issue for Rayong. The province has three waste-water treatment facilities that have theoretical capacity to treat around one third of provincial domestic waste-water. However, these systems are operating collectively at around 7% of their capacity.⁶ Many households are not connected and disputes over the original design and siting has meant that local authorities have been reluctant to seek the needed funding for operations and maintenance. Now the plants are degraded and in need to major rehabilitation. Plans are underway to provide those upgrades over the next few years – but the issues of ongoing costs and local management capacities still need to be resolved. Further, while houses not connected to the sewer are required to have a septic system, these are frequently non-functional, and many older houses pass raw sewerage directly to the environment. Some confusion over local bi-laws and challenges in enforcement compounds the problem. For example, some residents and small commercial outlets take the view that only grease traps are required by law (interviews, Regional Environment Office).

Figure 14-1: Surface water quality sampling location by PCD



Source: PCD

Industries are also impacting on water quality. Yet, there are a number of issues that constrain action to address the problems. First, pollution monitoring and control is driven by ambient water pollution standards for industry. Ambient air and water quality standards are levels of pollutants that are officially permitted in the receiving air or water. They are challenging to apply and depend on a credible understanding of carrying capacity of receiving bodies. Individual factories may be within point source standards but collectively take receiving bodies beyond their sustainable limits. The air and water pollution situation in Rayong Province requires application of point source standards for industry and other polluting sectors, as well as ambient standards.

Second, enforcement is not supported by adequate financial incentives. A maximum fine for discharging effluents beyond standards is only 5,000 Baht (~USD\$160) per day. To date, few industrial polluters have been fined – they are handed on to the Department of Industry and Works for negotiated settlements. Only local scale piggeries tend to be caught with fines based on community complaints. When dealing with thousands of industrial and commercial enterprises complaints from the public tend to be the main trigger for investigation and control (interviews, Regional Environment Office, 2019).

Coastal water near Map Ta Phut

PCD monitors water quality around Map Ta Phut Port (Figure 14-2). The number of sampling points changed from 2015 to 2016 (from 42 to 21). This raises the concerns regarding repeatability of results, which show large fluctuations (Table 14-2). In addition to these specific measurements, PCD has found the inner Gulf of Thailand to be the most polluted of Thailand's coastal waters.⁷

Sub-surface water quality

PCD has begun monitoring sub-surface water quality, which, over 2015- 2016, varied with depth. Deeper monitoring wells detected levels of iron, manganese, lead and arsenic above national standards, while from shallower wells several VOCs were also detected. The monitoring has all be done in the vicinity of the Map Ta Phut industrial area, because of the PCD pollution control zone covering that region (Table 14-3).

Lower Rayong surface water quality has been poor for at least a decade, with domestic sewage as a leading factor in deteriorating water quality.⁸ That problem has reached critical levels due to increasing populations and densities. In agricultural areas, ammonium is a common pollutant and an indicator of pollution from fertilisers (interviews, Regional Environment Office, 2019).

Figure 14-2: Water quality sampling points around Map Ta Phut Port



Source: PCD

⁶ Pollution Control Department, 2017, Environmental situation in eastern region 2016, <https://drive.google.com/file/d/0Bws-qTXZ5yY2aDB1RHh5MWY4Rm8/view>, accessed 29 May 2019

⁷ http://infofile.pcd.go.th/mgt/PollutionReport2015_en.pdf

⁸ http://infofile.pcd.go.th/mgt/PollutionReport2015_en.pdf (the details in this publication were further substantiated by interviews, conducted at the Regional Environment Office, at Map Ta Phut Municipality, and with PCD).

Table 14-3: Percentage of shallow and deeper samples not complying with standards

Shallow underground water quality parameter	2015	2016	Underground water quality parameter	2015	2016
Iron (Fe)	29%		Iron (Fe)	88%	75%
Manganese (Mn)	13%	19%	Manganese (Mn)	50%	50%
Lead (Pb)	1%		Lead (Pb)	38%	50%
Arsenic (As)	25%	22%	Arsenic (As)	25%	25%
1,2 Dichloroethane	2%	2%			
Carbon tetrachloride	2%				
Tetrachloroethylene	1%				
Trichloroethylene	2%	2%			

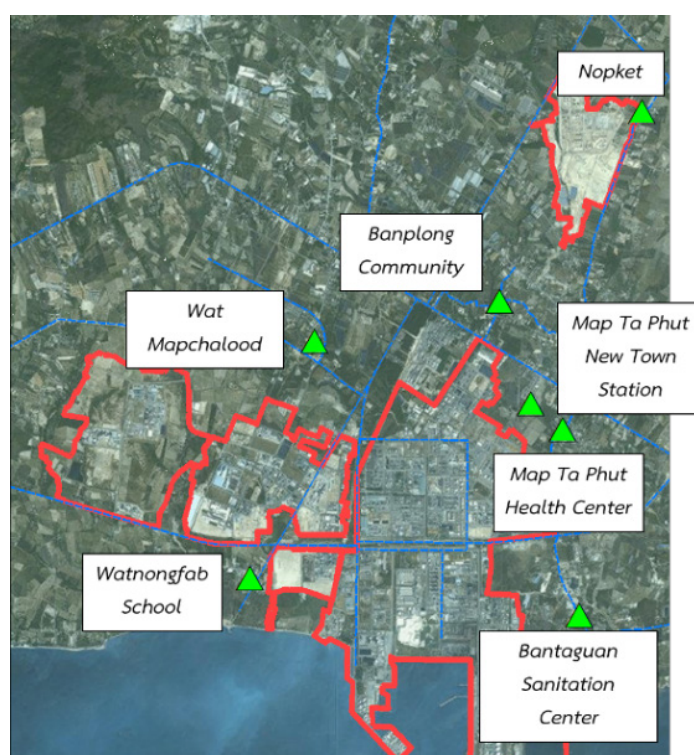
Source: PCD

Air Quality

The main sources of air pollution in Rayong province are traffic (road and sea) and industry. Traffic pollution is increasing, despite the tightening of national emissions standards. The government does have national policies promoting a modal shift in transport away from road traffic to rail traffic, and in line with this the EEC development plan includes the construction of a double track freight line between Map Ta Phut Port and Bangkok, as well as a high-speed passenger rail system linking U-tapao Airport with Suvarnabhumi and Don Mueang airports.

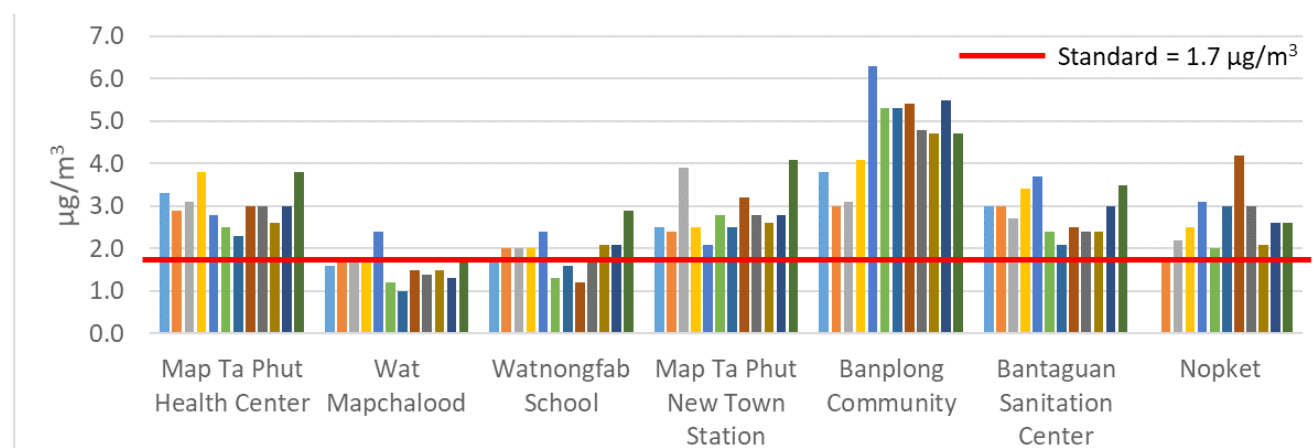
Traffic-related emissions are analysed in the transport baseline assessment report. Data was only available from 2008 to 2015 and trend line analysis is not strong. However there is an indication of a general increase in emissions of carbon monoxide, particulate matter and nitrogen oxides. Industry analysis is based on data gathered by the Pollution Control Department, which has focused on the pollution control zone around Map Ta Phut industrial area. PCD is not able to measure point source pollution at individual factories within industrial estates. That responsibility rests with the Industrial Estate Authority of Thailand (IEAT), which manages individual estates in Rayong. PCD measures ambient levels of air pollution once a month at seven different stations around the industrial zone (interviews, Rayong Provincial PCD Office). Figure 14-3, shows the locations of the seven air monitoring stations, and Figure 14-4 the average annual results for benzene from each station over the period 2007 – 2018.

Figure 14-3 Location of air monitoring stations for volatile organic compounds by PCD



Source: PCD

Figure 14-4: Annual average atmospheric concentrations of Benzene around the Map Ta Phut industrial area 2007-2018



Atmospheric concentrations in the vicinity of Map Ta Phut routinely breach the national standard. The results for other VOCs show similar pollution levels. Despite national legislation to encourage emissions reductions (the 80:20 trading and offset scheme⁹), emissions of VOCs show an upward trend at most stations (Figure 14-4). Three VOCs – Benzene, Butadiene and Dichloroethane – were found to be consistently above national standards in Map Ta Phut and nearby areas (Figure 14-5).

Solid and Hazardous Waste

Municipal solid waste is reported on in the urban development baseline assessment. In summary, around 1,000 – 1,200 tons per day of solid waste are received at waste transfers centres in Rayong each day, including 400 – 500 tons daily from Pattaya City (interviews, Regional Environment Office, 2019). Nationally solid waste generation has been increasing close to 2% each year. Rayong's waste transfer centres include a secure temporary storage site for hazardous waste, however this storage site is close to full capacity. One challenge is the inability to sort waste fast enough at the transfer centres in Muaeng Rayong and in Klaeng. Thus, waste, including hazardous waste, is accumulating in these centres. Ideally there would be source separation of waste at the household, commercial enterprise and factory level. When waste is separated at source, garbage collection often mixes the wastes again (interviews, Regional Environment Office, 2019).

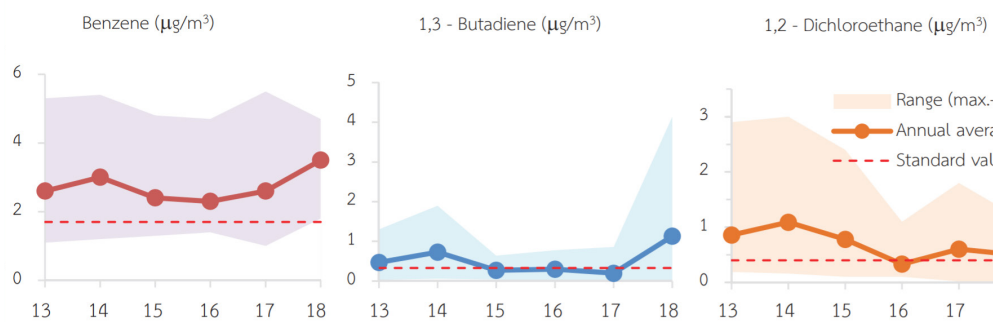
Rayong solid waste reflects the national breakdown including plastic bags (18.9 per cent), plastic beverage bottles (8.6 per cent), plastic shopping bags (8.4 per cent), foam plates and bowls (6.96 per cent), straw and swizzle sticks (4.6 per cent)

and plastic cups (3.6 per cent). As of this year, the Regional Environment Office does have a small budget for promoting source separation of waste, however it is only enough to work with 10 communities annually. And nationally in 2019, the Prime Minister Prayut Chan-o-cha, launched the 'Thailand Public-Private Partnership for Plastic and Waste Management' initiative which could see additional resources for managing Rayong's solid waste challenges. Solid waste management remains a problem across the EEC.

Solid waste in Rayong includes hazardous and non-hazardous waste. Figure 14-6 shows the non-hazardous waste received by waste disposal centres in the EEC over the period 2015 – 2017. Until 2017, Rayong Province was generating and collecting 30-50% more solid waste than Chonburi and Chachoengsao. In 2017, Chonburi and Rayong had similar levels of collection. However, the Regional Environment Office in Chonburi, and others, have reported that around 400 – 500 tonnes of solid waste is imported into Rayong from Pattaya city each day. The city no longer has the capacity to deal with its waste effectively (interviews, REO, May 2019).

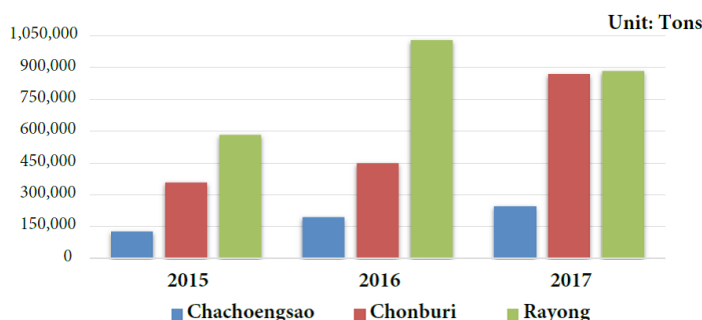
The pollution data for Rayong tends to lack precision. Figure 14-6 adapted from the Department of Public Works suggests Rayong is generating around 900,000 tons of non-hazardous solid waste a year. Yet, 2019 data from the Regional Environment Office suggests that in Rayong industry alone is generating around 6,300 tons per day or 2,300,000 tons per year in Rayong Province. Hazardous wastes make up around 2,300 (37%) or 840,000 tons annually. As a proportion of total pollution load, hazardous wastes are increasing. Figure 14-7 shows that almost one third of solid waste is improperly disposed of and that, despite the national 3Rs program, only about 7% of solid waste is recycled in Rayong Province.

Figure 14-5: Concentration of Benzene, 1, 3-Butadiene, and 1, 2-Dichloroethane in the atmosphere in Map Ta Phut and nearby area, Rayong province



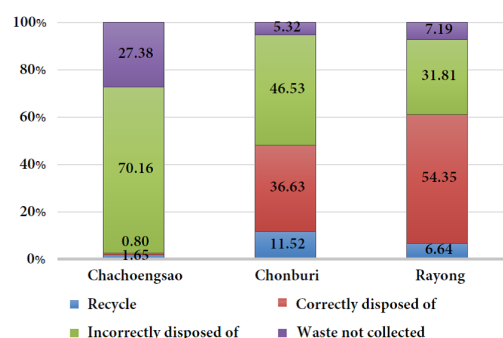
Source: MONRE Pollution Control Department, 2019, Thailand State of the Environment 2018

Figure 14-6: Non-hazardous waste received by EEC disposal centres (2015 - 2017)



Source: Adapted from Department of Industrial Works's website, 2017

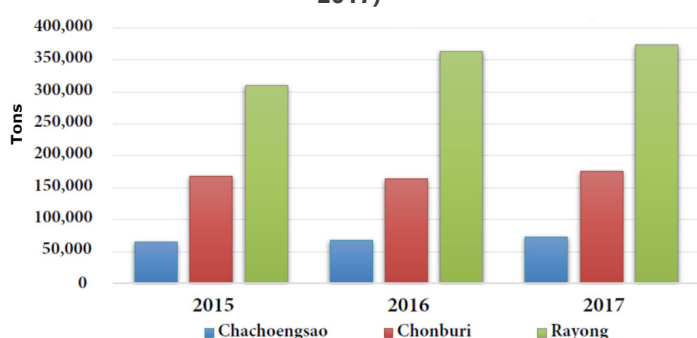
Figure 14-7: Solid waste management in EEC provinces leaves much waste improperly disposed of or treated



Source: Regional Environmental Office 13 (Chonburi), 2016: Environmental Quality Situation Report in Eastern region

Hazardous waste comes predominantly from Map Ta Phut industrial area and from the 40% of factories located outside of estates.¹⁰ Disposal is managed by private companies which are licenced to deal with hazardous substances. Some waste is transported out of Rayong for incineration although the arrangements for the most appropriate treatment are not yet settled. The remainder is sent to secure landfill sites. While the Department of Industrial Works has responsibility for oversight of hazardous waste disposal, the Regional Environment Office plays a role in advising which companies are suitable for disposing of each category of hazardous waste (interviews, Regional Environment Office, 2019). Hazardous waste is a growing issue across the three EEC provinces, and particularly in Rayong, as shown in Figure 14-8. Yet, more recent data is showing that much higher quantities of hazardous wastes are generated in the province. These discrepancies in data magnify the challenges of managing waste-streams in Rayong and the other EEC provinces.

Figure 14-8: Hazardous waste by province in the EEC (2015 - 2017)



Source: Adapted from Department of Industrial Works's website, 2017

Contaminated sites

Another growing waste challenge relates to factories that have closed down. According to the Regional Environment Office, many of these factories are not satisfactorily decommissioned, and hazardous wastes and chemicals remain in the buildings and grounds without clear responsibility for clean-up. Pollutants can leach into the ground, groundwater and surface water bodies. There have been incidents of fires leading to hazardous emissions.

With increasing transport of hazardous materials into and within the province, the potential for accidents is growing. The major oil spill in 2013 was referenced earlier. In May 2019 a container caught fire in Laem Chabang Port, Chonburi Province. It was in a cargo ship and contained unregistered calcium hypochlorite. It took 18 hours to put out the fire, and over 200 people were admitted to hospital with burns, eye irritations and breathing difficulties.¹¹ In an intensely developed industrial and transport hub, accidents of this kind can only be avoided through rigorous enforcement of standards and operating procedures.

8. Future trends without the Rayong Provincial Development Plan

- ✓ Hazardous waste
- ✓ Solid waste
- ✓ Water quality
- ✓ Air Quality

Governance

There is unlikely to be substantial advances in having environmental action plans developed at the regional level gaining more traction with provincial and sectoral authorities operating in Rayong. An important opportunity exists with the MONRE EEC environment plan being picked up and integrated into the next Rayong Provincial Development Plan to be revised over the next two years. That would require a concerted collaboration between many agencies at national, region and provincial level. It would need to come with a strong commitment at national level to provide the budget for implementation unencumbered by complicated disbursement procedures which make it difficult for Rayong Authorities to access. Also, it would require a significant increase in local government capacities to manage and enforce environmental measures, development controls and safeguards. The challenge of having the national, regional and local environmental authorities limited to monitoring and reporting functions while relying on other agencies to respond and enforce will continue for the foreseeable future. It is a significant impediment to improving environmental quality in Rayong Province, as is the lack of a system of area wide and site/plant specific environmental management plans which are strongly enforced.

Solid and hazardous waste

Solid waste management will be an increasing problem in Rayong as industry and urban areas expand and populations grow. Nationally, between 2016 and 2017, the PCD reported that hazardous waste increased by 28 percent. That trend is accentuated in Rayong Province – the most important industrial, transport and energy hub in the country. Management of the central waste transfer station is described as being weak, processes are not quick enough to keep up with waste generation, land fill site are full and current efforts to implement source separation have been small in scale, and have met with resistance both from households and from garbage collectors. Despite these problems, Rayong also receives 400 – 500 tons of MSW each day from Pattaya City, an import likely to grow before it is

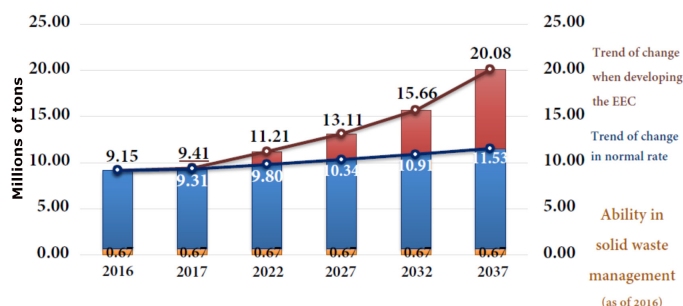
⁹ The 80:20 offset scheme works when new companies begin operating in an area. For example, if a new project will emit 80 tons/hr of SO₂ or NO_x, the new project has to find a partner or partners in the Map Ta Phut area to reduce existing emissions of the concerned pollutant by 100 tons/hr to offset the emissions added to the area by the new project. This means that the cumulative emissions including the new project will be reduced by 20 tons/hr.

¹⁰ Department of Industrial Works, 2019

¹¹ https://thethaiger.com/hot-news/environment/just-how-many-hazardous-chemicals-are-going-through-laem-chabang-port?utm_source=Mekong+Eye&utm_campaign=bc934e1278-EMAIL_CAMPAIGN_2018_01_10_COPY_01&utm_medium=email&utm_term=0_5d4083d243-bc934e1278-380870845

resolved. This trend highlights a broader problem in the eastern region of an increasing solid waste loading – with hazardous wastes a growing proportion of the total. Rayong is unlikely to be able to solve its own waste management issues by exporting waste to neighbouring provinces. The urgency of this management challenge is highlighted in Figure 14-9, which shows current management capacities and projected solid waste production in the EEC up to 2037.

Figure 14-9: Projected solid waste trends in the EEC (2017 - 2037), with current management capacities



Source: MONRE 2019

Hazardous waste as a growing proportion of total load is of particular concern because of the slow separation of waste in the central transfer station and the lack of a clear management arrangements for registration and disposal. Rayong has no hazardous waste incineration capacity and the increasing incidence of illegal disposal are poorly reported and resolved. The secure storage areas for hazardous waste is at capacity (interviews, Regional Environment Office, 2019).

Hazardous waste is managed by private companies, and what is not exported out of Rayong for incineration is sent to secure landfills in the province. There is a risk of spillage (for example because of vehicular accidents), and risks of illegal dumping. Nationwide, in 2016, 1.9 million tons of hazardous industrial waste was unaccounted for after leaving the factory gates.¹² Illegal pits for disposal of hazardous wastes are wide spread in Rayong province. The inadequate management and treatment of hazardous wastes in Rayong is reaching a critical level.

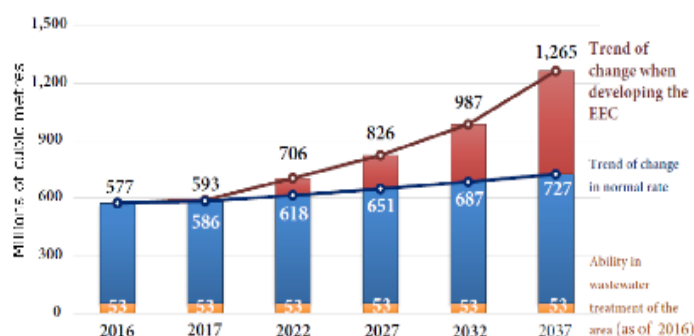
Water quality

Poor water quality will continue to be a serious issue for Rayong without concerted action from all levels of government. Major challenges include the lack of wastewater treatment facilities, lack of budgets and local capacities for operating existing facilities, lack of piping to pollution sources, and a lack of capacity and authority to inspect and ensure that factory waste treatment facilities and domestic septic systems are operating properly. These factors are highlighted in Figure 14-10, which shows projected wastewater production in the EEC to 2037. In the next 20 years, waste water load will double in EEC provinces if planned developments go ahead.

It can be anticipated that industry will become more compliant with waste water legislation, especially as new

industries develop under more rigorous environmental and development controls. A key issue will be improving environmental performance in existing operations. Pollution legislation needs to be revised to tighten incentives for good performance and increase monitoring and enforcement capacities with environmental and local agencies. There will be ongoing challenges in managing industry following ambient effluent standards and then negotiating reductions in point source contributions when those standards are exceeded. Ideally, Thailand would introduce a dual system of point source and ambient standards targeting those sectors with the greatest potential for serious pollution loads and toxicity. Industries with high toxicity and high load effluents are expanding in Rayong. They are linked to a wide range of petro-chemical processes as well as leather or paper manufacturers for example. Levels of heavy metals around recycling plants and smelting plants and within land fill leachates is a potential serious problem which is not well studied. The condition of river and canal water quality is continuing to degrade.

Figure 14-10: Projected waste-water treatment volumes (2017 - 2037), and current management capacities



Source: MONRE 2019

The number of industrial operations, and the number of people living and working in Rayong will grow significantly over the next decade. This will put additional pressure on waterways and on water quality. Water quality is likely to deteriorate further in Rayong before adequate management systems are implemented. Some studies have drawn similar conclusions for coastal water quality, given trends between 2006 and 2015.¹³ Certainly, pollution hot spots in coastal areas due to concentrations of point source effluents are more likely to expand than reduce in the current planning period.

Air quality

The main drivers of air quality are:

- Number of vehicles on the roads and variable compliance with emissions standards
- The expansion of heavy industry and variable compliance with standards
- The number of tankers and cargo vessels using Map Ta Phut port with limited environmental controls

¹² OECD, 2018, Development Pathways Multi-dimensional Review of Thailand; Thai Government, Department of Industrial Works, 2019

¹³ MONRE, Pollution Control Department, 2016, Pollution Report 2015, http://infofile.pcd.go.th/mgt/PollutionReport2015_en.pdf

¹⁴ <https://www.bangkokpost.com/news/environment/1676592/a-clear-path-to-cleaner-air->

¹⁵ <https://www.eeco.or.th/en/project/infrastructure-development/map-ta-phut-port>

The number of vehicles in Rayong will continue to increase. Because of expansion of the rail network: both the planned double track line to Map Ta Phut port and the high speed link to U-tapao Airport, the increase in road transport may plateau in the long term. Details on the change in freight capacity as a result of the double track rail link are not available, but some estimations about the number of vehicles that the high speed rail link will replace are included in the transport baseline assessment. Despite these counter-trends there will still be a significant increase in the number of vehicles over the next decade. The emissions from vehicles should decline over time because, for example, over the next three years, Thailand is expected to tighten emissions standards from the current Euro III (heavy vehicles) and Euro IV (light vehicles) to Euro VI for all vehicles.¹⁴

Map Ta Phut Port has the capacity for around 15,000 vessels annually, and with the planned upgrades for enlarged liquid natural gas importing (see energy baseline assessment),

this number will grow. In 2016, 43 million tons of shipments passed through Map Ta Phut Port, and the phase III expansion of the port under the EEC will see that capacity grow by a further 19 million tons of petrochemicals and natural gas.¹⁵ The upgraded port facilities will have the capacity for around 21,000 vessels through each year. This will increase air pollutants from shipping substantially, with local effects being particularly predominant during the wet season when prevailing winds come from the south-south-west (Saeaw & Thepanondh, 2015). It also has the potential to increase the incidence of spills and accidents.

Under the EEC plan, the focus of industrial development is intended to be on lower polluting high technology industries. In addition to strategies such as the 80:20 scheme, Thailand has targets under the UNFCCC to reduce greenhouse gas emissions and increase renewable energy in its power generation mix. With Rayong contributing around 20% of Thailand's power generation capacity, these factors make for a counter-trend against rising industrial emissions.

9. References

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STRATEGIC THEME: CLIMATE CHANGE

Image: Jittrapon Kaicome

1. Scope

This baseline assessment describes the historical incidence of natural disasters and past climate changes in Rayong Province and surrounding areas and projected changes to climate to 2050. The Province has experienced frequent drought and flood events, as well as coastal erosion and sea level rise. Climate change projections to 2050 indicate more severe dry periods during the dry season and potential for more intense, extensive and frequent flooding during the wet driven by catchment wide rainfall, storm surge and mounting sea levels. The analysis provides information on natural disasters and climate change as a basis for assessing their potential impacts on Rayong province and the adaptation measures required as part of its development strategy. It does not consider the contribution to climate change of industry and development sectors in Rayong and associated mitigation responses.

2. Overall context

Rayong Province is defined by two river basins running north to south to the Gulf of Thailand – the Klong Yang (or Rayong River) and the Presae River (Figure 15-1). The basins are bounded by hilly areas in the west, centre and east of the province. Rayong's main reservoirs are located in the upper reaches of those rivers which both have their source in neighboring Chonburi Province. The management of those resources by the Royal Irrigation Department and the private sector entity – East Water – has fundamental implications for the nature and extent of development in Rayong Province, as well as the quality of life. The province has a growing population with increasing densities and within the next decade 50% likely to reside in urban areas and most close to the coast and along the river corridors. Already public services such as health, education, sewerage and waste treatment is failing to meet demand.

Industry is expanding in terms of production and area occupied with increasing concentrations in industrial estates – but many plants are still operating outside. Their water, energy and materials demand is increasing leading to a growing dependency on road and sea transport and distribution systems to keep supply chains open.



STRATEGIC ISSUES OF CRITICAL CONCERN FOR SUSTAINABLE DEVELOPMENT IN RAYONG

- ✓ Increased temperature and reduced rainfall in dry season leading to increased drought conditions
- ✓ Increased flooding in wet season due to (i) increased intensity of rainfall and storm surge, and (ii) sea level rise
- ✓ Increased number of hot days
- ✓ Increased intensity of storms and winds

SUSTAINABLE DEVELOPMENT OBJECTIVES*

- ✓ Enhance capacities to adapt to climate change;
- ✓ Rayong Province, the EEC and sector agencies operating in Rayong prepare climate change adaptation plans and allocate budget for their implementation

Investment in transport infrastructure and stock is one of the highest development priorities in the province and related sectors, in anticipation of and to support growing industrial requirements.

The province is a national energy hub – driven by offshore natural gas – and by increasing power demand nationally and within Rayong as part of the Eastern Economic Corridor special economic region. The province has a combination of extensive decentralized power sources linked to industrial estates and centralized facilities such as ports, large power plants and transmission to feed the national grid. The energy and industry sectors are the drivers of Rayong's development and position as the highest provincial GDP per capita in the country. Against that intensive development transformation, the agriculture sector is struggling to find its place. Still occupying most of the province, traditional agriculture is becoming less economic and uncompetitive – but with important cultural and heritage values which need to be maintained.

It is against this dynamic backdrop, that climate change is projected to bring substantial pressures on all sectors and areas within the province, requiring significant adjustments and investments to build resilience and to reorient development to reflect a changing resource base and conditions. To date, there has been very little attention given to climate change in Rayong – or even within the wider EEC – the issue being left to national level agencies to address. The Office of the National Economic and Social Development Council (NESDC) and the Office of Natural Resources and Environment Policy and Planning (ONEP), have promoted climate change mainstreaming into planning and budgeting functions of government through the Twelfth National Economic and Social Development Plan (NESDB) (2017-2021), Thailand's Climate Change Master Plan (2015-2050) and the National Adaptation Plan (2015-2023). Yet, those important initiatives have not been expressed effectively in the Rayong Provincial Development Plan or within plans and budgets of sectors operating within the province in terms of adaptation strategies. The national effort too has focused more on mitigation of greenhouse gases than adaptation to projected climate changes and sea level rise.

The Regional Environmental Office (REO) is responsible for breaking down the national climate policy framework into the regional context, guiding provincial planning officials on climate policy integration and ensuring the local context and climate change aspects are considered. Yet the REO in the Eastern Seaboard region reported that provinces and sectors operating within their borders were not taking the REO's regional environment management plan, including climate

change adaptation, seriously or seeking to implement it as an integral part of their development plans (see the SEA environmental quality baseline assessment).

3. Climate change projects

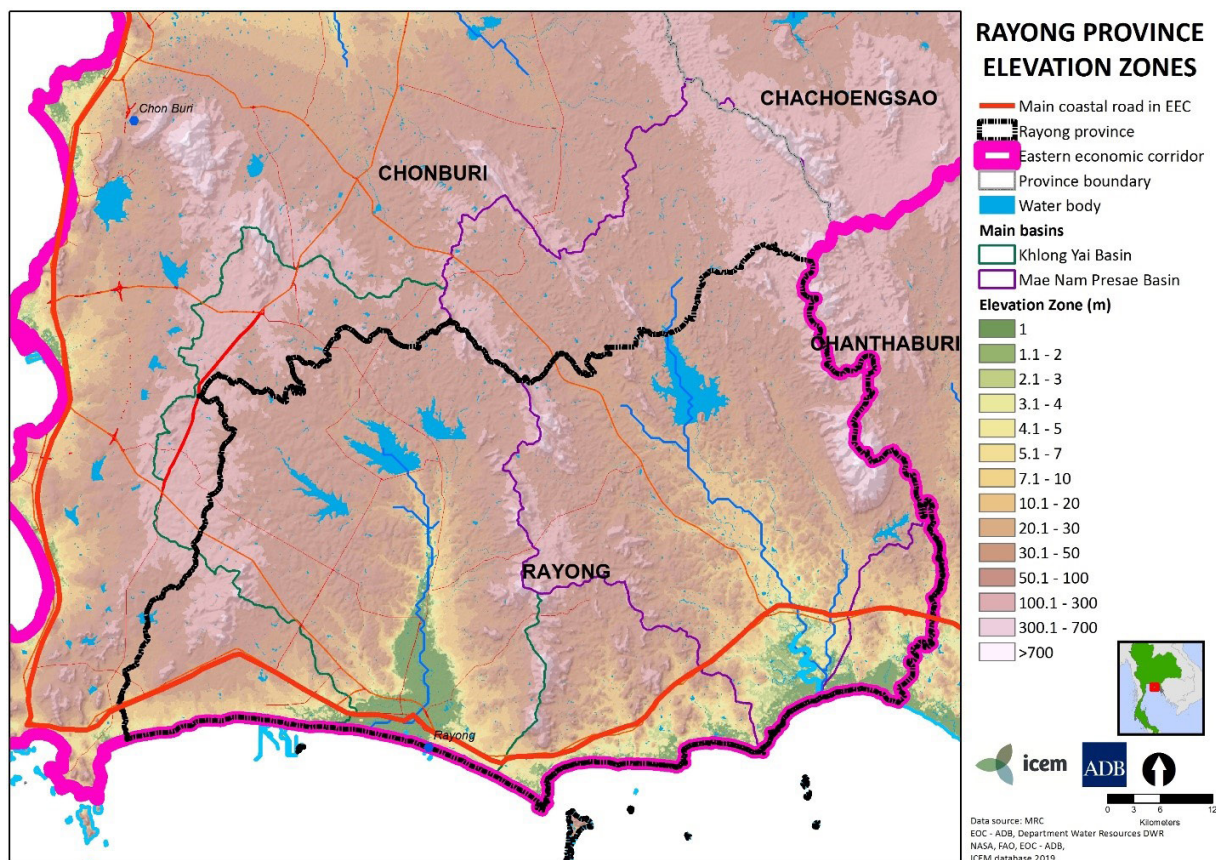
The current Rayong Provincial Development Plan includes several small climate change adaptation projects relating to awareness raising and mangrove rehabilitation.

The German supported Climate Policy Project (2018-2021), has the goal of helping all 77 provinces in Thailand take into consideration climate change impacts and integrates climate policy into their development planning.

4. Key government stakeholders

- National Climate Change Committee
- NESDC
- Office of Natural Resources and Environmental Policy
- Eastern Economic Corridor Office
- Regional Environment Office
- Provincial Environment Office
- Pollution Control Department
- Department of Public Works and Town & Country Planning
- East Water
- Rayong Governor's Office

Figure 15-1: Rayong province topography



5. Key government policies and plans that influence response to climate change in Rayong

Thailand's Climate Change Master Plan (2015-2050) (CCMP): was developed by the ONEP, under the direction of the Ministry of Natural Resources and the Environment as a framework of integrated policies and action plans relating to climate change. The plan lays out a vision to achieve climate-resilient and low carbon growth in line with the SDGs by 2050. In 2015, Cabinet approved the CCMP in which adaptation is one of the three principal components. The plan's adaptation measures relate to six sectors - water management, flood and drought; agriculture and food security; human health; tourism; natural resources, and human settlements and security.

The next policy layer - **Thailand's National Adaptation Plan (2015-2023)** provides more detail on those themes, focusing on water resource management, ensuring food security, sustainable agriculture, managing health impacts of climate change, marine conservation and coastal rehabilitation, increasing forest cover, biodiversity protection, sustainable tourism, and human security. The NAP's work plan – the Thailand Country Programme on Climate Change 2017, also picks up on those natural resource based themes. It is significant that this hierarchy of climate change policy and plans does not give priority to adaptation in the key development sectors of industry, energy and transport – instead with those solely through mitigation response. The assumption appears to be that mitigation within those sectors would also achieve resilience and adaptation to climate change.

NESDC has identified **nine other policy frameworks which address climate change priorities** (Figure 15-2). In those too, emphasis is given to mitigation. Despite this strong policy commitment to climate change at national level, the existing institutional arrangements and procedures for development planning and budgeting has meant that it has had little influence at provincial level and to sector and local development priorities on the ground.

Figure 15-2: Integration of Climate Change into Policies and Plans in Thailand



Source: NESDC, 2016

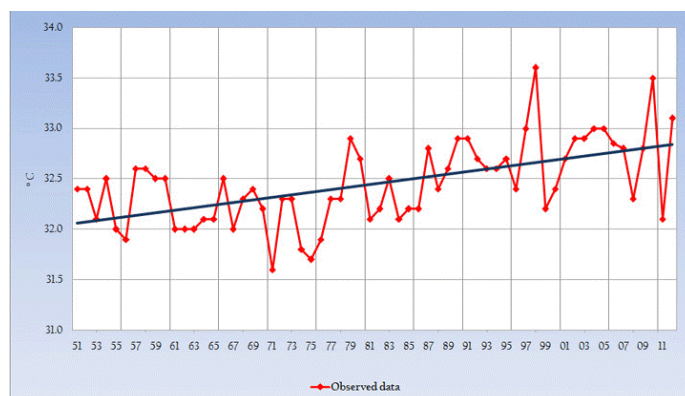
6. Past trends and current situation

Over the past 70 years, Rayong province has experienced increases in average temperatures and reductions in average rainfall, but with a higher incidence of extreme rainfall events leading to a more frequent floods and longer drought periods. Over the past 25 years Thailand has experienced higher rates of sea level rise than the global average which when combined with subsidence has created extensive areas at risk of erosion and flooding.

Temperature

Annual mean temperature anomalies indicate an increase in temperature by 1°C since 1951 in most of Thailand. The frequency of extreme temperatures has also increased since 1951, especially in coastal regions. In the year 2015, the annual mean temperature of 27.9°C indicated a 0.8°C increase compared to average temperatures. It was Thailand's second warmest year in 65 years record.

Figure 15-3: Annual mean maximum temperature in Thailand 1981 to 2012



Source: Thai Meteorology Department 2014¹

Rainfall

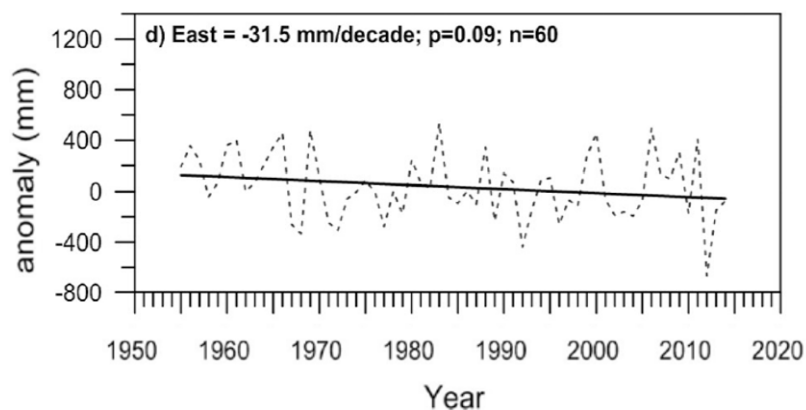
The late 1970s to the mid 1990 in Thailand experienced an unusual decade-long deficit in annual precipitation accompanied by a reduction of rainy days. From 1955 to 2014 the gauge stations with significant decreasing trends were generally located in East Thailand (Figure 15-4).² A similar trend for Thailand overall was found when figures are averaged (Figure 15-5). The main source of rainfall in the Eastern region comes from southwest monsoon which brings abundant rain during May to October with the number of wet days exceeding 10 days. The highest rainfall and wet days were in August at Khlong Yai with 1000mm and 25 wet days, respectively. The 40-year average of rainfall is 1921mm.³ Since 1955 the number of consecutive wet days each year in Rayong province has decreased.

¹ <https://www.tmd.go.th/en/climate.php?FileID=7>

² Atsamon Limsakul and Patama Singhruck, 2016, Long-term trends and variability of total and extreme precipitation in Thailand Atmospheric Research 169 (2016) 301–317

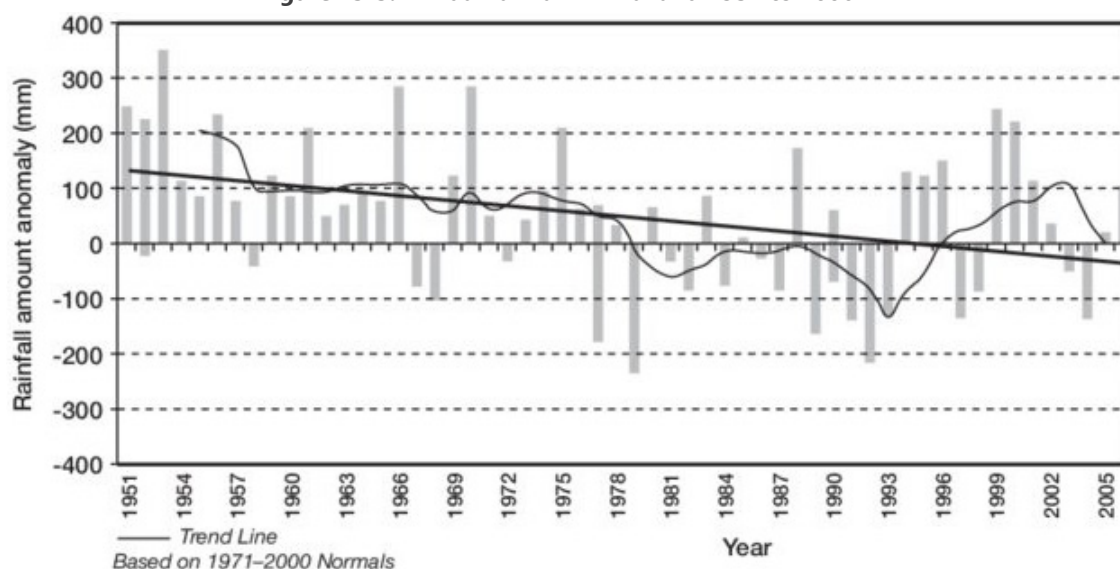
³ Wonlee Nounmusig, 2018, International Journal of GEOMATE, June, 2018 Vol.14, Issue 46, pp.150-155

Figure 15-4: Reduction in average annual rainfall from 2051 to 2014 in Eastern Thailand



Source: Atsamon Limsakul and Patama Singhruck, 2016

Figure 15-5: Annual rainfall in Thailand 1951 to 2006



Source: Danny Marks, 2011⁴

While precipitation has become less frequent in most parts of Thailand with a significant reduction in the occurrence of consecutive wet days, rainfall events have become more intense. Heavy rainfall events are contributing an increasing fraction of annual totals. There has been a greater risk of disasters associated with increased precipitation extremes, including coastal and flash floods. In 2011, when Thailand experienced the worst and most extensive flooding during the 60-year record examined, it was a year of exceptionally extreme precipitation events. The monsoon season in that year was the wettest on record.

The trends for frequency and intensity of storms is not

as clear. From 1951 to 2000 the significant decrease in September rainfall over Thailand was found to be related to a weakening trend of westward-propagating tropical cyclones over the Indochina Peninsula.⁵

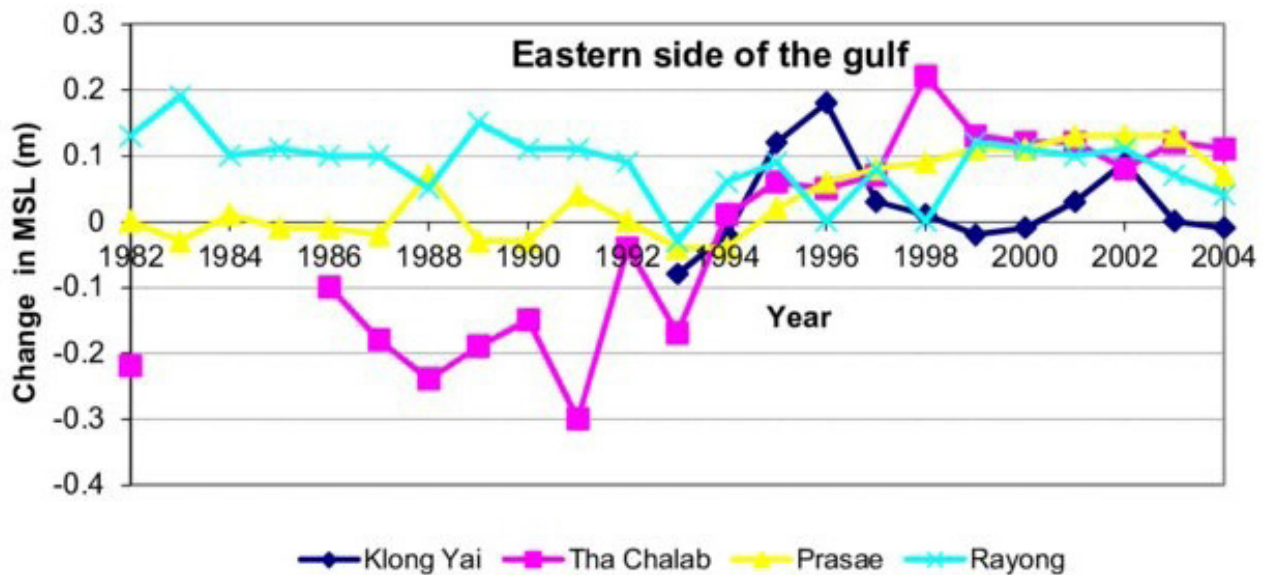
Sea level rise

The annual local mean sea level (MSL) at 13 tide gauge stations bordering the Gulf of Thailand in Thai waters was used to investigate sea-level rise over the last 25 years (1985-2009). Averaging the annual local MSL by region into a single time series revealed a linear trend for the sea-level rise of about 5 mm/yr over that period.

⁴ Danny Marks 2011, Climate Change and Thailand: Impact and Response, Contemporary Southeast Asia A Journal of International and Strategic Affairs 33(2):229-258

⁵ Takahashi, H.G., Yasunari, T., 2008. Decreasing trend in rainfall over Indochina during the late summer monsoon: impact of tropical cyclones. J. Meteorol. Soc. Jpn. 86, 429-438

Figure 15-6: Fluctuations in the annual MSL during 1982-2004 at four tide-gauge stations along the eastern side of the Gulf of Thailand



Source: Pramot Sojisuporn et al., 2013⁶

Drought and floods

Rayong province has experienced floods and drought with some districts identified as having “severe” risk from both extreme events (Figure 15-7). Work by the Thai Hydro and Agro Informatics Institute has demonstrated the importance of understanding the incidence of flood and drought basin wide to better assess implications for downstream areas. Based on historical incidents the Institute developed risk maps for Rayong Province with a focus on Map Ta Phut (Figures 15-8 (a) and 15-8 (b)). They found that the Mab Ta Phut area has a risk of drought but upstream areas supplying water to Mab Ta Phut have a severe drought risk. One also has a risk of flooding.

Anecdotal information on flooding in Rayong shows it is a significant issue with economic, social and environmental impacts, as evidenced in the examples which follow.

2006: Flood alert for East - The Nation 2 July, 2006 - The eastern provinces of Rayong, Chanthaburi and Trat have been placed on flood alert. The eastern provinces face heavy downpours, and residents in flood-prone areas should be on alert, it warned. Waves in the Andaman Sea and the Gulf of Thailand will be strong and up to three metres high. Fishing vessels are advised to sail with caution and small craft warned not to leave port.

2008: Reservoir In Rayong Bursts - September 29, 2008 About 50 households affected as flash flood hits village in Rayong - Muddy waters from a broken reservoir damaged households in Rayong's Bankhai district. Villagers had to flee their houses to safety. More than 10 vehicles were washed away almost half a kilometre from parking areas and garages. The flood lasted 20 minutes before the reservoir ran out of water.⁷

2012: EEC is in flood-disaster zone - 21 September 2012 (NNT) – DDPM Director-General Wiboon Sanguanpong said on Thursday that a total of 15 provinces have been declared flood-disaster zones including Rayong.

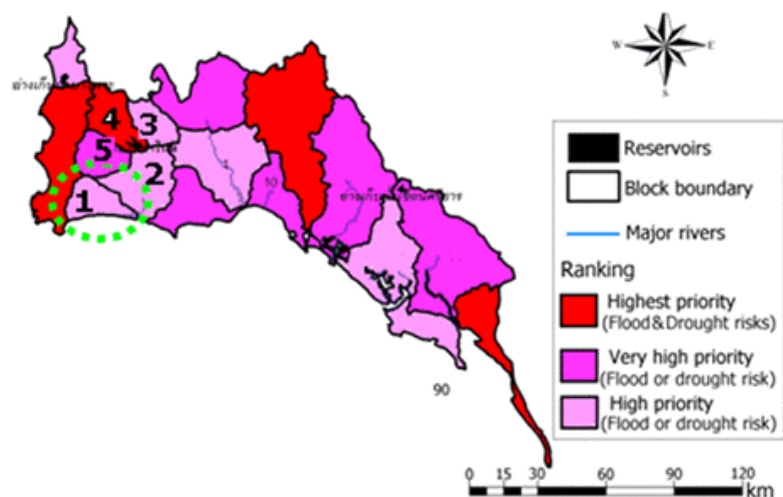
2015: Two flood-hit districts in Rayong declared disaster zones - 18 September 2015 (NNT) – Two districts in Rayong have been declared disaster zones after they were heavily hit by tropical storm Vamco. The provincial administration and relevant units have urgently distributed assistance to the affected people.

Efforts were mobilized to help 4,000 households in Ban Chang district. Almost 30 villages there have been flooded with the water of up to 1.5m. Main roads in Rayong to Bangkok and Chanthaburi have been submerged and only large vehicles can pass. The other district declared disaster zone is Mueang Rayong which is adjacent to the heavily flooded Bang Lamung district in Chonburi province. Tap Ma sub-district in Mueang Rayong is the most critically flooded area.

⁶ Pramot Sojisuporn, Chalermrat Sangmanee and Gullaya Wattayakorn, 2013, Recent estimate of sea-level rise in the Gulf of Thailand, January 2013, Maejo international journal of science and technology 7 (Special Issue):106-113

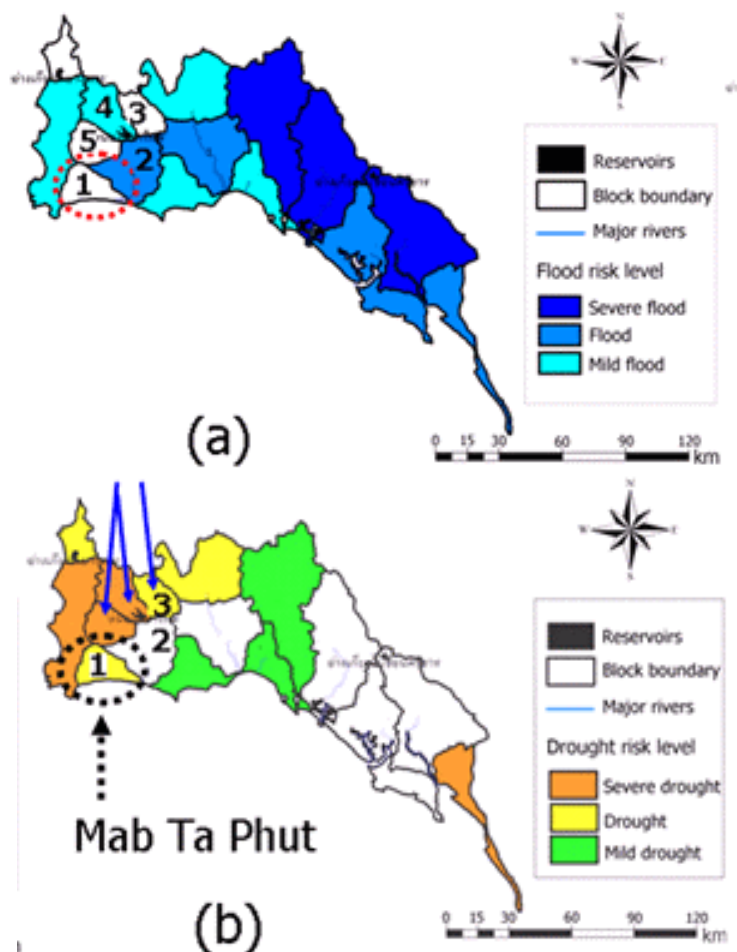
⁷ <https://forum.thaivisa.com/forum/129-eastern-thailand-forum/>

Figure 15-7: Ranking of priority based on flood and drought risk level



Source: HAI, 2019⁸

Figure 15-8: Flood (a) and drought (b) risk maps of the East Coast - Gulf Basin



Source: HAI, 2019⁸

⁸ Royol Chitradon, Surajate Boonya-aroonnet, Poranee Thanapakpawin, 2009, Risk Management of Water Resources in Thailand in the Face of Climate Change, Hydro and Agro Informatics Institute (HAI), Thailand, <http://www.thaiwater.net/web/index.php/knowledge/128-hydro-and-weather/295-riskmanagementclimate.html>. Accessed June 2019.

Figure 15-9: 2015 Flooding in Rayong: Continuous rain in the wake of tropical storm Vamco has caused landslides, swept away houses and created chaos on the roads.



Source: The Nation/Asia News Network – 19 Sep, 2015

2017: Flooding in Rayong - March 29, 2017 - Several districts in Rayong province briefly came under water on Wednesday after the province was struck by torrential rains.⁹

Figure 15-10: 2015 Flooding in Rayong



Source: https://news.lovepattayathailand.com/wp-content/uploads/2017/03/236_Flood.jpg

2017: Flooding in eastern region, since 5th July to 15th August 2017, continuous heavy rain influenced by tropical storm TALAS and tropical storm SONCA have caused a widespread flooding in several provinces in the eastern region including Rayong.

2018: Most provinces warned of heavy rain, floods and landslides - 30 Jul 2018: Fifty-nine of the country's 77 provinces including Rayong were warned to brace for floods, burst riverbanks, extreme runoff and landslides as heavy rains are expected in upper Thailand on July 30-31. People living along the coast of the East were warned of strong winds during this period.

2019: Tropical storm devastates parts of eastern Thailand

– 15 Jan 2019: The effects of Tropical Storm Pabuk where felt in eastern Thailand this morning causing widespread flooding and collapsed buildings. The devastating cyclone smashed into the southern coast yesterday causing powerful waves, heavy rain and winds. Hundreds of thousands of residents and tourists were evacuated and moved to temporary shelters while the storm passes. Rayong, on the eastern seaboard of the country, experienced flooding as the weather spread across the Gulf of Thailand.¹⁰

Drought in Rayong Province is more challenging to document as it is a concept which relates mainly to inadequate water for rain fed agriculture. Water may be available to meet domestic and industrial demand but be inadequate in a dry season for rain fed agriculture and especially for environmental purposes. In recent years for example, Rayong's water resources have not been managed to sustain environmental flows in its two main rivers, leading to degraded ecosystems and concentrated pollution loads.

2005: Severe drought in Rayong led to a conflict in water resource allocation among the agricultural, industrial, and domestic consumption sectors. It was so severe that the industrial sector had to transport in water by truck from nearby regions (Royol Chitradon et al 2009)

2016: Drought takes toll on waterfall fishes at Khao Chamao park in Rayong - May 14, 2016 The long summer drought in the country's eastern region has taken a toll on Khao Chamao waterfall in Rayong province. Indigenous freshwater fish known as "pla pluang" have died. Khao Chamao national park officials said they have collected almost a ton weight of pla pluang fish from the pond on the second level of the waterfall. The water gets warmer and is polluted, and with no oxygen, park officials said.¹¹

2018: "Lack of water or drought are really serious problems in Rayong Province." Montri Sak Phibunrat, 2018, Effectiveness of Water Management: A Case Study in Areas Rayong Province, Journal of Rangsit Graduate Studies in Business and Social Sciences Vol 4 No 1 (2018)

Figure 15-11: Drought causing fish die off in Khao Chamao Park, Rayong Province



Source: See footnote 11

⁹ <http://thairesidents.com/local/rayong-badly-flooded-hour-long-heavy-rain/>

¹⁰ <https://www.newsfltropical-storm-devastates-parts-of-eastern-thailand>

¹¹ <https://forum.thaivisa.com/topic/917361-drought-takes-toll-on-waterfall-fishes-at-khao-chamao-park-in-rayong/>

7. Future projections and trends in climate change

For the purposes of this baseline assessment on climate change in Rayong Province, the Mekong River Commission projections and data have been applied. In consultation with member countries, the MRC adopted three Global Climate Models (GCMs) as best fit for the Mekong region. One of those models was shown to project greater seasonal variance – the French IPSL-CM5A-MR. The model provided greater insights into the range of temperature and rainfall which can be expected in various future time slices. For that reason, the IPSL-CM5A-MR projections under the 4.5 and 8.5 scenarios (or RCPs – Representative Concentration Pathways) are used to communicate changes in this report. The SEA also applied the two other MRC GCMs to Rayong province – ie GISS and GFDL – and those results can be made available to interested stakeholders.

In summary, climate changes projections to 2050 indicated that Rayong province will experience less rainfall during both the dry and wet seasons (Table 15-1) and increased temperatures in both seasons (Table 15-2). The more extreme RCP 8.5 has rainfall increasing in the wet season and as the time slice moves closer to 2070 (Table 15-1). Those changes will bring increased likelihood of more intense droughts but with rainfall coming in more intense events. With higher average temperatures and warmer air that can hold more water, a pattern might emerge of lengthy dry spells interspersed with brief but heavy rainfall and possible flooding.

Projected rainfall changes

The maps of Rayong show future conditions vary from west

to east. During the wet season under RCP 4.5 for 2050, the reductions in rainfall are rather consistent throughout the province at around minus 1% (Figure 15-13). But moving to 2070 the reductions continue at that level in the east of the province while increasing by around 2% towards Western Rayong. In the dry season, for RCP 4.5 and 8.5 the reductions in rainfall are consistent across the province although more marked to 2050 at around minus 6 – 8% (Figure 15-14) and in the east of the province moving towards minus 10 to 15% for 2070 under RCP 8.5 (Figure 15-14).

Projected temperature changes

Rayong is projected to experience higher temperatures during the wet and dry seasons and increasing as the province moves towards the 2070 time slice (Figure 15-16). Temperatures are projected to rise by 2°C to 2.3°C during the 2050 dry season and to 2.2°C to 3.2°C by 2070 with further increases to 3.6°C during the 2070 wet season. Temperatures will tend to increase more in the northern half of the province where reservoirs are located especially under RCP 4.5 in 2070 (Figure 15-16).

Sea level rise

Already Thailand is experiencing rate of sea level rise higher than the global average at 4-6mm/yr. The Intergovernmental Panel on Climate Change's (IPCC) fifth assessment report (AR5) a likely rising rate of 8 mm/yr to 16 mm/yr for sea-level projections moving towards the late 21st century (2081–2100). For Thailand that might involve a close to doubling of past SLR rates. For the entire country, the future projected beach loss rates in 2081–2100 relative to the reference period 1986–2005 are 55.0% for RCP4.5 (30.49 km²) and 71.8% for RCP8.5 (39.77 km²) in which many beach zones will be completely lost. With a 1-m SLR, total beach loss rate

Table 15-1: Projected changes to average rainfall in Rayong Province - 2050 – 2070 – Model IPSL-CM5A-LR

RCP 4.5	Baseline (mm)	In 2050 (mm)	Change in 2050 (%)	In 2070 (mm)	Change in 2070 (%)
Annual rainfall	1553.3	1522.1	-1.9	1575.5	1.5
Dry season	284.8	263.0	-7.6	282.5	-0.8
Wet season	1268.5	1259.1	-0.6	1293.0	2.1
RCP 8.5	Baseline (mm)	In 2050 (mm)	Change in 2050 (%)	In 2070 (mm)	Change in 2070 (%)
Annual rainfall	1553.3	1543.7	-0.5	1543.3	-0.5
Dry season	284.8	265.8	-6.7	258.5	-9.2
Wet season	1268.5	1277.9	1.0	1284.8	1.5

Source: www.worldclim.org

Table 15-2: Projected changes to average daily maximum temperature Avg Tmaxin Rayong Province - 2050 – 2070 – Model IPSL-CM5A-LR

RCP 4.5	Baseline (°C)	In 2050 (°C)	Change in 2050 (°C)	In 2070 (°C)	Change in 2070 (°C)
Ann. Avg T _{max}	32.0	34.0	1.9	34.3	2.3
Dry season	32.4	34.3	1.9	34.6	2.2
Wet season	31.6	33.7	2.0	34.0	2.4
RCP 8.5	Baseline (°C)	In 2050 (°C)	Change in 2050 (°C)	In 2070 (°C)	Change in 2070 (°C)
Ann. Avg T _{max}	32.0	34.4	2.4	35.4	3.4
Dry season	32.4	34.7	2.3	35.6	3.2
Wet season	31.6	34.1	2.5	35.3	3.6

Source: www.worldclim.org

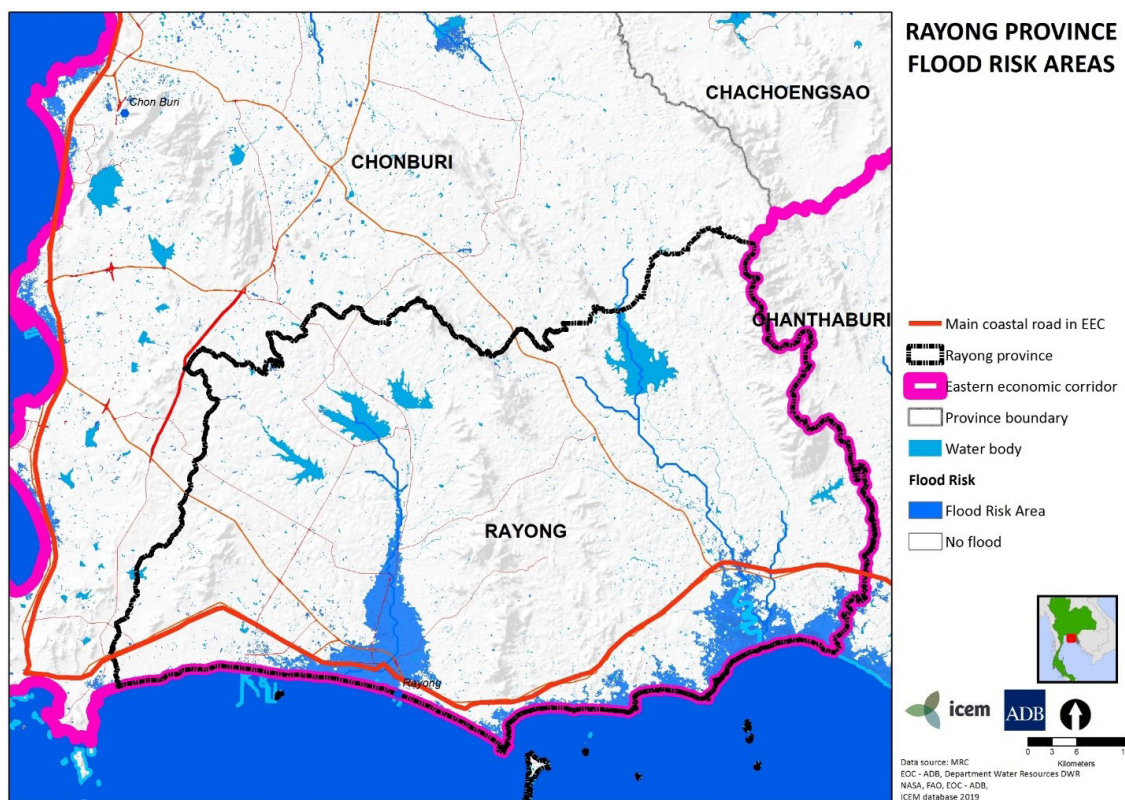
could be over 147% - affecting beach zones and other coastal areas.¹²

Areas of future flood risk

Figure 15-12 illustrates a scenario for future flooding in Rayong province to 2050 which combines an intensive rainfall event in the upper watersheds, sea level rise and storm surge. Much of the provinces coastal strip and river estuarine

regions are below 3m which exposes those areas and the infrastructure, communities and natural assets within them to a worst case scenario involving intensive rainfall upstream and localised combined with a severe tropical storm and assuming that sea levels continue to rise. Hardest hit would be the two river estuarine areas and flood plains well into central Rayong Province. Also, the coastal zone between the two estuaries and extending eastward to the border area with Chanthaburi Province would be extensively at risk.

Figure 15-12: Rayong province flood risk combining sea level rise, intensive rainfall and storm surge



8. Links to other sectors and themes

Natural disasters and climate change affect all development sectors. Climate change is already affecting development activities in Rayong Province and all sectors need to integrate the projected changes into their short, medium and long term planning.

Water sector: Water is a critical natural resource in Rayong and its availability and distribution will be one of the most important constraints on development in the province. Less rainfall in the dry season and higher temperatures will reduce water availability and potentially increase conflicts over water allocation and distribution. Reduced rainfall and higher temperatures in the wet season to 2050 will aggravate water shortages. Increasing temperatures will warm up water bodies and cause algal blooms to become a more significant problem in rivers, ponds and reservoirs. These naturally occurring algal blooms are supercharged by increasing nutrient pollution – worsened by cycles of drought

and intensive rainfall – and warmer waters.

Industry: Climate change is likely to result in a significant increase in industrial losses and damage. Small and medium-sized enterprises are especially vulnerable. They lack the technical expertise and have insufficient financial resources needed to adapt. Many industrial locations are exposed to projected climate risks, especially those close to coast and river flood plains. Of special concern are solid waste landfill sites and storage sites for hazardous goods and wastes.

Water shortages are already a major issue and climate change is projected to make existing problems worse. Industry costs will rise as the demand for tighter control and monitoring of water usage grows.

Extreme events such as storms and floods have the potential to disrupt supply chains making access to resources and materials more challenging and expensive. Rising electricity and transportation expenses may increase the cost of moving goods. Resource scarcity could drive companies to use alternative materials and recycle more waste.

¹² Sompratana Ritphring, Chatuphorn Somphong, Keiko Udo and So Kazama, 2018, Projections of Future Beach Loss due to Sea Level Rise for Sandy Beaches along Thailand's Coastlines, Journal of Coastal Research SI 85 541–545 Coconut Creek, Florida 2018

As temperatures rise, working conditions in some sectors may become harsher. Jobs that require physical labor, especially outdoors, will become more challenging, and health and safety risk in these industries will rise. This will increase costs in these sectors.

Regulations aimed at mitigating and preventing pollution will also significantly impact businesses. Companies that produce high levels of emissions will have to invest substantial funding into upgrading their facilities to reduce, capture or eliminate them.

Agriculture: The projected changes in climate will be especially challenging for agriculture – requiring adjustments to cropping patterns and crop types and water management regimes. Though warmer temperatures can help crops grow more quickly, for many crops—like grains—the faster the growth, the less time seeds have to mature, reducing yields. Temperature rise leads to greater evaporation rates and plant transpiration, which results in water loss in soil and plants. Higher CO₂ levels can affect crop yields, increasing plant growth. But, elevated CO₂ has been associated with reduced protein and nitrogen content, resulting in a loss of quality.

Extreme events, especially floods and droughts, can harm crops and reduce yields. Dealing with drought could become particularly challenging in areas of rain fed agriculture where rising summer temperatures cause soils to become drier. Although increased irrigation might be possible in some places, in other places water supplies may also be reduced, leaving less water available for irrigation when more is needed.

Many weeds, pests, and fungi thrive under warmer temperatures and increased CO₂ levels. The ranges and distribution of weeds and pests are likely to increase with climate change. This could cause new problems for new and existing crops previously unexposed to these species. Human health may be at risk by increased pesticide use due to increased pest pressures and reductions in the efficacy of pesticides. The effects of climate change will need to be considered along with other evolving factors that are affecting agricultural production in Rayong, such as changes in farming practices and technology.

Fisheries: Warmer water temperatures are likely to cause the habitat ranges of many fish and shellfish species to shift, which could disrupt coastal and marine ecosystems. Carbon dioxide in the air will acidize sea water and rising sea levels will change the ecology of the fishing grounds. Shellfish, like clams and oysters, find it much more difficult to grow in a more acidic environment. Fisheries will be affected by changes in water temperature that make waters more hospitable to invasive species and shift the ranges or lifecycle timing of certain fish species.

Energy: Climate change is likely to increase electricity demand for cooling in the summer. New infrastructure investments may be necessary to meet increased energy demand, especially peak demand during heat waves. Climate change could affect the amount of water available

to produce electricity or extract fuel. In Rayong where water is already scarce, competition for water between energy production and other uses could increase.

Sea level rise and more frequent intense storms could disrupt energy production and delivery by damaging electricity infrastructure, fuel delivery infrastructure and equipment, power plants, or storage facilities. Much of Rayong's energy infrastructure is located in the coastal zone and therefore sensitive to sea level rise and storm surge. For example, fuel ports and the generation and transmission lines that connect to the national grid and bring electricity to major urban coastal centers are at risk. Offshore drilling platforms and gas pipelines are vulnerable to extreme weather events. Changes in the frequency and severity of storms and other extreme events may also damage energy infrastructure, resulting in energy shortages that harm the economy and disrupt peoples' daily lives. Flooding and intense storms can damage power lines and electricity distribution equipment. These events may also delay repair and maintenance work.

Transport: Climate changes could increase the risk of delays, disruptions, damage, and failure across land-based, air, and marine transportation systems. Most transportation infrastructure being built now is expected to last for 50 years or longer. Therefore, it is important to understand how future climate might affect these investments in the coming decades.

Railways and marine transportation that move large amounts of oil and coal are vulnerable to climate change. More intense rainfall and storms can threaten roads by flooding tunnels, overtopping bridge culverts and degrading road surfaces. Higher temperatures can cause pavement to soften and expand. This can create rutting and potholes, particularly in high-traffic areas and can place stress on bridge joints.

Exposure to flooding, intense rainfall and extreme temperatures also shortens the life expectancy of highways and roads. The stress of water may cause damage, requiring more frequent maintenance, repairs, and rebuilding. Road infrastructure in coastal areas is particularly sensitive to more frequent and permanent flooding from sea level rise and storm surges. Changes in precipitation and sediment loads could affect marine transportation by reducing the navigability of coastal waters.

High temperatures cause rail tracks to expand and buckle. More frequent and severe heat waves may require track repairs or speed restrictions to avoid derailments. Heavy precipitation can wash out railway beds could also lead to delays and disruption, and tropical storms can flood or leave debris on railways, disrupting rail travel and freight transport.

Periods of extreme heat can affect aircraft performance and may cause airplanes to face cargo restrictions, flight delays, and cancellations. In the wet, increased rains and flooding may also disrupt air travel. Storms can force airports to close. Climate change may increase the frequency of these events and the number of airports that are affected. In addition to causing closures or delays, flooding may damage facilities, including airstrips.

Figure 15-13: Rayong Province - Baseline & Rainfall Change 2050 and 2070 - Wet season (%) RCP 4.5

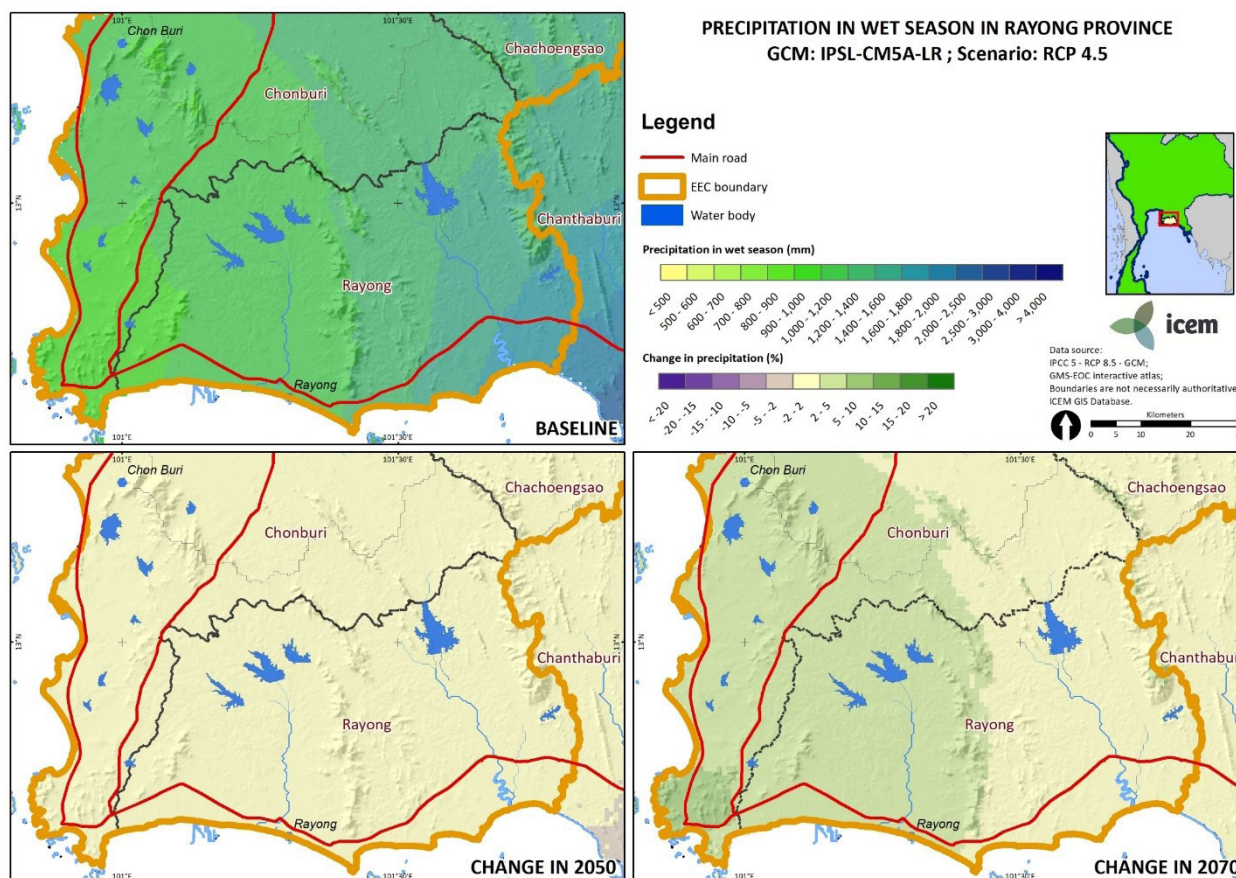


Figure 15-14: Rayong Province - Baseline & Rainfall Change – Dry season (%) RCP4.5

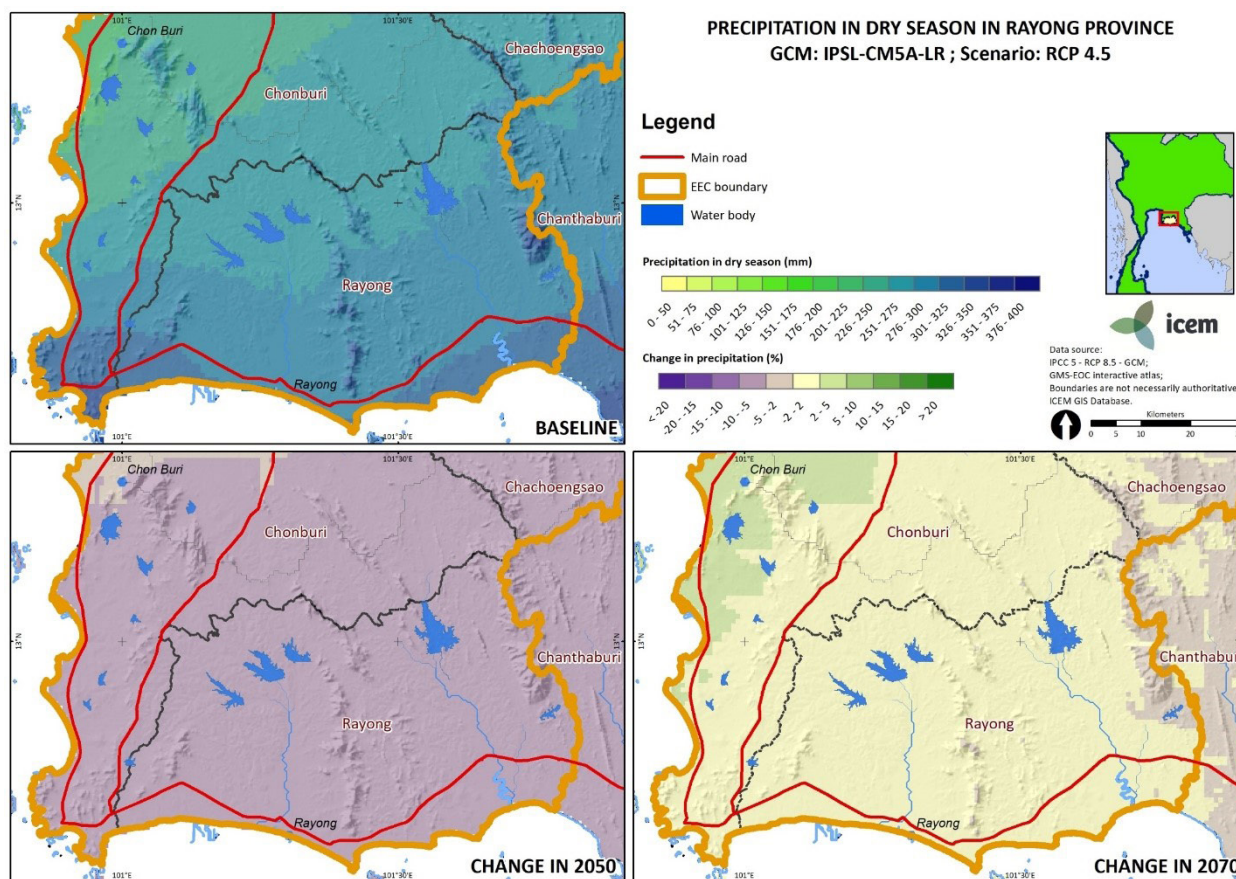
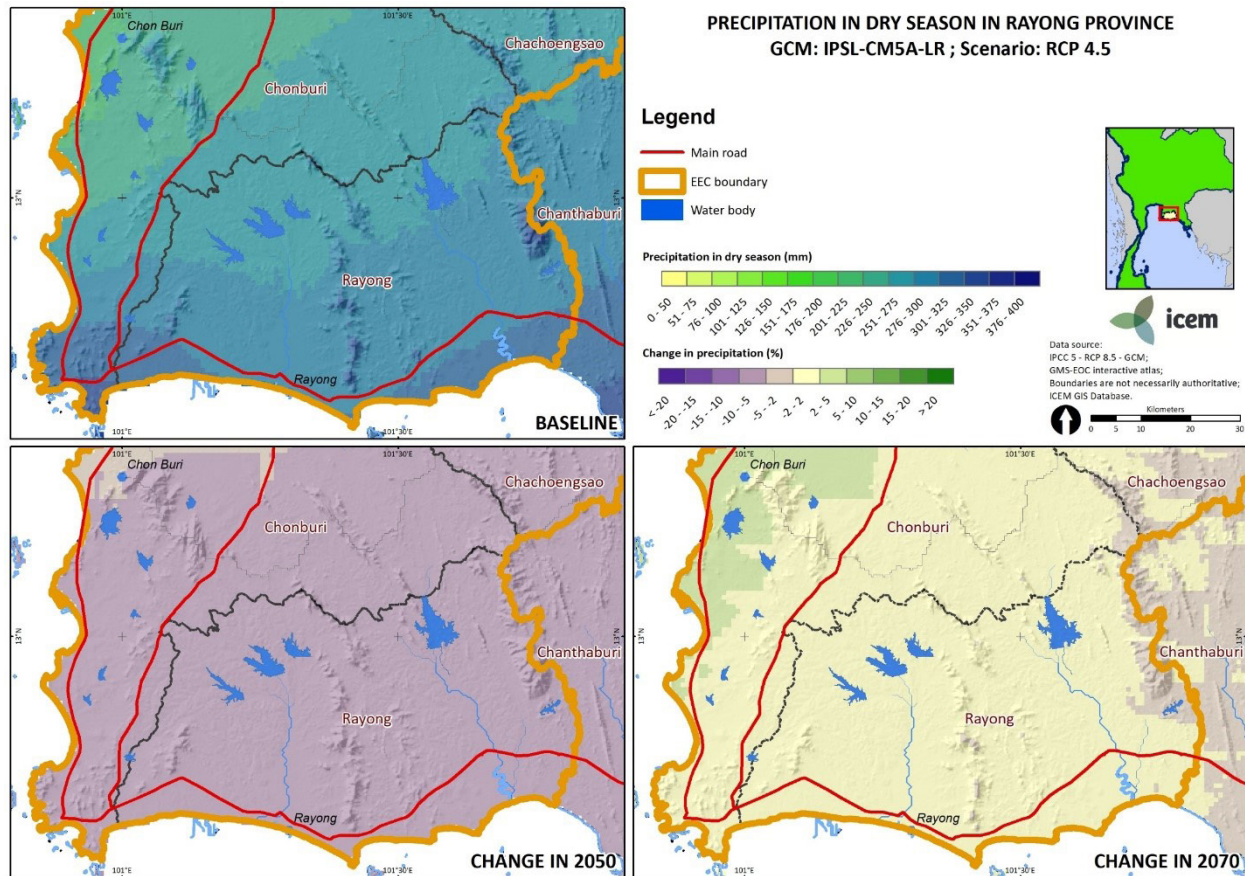
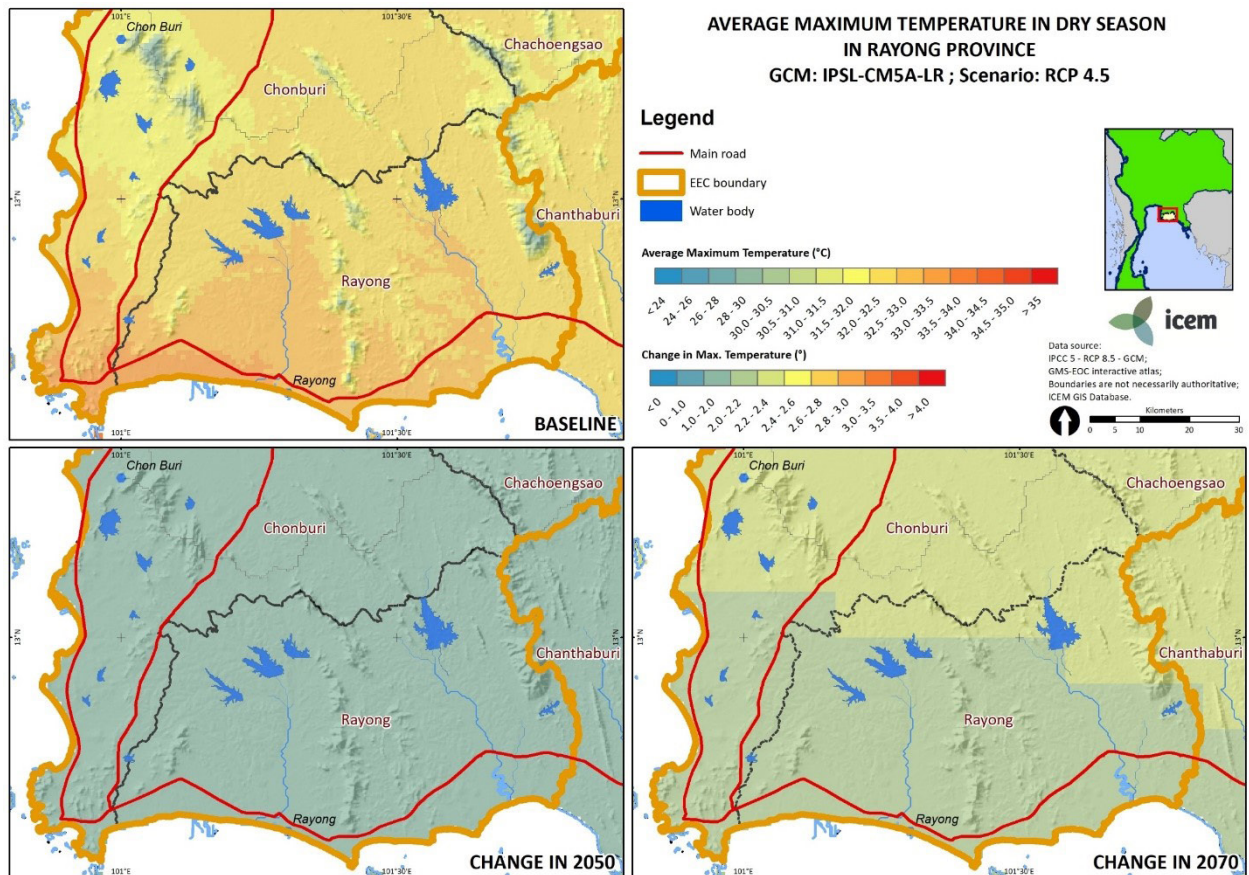


Figure 15-15: Rayong Province - Baseline & Rainfall Change – Dry season (%) RCP 8.5

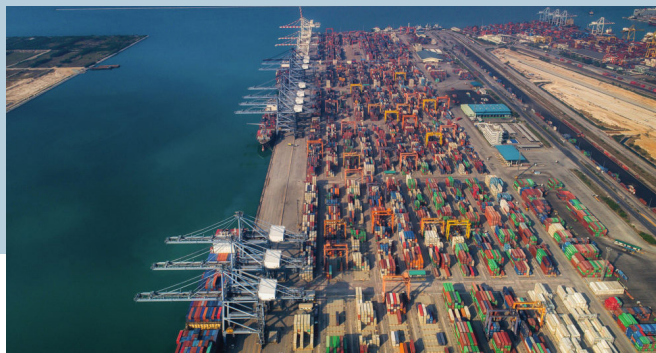


Source: ICEM 2019

Figure 15-16: Rayong Province - Average Max Temperature Change – Dry season - RCP4.5



Source: ICEM 2019



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