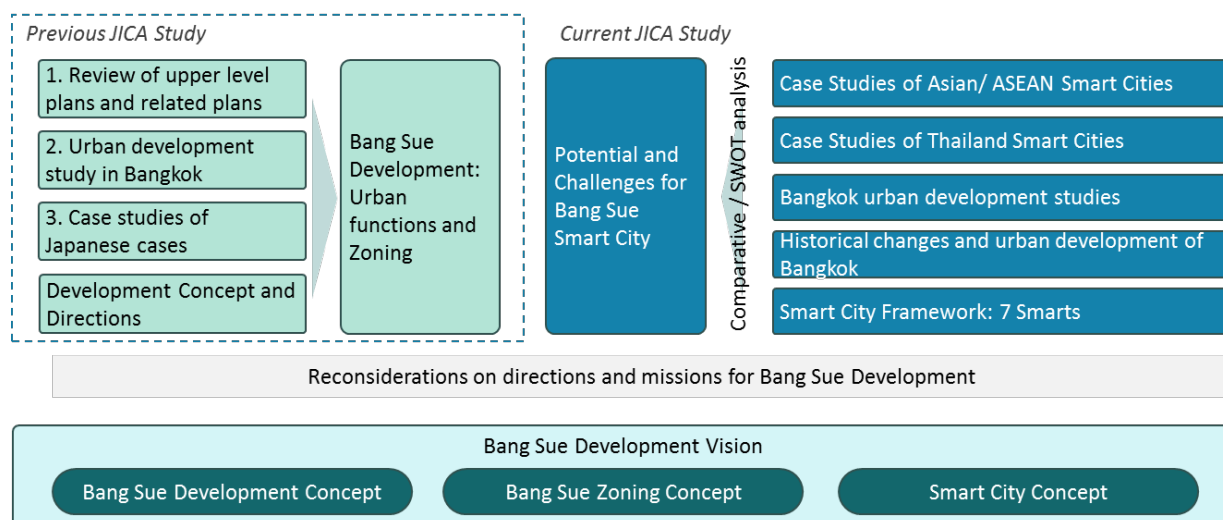


4. Smart City Concept for the Bang Sue Area

4.1 Vision and Concept

Urban functions, zoning, and general plans presented in the past fiscal year's research are referred to as a basis in considering the vision and concept for Bang Sue's smart city development. Specifically, the essences and directions of the development vision and concept set forth in the past study were followed and thus elaborated, while smart city elements were incorporated into them to set a new concept and a vision.



Source: JICA Study Team

Figure 4.1 Flow for the Vision and Concept

4.1.1 Existing Master Plan

(1) Vision and Concept of the Existing Master Plan

The concepts and vision proposed in the past fiscal year's research are as shown below. Terms such as “International”, “Diversity”, “Transportation Hub”, and “Public-Private Integration” have been advocated as keywords.

Table 4.1 Essence of the Draft “Development Concept Paper”

Essence	Contents
Vision	Gateway to “City of Angels”
Basic Concept	<u>Concept 1:</u> To grow up to a centripetal urban core in Bangkok Metropolitan Area, which plays important roles in the international community. - To form an international and regional business and interaction center. - To ensure sustainability including safety and environmental friendliness. <u>Concept 2:</u> To create an eternally beloved new central district full of various attractiveness. - To create various attractions of urban life, from old to new, from a bustle of market places to ultramodern skyscrapers. - To create a comfortable walking space so that everyone would enjoy strolling along decks and paths in the area. <u>Concept 3:</u> To create a visitor-friendly traffic terminal area comfortable for everyone.

Essence	Contents
	- To create a world-class traffic terminal area comfortable for both Thai and foreign visitors. - To upgrade the user-friendliness in terms of transfer by creating public spaces. <u>Concept 4:</u> To stepwisely realize the conceptual plan by both public and private sectors. - To enhance all kinds of partnership between public-private and private-private, beside a strong initiative by the public, in order to properly realize the conceptual plan.

Source: JICA “Data Collection Survey on Urban Redevelopment in Bang Sue Area”

Table4.2 Plan Formulation Policies

Policy	Matters for Care and Consideration
(1) To grow up to a centripetal urban core in Bangkok Metropolitan Area which plays important roles in the international community	- To elaborate an integrated master plan for successful redevelopment of the entire area. - To place core facilities including a landmark tower building, a smart city, etc. - To introduce attractive urban functions that boost development potential of the entire area.
(2) To create an eternally beloved new central district full of various attractiveness.	- To introduce the main facility to connect and organize each zones - To develop infrastructure and public spaces that make the entire area more attractive. - To prepare a guideline to promote a well-balanced area development. - Introduce upgraded infrastructure and facilities that will contribute to increasing the potential of the district. - Place (and guide people to) applications and functions that will increase the potential of the entire area. <u>Introduce guidelines for driving planned urban development.</u>
(3) To create a visitor-friendly traffic terminal area comfortable for everyone.	- To ensure comfortable transfer between railway stations and other transport modes. - To construct pedestrian decks and plazas. - To introduce a feeder transport mode (ex. BRT) and make the best use of ITS in the area.
(4) To stepwisely realize the conceptual plan by both public and private sectors.	- To elaborate a stepwise implementation plan ensuring feasibility and viability. - Consider an appropriate division of labor to ensure a “win-win” To introduce vitality and resources of private sector. - To consider the best role-sharing system that ensure a win-win partnership for both public and private sectors.

Source: JICA “Data Collection Survey on Urban Redevelopment in Bang Sue Area”

In the “International” aspect, Bang Sue area has been conceptualized as an international hub for Bangkok in The Twelfth Five-Year National Economic and Social development Plan (2017 - 2021).

(Reference) The Twelfth Five-Year National Economic and Social Development Plan (2017 – 2021)

*“To promote Bangkok to be the center of international business hub; educational center; international health and medical center, with high standard information and communication technology, in intermodal nodes, e.g., **Bang Sue. Cities should be developed with adequate allocation of land use, public utilities and facilities, social services, and housing.** In order to respond to the demand from increasing population, it shall consider solving urban environmental problems such as traffic congestion, solid waste, wastewater, air pollution, as well as providing better townscape, green areas, and public parks.”*

With regards to “Transportation Hub” aspect, in comparing and considering role sharing with Makkasan and Mae Nam, the urban and transport functions required in Bang Sue were outlined as follows.

Table4.3 Urban and Transport Functions for Three Locations Owned by SRT

Area	Required Urban Functions	Required Transport Functions
Bang Sue	- Office facilities accumulated around Bang Sue Grand Station - Interaction, tourism, and hotel facilities linked to existing tourism resources such as Jatujak Market and parks - Other urban functions including commercial and residential facilities	- Good connectivity among Bang Sue Grand Station, MRT Bang Sue Station, and SRT Bang Sue Station. - Relocation of Mochit Bus Terminal and local bus stops - Intra-area transport such as BRT - Walkways
Makkasan	- Office facilities accumulated around Makkasan Station - Functions as national and international information center - Functions for visitors such as conferences rooms and hotels	- Boosting demand for Airport Rail Link (ARL), land use, and population distribution along ARL - Ensuring walkway connecting Makkasan Station and buildings - Controlling traffic in the area
Mae Nam	- Residential, office and commercial facilities with an image of water front for branding - Commercial function for the people living around the stations - Open space for interaction	- Improvement of connectivity to SRT Mae Nam Station and BTS Gray Line Station - Ensuring walkway connecting Mae Nam Station and buildings

Source: JICA “Data Collection Survey on Urban Redevelopment in Bang Sue Area”

Furthermore, the following urban functions are proposed for “Diversity” aspect in the Bang Sue area.

(Reference) Approaches with the Industrial Promotion in Bang Sue Area (extracted from the previous JICA’s study report)

Bang Sue is a large-scale redevelopment district fully accessible from the airports and the existing central business district (CBD). In addition, considering the specific fields mentioned in the superior plans (the 20-year National Strategic Plan, the 12th National Economic and Social Development Plan, Thailand 4.0 etc.), it seems that an ideal industrial promotion in the area shall focus on sectors such as **MICE, tourism, medicine/health, and research and development (R&D).**

More specifically, Thailand can aim to further strengthen its MICE industry — which the country has expanded and predominates within the ASEAN countries — along with its medical/health tourism industry and biotechnology R&D industry. In this attempt, the country could consider integrating their **large scale MICE venues, advanced medical care, health-related industries/universities, and research institutions,** as well as develop medical/health related human resources/industry under their collaboration.

(2) Development Plan of the Existing Master Plan

The zoning and urban functions of Bang Sue Area are as summarized below.

Table4.4 Urban Functions to be assigned by Zone

Zone		Urban Functions to be Assigned	Bang Sue Area Zones
Zone A	1	Office/ commercial/ hotel	
	2	Commercial	
Zone B	1,2	Residential, commercial, office	
	3,4	Commercial	
Zone C		Super arena or MICE facilities of the same kind	
Zone D	1	Hotel/ residential/ office/hospital (high-end constructions in expectation of the increase of foreign guests)	
	2	Residential/ commercial/ hotel/ office	
	3	Residential/ commercial/ hotel/	
	4	Residential/ office	
Zone E (SRT Land)	1,2	Office/ commercial (including a high- rise which will be one of the main landmarks of Bang Sue Area, Knowledge center and incubation office space) Civic center (future headquarters of MOT)/ residential	
	3	Residential	
Zone F	1	Commercial (retail shops to be constructed under skydecks around Bang Sue Grand Station)	
	2	Office /commercial (including amusement facility) /residential/ hotel	
Zone G (KM 11)		High-end residential (garden city with abundant greenery space)/ commercial/ office/ hospital/ school	
Zone H	1	Office/commercial/residential	
	2	Office/commercial/residential/hotel	
Zone I		Residential (high-rise condominiums)/ commercial	

Source: JICA “Data Collection Survey on Urban Redevelopment in Bang Sue Area”

4.1.2 Direction of the Bang Sue Development

The basic direction for development are summarized as follows. This is based on the potential and obstacles of Bang Sue as a smart city (from the previous chapter) and the visions, concepts, and basic plan presented in the past fiscal year's research (from the previous section).

(1) Summary of attributes and potentials for Bang Sue Area development

Following the considerations in the previous sections, attributes and potentials of Bang Sue Area development could be outlined as below:

1) ASEAN regional context

- **Area-based approach:** A specific Smart City development site is designated in the Bang Sue Area
- **Multi-sectoral approach:** The Smart City development project is targeted to solve various urban issues by urban and spatial planning

2) Bangkok urban context

- **TOD approach:** Various roads and railways intersect while the existing bus terminal connects the suburban and regional areas. There is a huge potential for becoming a highly convenient transit hub.
- **New urban core development:** The area is distant from the traditional urban core and business center, which presents a huge potential for becoming a new CBD in Bangkok.
- **New urban form:** Away from the busy and dense built area of the traditional urban area, Bang Sue could present a new urban form for Bangkok.

3) Bang Sue district context

- **Existence of prominent Thailand companies:** PTT and Energy Complex, offices of SCG is located in the area, and there is a plan to establish Head Office of SRT. There is a potential for formation of new business district by agglomeration of these prominent Thailand companies.
- **Large green area:** Chatuchak Park is known for one of the largest parks in the city and place for rest.
- **Unique infrastructures:** Existence of gas pipeline, as well as transport related infrastructures such as train station, bus terminal, and highways constitute a unique infrastructure setting.
- **Traditional urban lifestyle:** Chatuchak Weekend market and residential areas are representative of traditional urban lifestyle in Bangkok.

4) People and user-wise context

- **Diversity of people:** People of wide age range and income level, with various purpose, different place of residence, nationality is expected to come to the area.

(2) Mission for Bang Sue Smart City Development

The mission for Bang Sue Smart City Development could be outlined as below:

- ❖ To create a new urban core which would be a hub for business, living and recreation.
- ❖ To fulfill the potential of the “Largest Station in South East Asia” Through TOD approach.
- ❖ To propose a new urban lifestyle by merging the traditional and modern global trend.
- ❖ To serve as a show case model for ASEAN cities by embodying problem-solving approach.

4.1.3 Bang Sue Smart City Development Vision and Concept

(1) Development Vision: “Global Gateway Bang Sue”

The development vision that the Study Team propose is:

“Global Gateway Bang Sue”

The Area is envisioned to become a city where new businesses and industries, educations, lifestyle and culture come together, merge and take-off.



Source: JICA Study Team

Figure4.2 Development Vision: “Global Gateway Bang Sue”

The future Bang Sue Area will be an innovative city in which lifestyles can be diverse, prosperous, and progressive than was ever before in Thailand. Smart city features such as Smart Mobility, Smart Economy, and Smart Education will accelerate people’s activities across the office, residential, educational, and commercial areas centering Bang Sue Station. The existing resources and culture in the Bang Sue area – for example the park and Chatuchak market – will synchronize with the new features to create a whole new vibe.

The coordinated smart city technology and services will nurture both the city and the people who work and live there. The Bang Sue-born-technologies and urban systems that could be become a successful model to which other cities in Thailand, and Asia could refer.

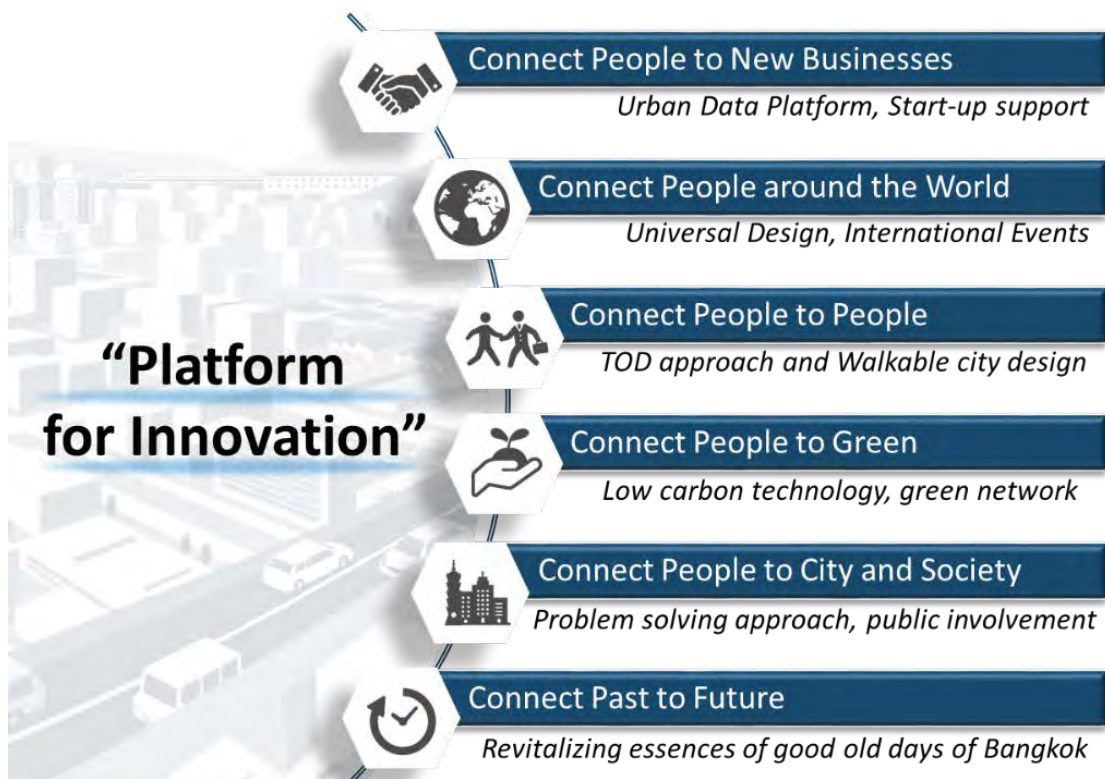
There are seven gateway components to support this vision:

- **Gateway for Business** to create new type of industries by connecting globally established companies with local/ start-up companies.
- **Gateway for Urban Lifestyle** to promote a sustainable and convenient lifestyle by connecting people with smart lifestyle technologies.
- **Gateway for Education** to enabling young generation to learn, or get inspiration by the new and trending ideas, while encouraging all generation for lifelong learning by promoting interaction with new technologies, educational facilities including schools, and other learning opportunity.
- **Gateway for International Culture** to promote encounter with various culture and global or modern trend by facilitating interactions among local and international people, events and commodities.
- **Gateway for Traditional Culture** to facilitate and set out Thailand or Bangkok's culture by promoting interactions between local and international people, events and commodities.
- **Gateway for Rest and Recreation** for people to come and relax, have time off from the urban clamour by connecting people with green open spaces, recreational facilities, and recreational events.
- **Gateway for Innovation** to spread new ideas and technologies created by interaction among industry, public, and academia.

Weaving together each of the seven gateway function is the Smart City function – the “Platform for Innovation” which catalyse connection and interaction to support the continuously evolving city.

(2) Bang Sue Smart City Concept: “Platform for Innovation”

The Smart City function would be the foundation on which the vision of “Global Gateway Bang Sue” would stand. The Bang Sue Smart City shall be developed embodying the concept of “Platform for Innovation”, a platform which catalyze connection and interactions among people, businesses, social needs, technologies and culture. Through connections and interactions, Bang Sue would become a place where people get inspired. innovative ideas would be generated and thus implemented and demonstrated in the Area to enhance living comfort or to solve urban issues.



Source: JICA Study Team

Figure4.3 Bang Sue Smart City Concept: “Platform for Innovation”

The stations in and around Bang Sue area are the platform for people to come and go physically. At the same time, Bang Sue area itself will conceptually function as the “platform” to create innovations as a whole.

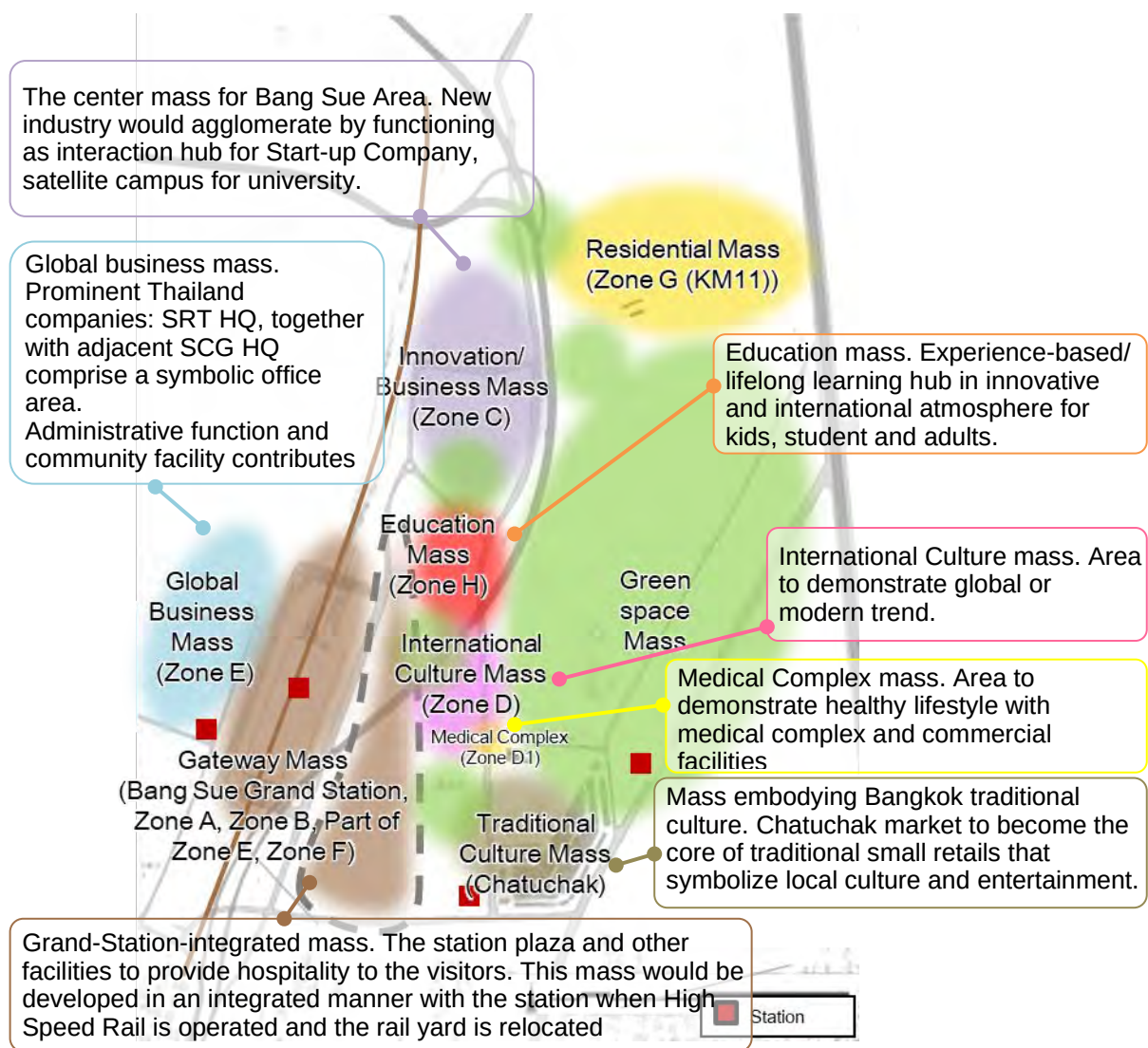
In a more concrete term, people, who has multiple missions and problems get on and off the train at the Bang Sue Grand station, have a chance to come across the good partner with good idea for innovations on the “platform”. Bang Sue area is the place where they can share the problem and make an innovation with their own ideas and technologies with a lot of innovative start-ups and labs, Bang Sue will become the global business hub in Asia.

(3) Bang Sue spatial planning concept

The zoning of the area is redefined to embody the concept.

Zones are reorganized to a larger unit of a mass. A distinct function is assigned to each mass so that the activities inside the zone are promoted and enhanced, while effectively interlinking with each other to catalyze a “chemical reaction”, which further vitalize activity and inject new element to the area.

Meanwhile, a sky deck network and public transport network would be developed to enable active movement and interaction of people. Bang Sue Development Concept and Smart City Criteria of Thailand.

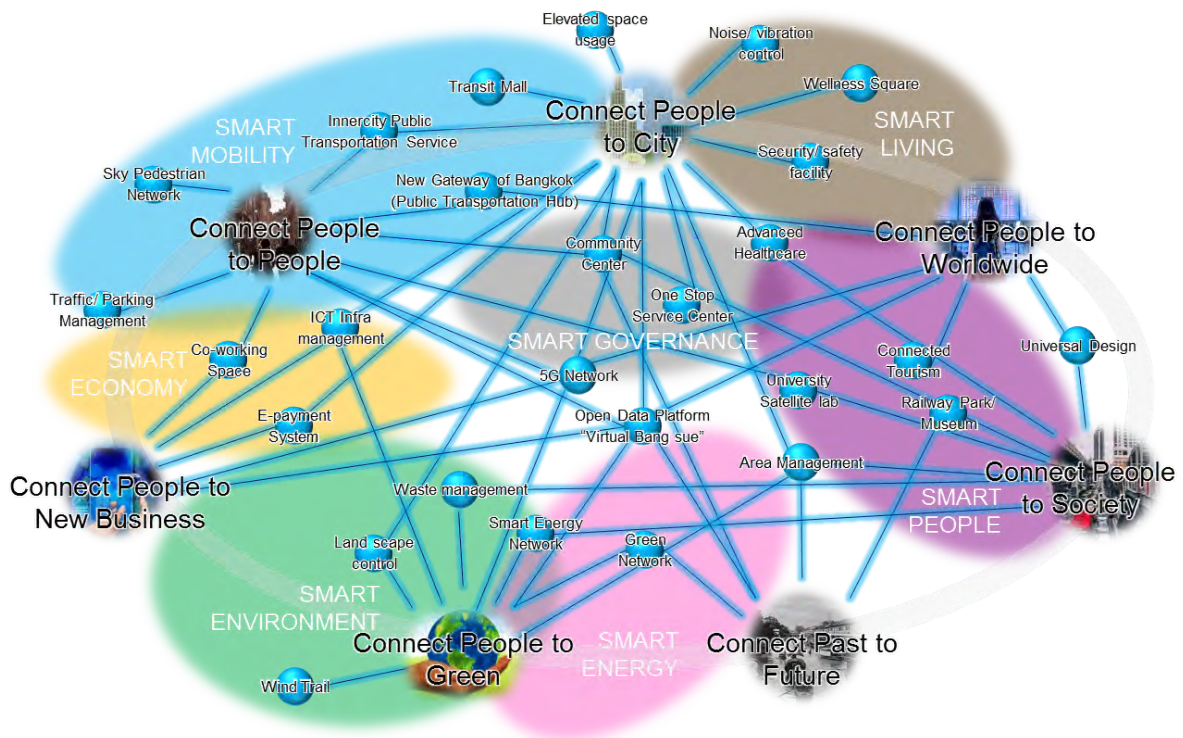


Source: JICA Study Team

Figure4.4 Bang Sue spatial planning concept

(4) Bang Sue Smart City Concept application

Smart technologies and services function as the applications for realizing connection. The proposed smart technologies and services conforms to Thailand's Smart City Framework of "Seven Smarts".



Source: JICA Study Team

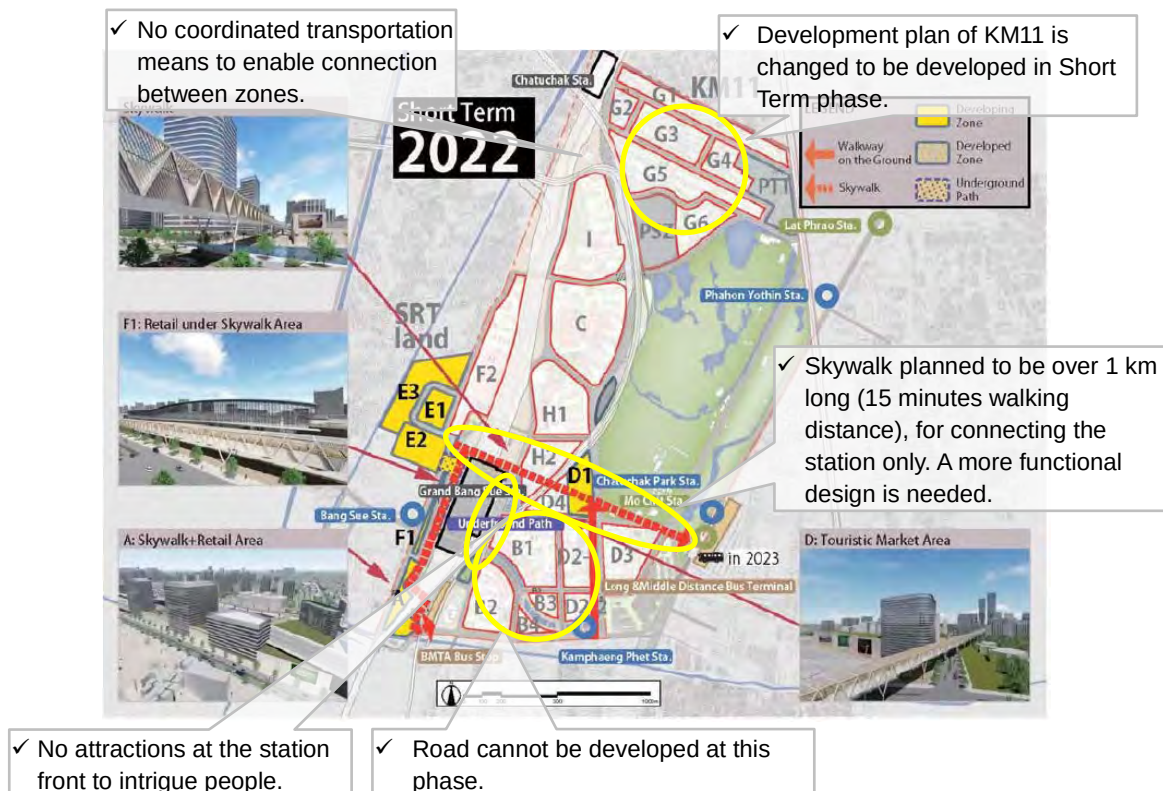
Figure4.5 Bang Sue Smart City Concept and Smart City Criteria of Thailand

4.2 Integrated Spatial Planning

4.2.1 Issue on spatial planning for Bang Sue regarding current situation and master plan

Listed below are the issues of spatial planning for Bang Sue with respect for the current situation and the masterplan.

- The existing railway, the elevated railway currently under construction, the trunk roads, and the elevated expressway spatially divides the area. To enable access between eastern zones and western zones, overpass or underpass would be necessary at crossings with railway and roads.
- Measures are needed to enable smooth mobility of the people, especially given that distance between stations and zones are longer than five-minute-walking distance.
- Overall design for built environment is needed to be considered, taking into account natural environment such as wind flow, sunlight while also harmonizing with adjacent areas such as Chatuchak Park. The current plan proposes buildings standing higher than 100m.
- Consideration of connection and interactions within the area, and with outside the area is needed.
- Back bone infrastructure to promote real estate private investment would be needed to be established in early stage. The infrastructure system should allow for phased development for usage over 100 years.
- Universal design should be introduced so as to enable comfortable living, working and transport for all people.



Source: JICA Study Team

Figure 4.6 Issues of spatial planning: short term development plan

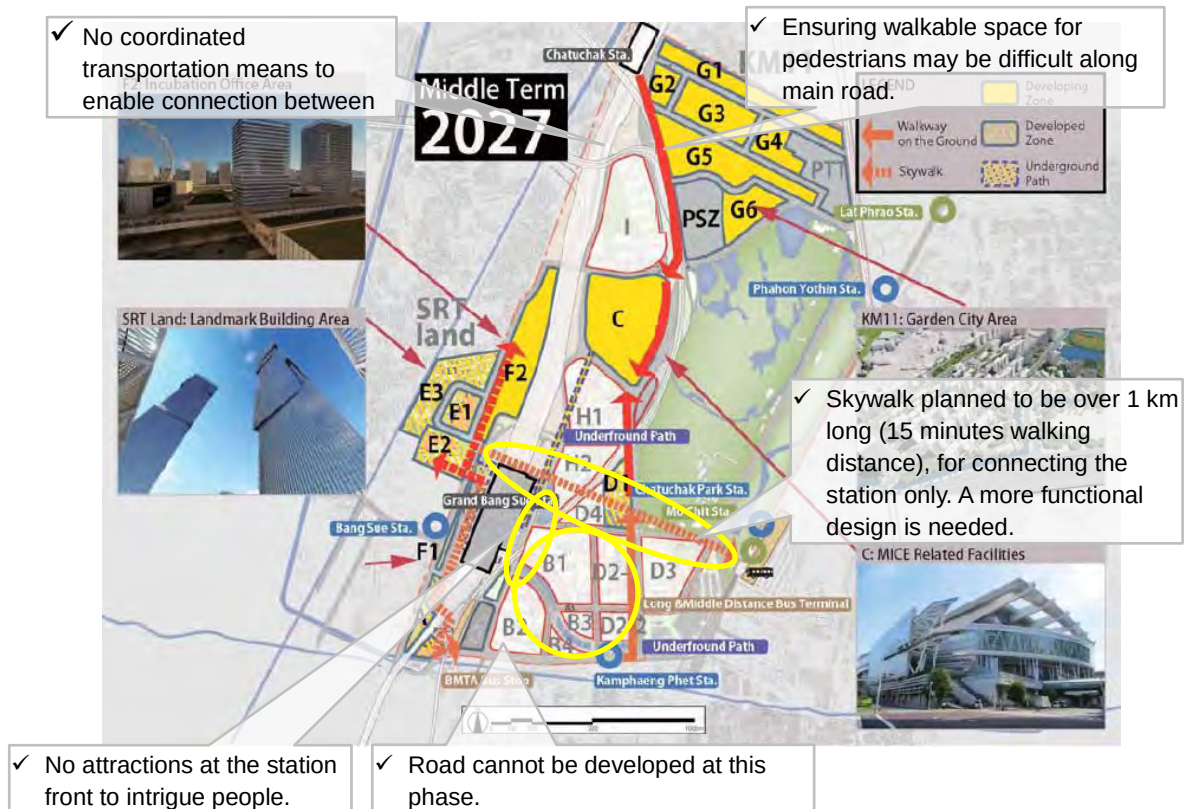


Figure4.7 Issues of spatial planning: middle term development plan

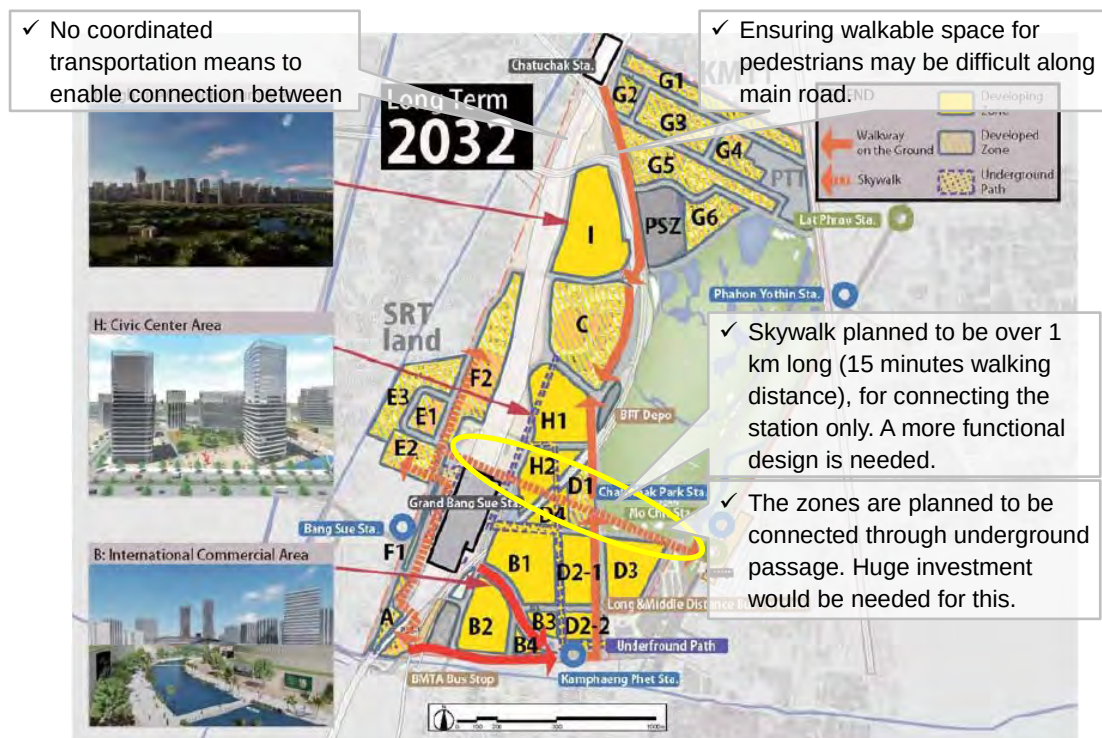


Figure4.8 Issues of spatial planning: long term development plan

4.2.2 Direction for measures and integrated design concept

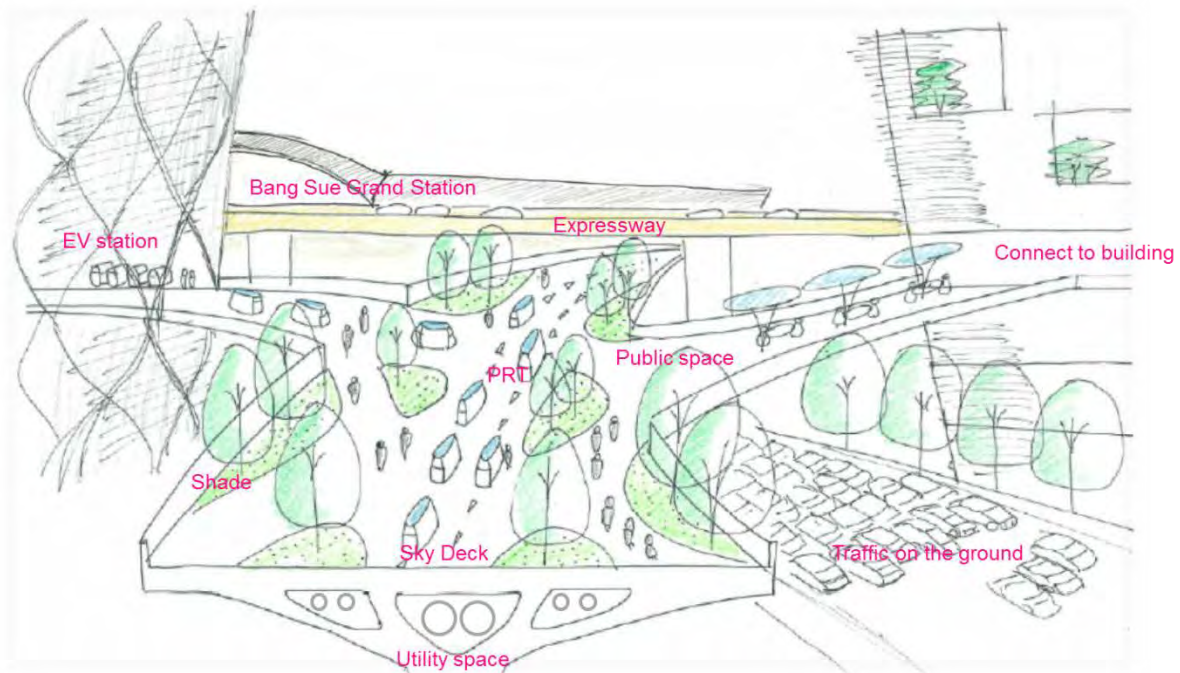
(1) Directions for integrated design concept

To resolve the issues raised in the previous section and to enhance attractiveness as an urban space, directions for measures are outlined below:

- Development of an Mobility Network consisting of Sky Deck Network and Public Transport Network which covers the whole area and connects main area and facilities
- Ensuring integrity as an urban space by establishing a policy (guideline) which would orient private investment in a coordinated manner, for example, securing green building and green spaces, ensuring good access and connection to the above mentioned Mobility Network; introduction and utilization of green/ efficient energy.
- Coordination with the currently existing infrastructures.
- Phased infrastructure development which synchronizes with the planned development scenario, especially the railway depot and bus terminal facility.

(2) Infrastructure system for integrated design concept

The utility, transport and other infrastructures are proposed to be implemented in the whole area as one system. This would contribute to enhancing the efficiency as a whole, while producing and directing an integrated area development in both functional and perceptual sense. As infrastructure systems to support the integrated design the Study Team proposes systems such as: sky deck network, the utility network, and data platform. The figure below indicates the conceptual image of integrated design for the Bang Sue Area.



Source: JICA Study Team

Figure4.9 Conceptual image of integrated design for Bang Sue

Based on these spatial design concept, the image perspective of the Bang Sue Area after full phase development is elaborated as follows.



Source: JICA Study Team

Figure4.10 Perspective view of the Bang Sue Area under integrated design

1) Sky deck network

The development of sky deck network is proposed as a key concept which could enhance the connectivity between separated zones and realize the integrated development of Bang Sue. Although the proposed concept of sky deck network and transport network including PRT (Personal Rapid Transit) is described in detail in a later section, the sky deck network could create public spaces with greens and realize Walkable City with eco-friendly transport.

2) Common utility connecting network (Common duct)

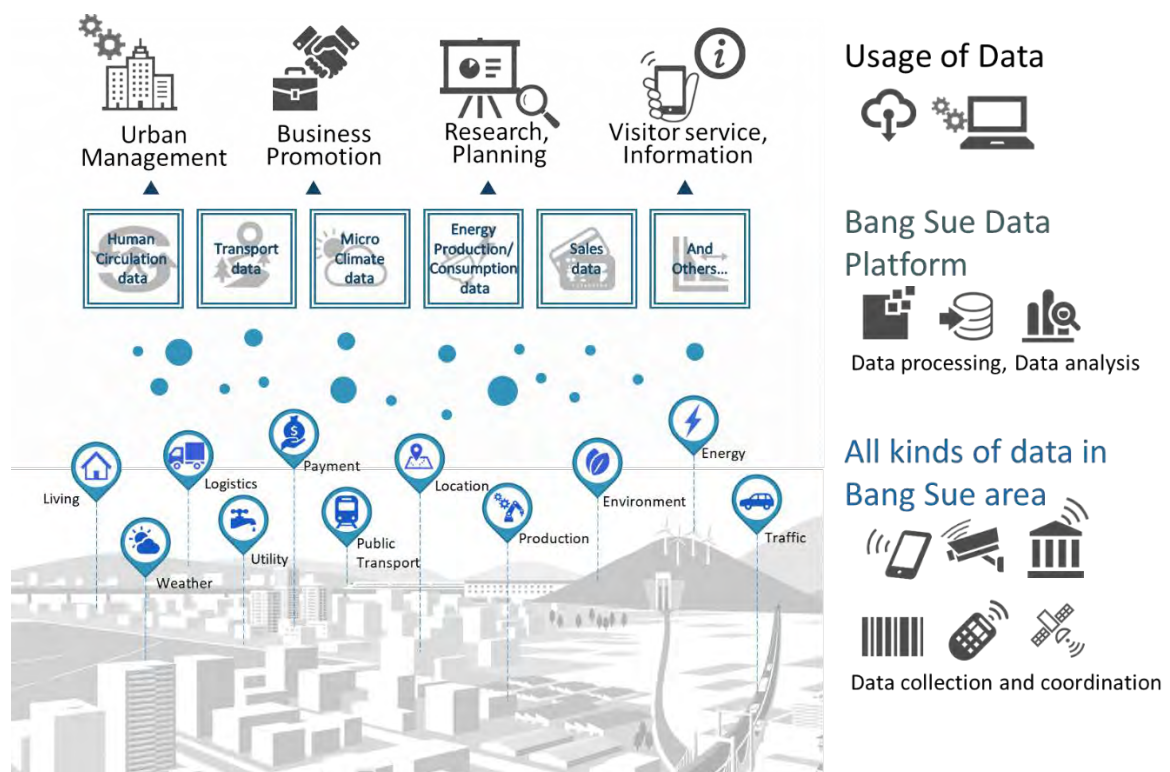
The development of common utility infrastructure network, which could accommodate different utility supply pipelines such as electricity, gas, cooling water pipe and communication cable, is proposed as an indispensable infrastructure for the Bang Sue Area. In Japan, for example, the installment of common ducts in main roads has been contributing to realize efficient operation and maintenance of utility supply pipelines in the urban development areas. This is because those common ducts is designed to have enough spaces enabling engineers and mechanics to go through for maintenance and rehabilitation works. In addition, expansion of infrastructure networks according to the phased development of zones becomes easier by installing common ducts in advance. Furthermore, the construction of common ducts will also enhance the resilience of the city and improve city scape and efficient land use. Those common ducts have been constructed with appropriate cost sharing between public and private sectors in Japan.

3) Data platform

Establishing a framework and system to collect and utilize the various kinds of data generated in the city is becoming a recent trend for Smart City development across the globe. In Bang Sue area, all kinds of data ranging from: people's activity data (e.g., transport data, payment data,

other activity data), facility and infrastructure operational data (e.g., energy usage data, public transport operation data, facility service operation data), and external data (e.g., weather data, environment data, and other relevant data) could be collected and aggregated in a database. Through a data platform – “Bang Sue Data Platform”, these data could be extracted, analysed and thus be utilized for many purposes depending on users’ needs, such as: optimized operation planning; business promotion and marketing; or application for adaptive maintenance of infrastructures and facilities.

The early development of data platform would be expected to providing foundation on which big data would be collected, analysed, and then utilized for integrated and effective management and development of the city.



Source: JICA Study Team

Figure4.11 Conceptual image of Bang Sue Data Platform

Three Smart Component of: Smart Mobility, Smart Energy, and Smart Environment are focused in this study, as these three components were identified as focal area following consultation with Thailand Government and stakeholders. The project concepts are described in the following sections based on the three focal Smart Components.

4.3 Smart mobility

Through discussions with government agencies and related organizations in Thailand, it was confirmed that the Bang Sue area, which has a new terminal station, is expected to serve as a major transportation base in the Bangkok region and the priority of smart mobility planning which becomes a model of other cities is high. In the Bang Sue area development, how to respond to the diverse transportation needs of people inside and outside the area and how to think of smart mobility as a solution in such a response has been discussed as an important issue.

In this section, the concept design of smart mobility in the Bang Sue area based on these discussions and analysis of traffic around the Bang Sue area is examined.

4.3.1 Current Mobility Situation around the Bang Sue Area

Following the motorization in Bangkok, traffic congestion in the area has deteriorated, while many countermeasures have been implemented by different actors. For example, according to a report by the Traffic and Transportation Department of BMA, the average speed on main roads dropped from 22km/h in 2009 to 19km/h in 2012, whereas the number of vehicles in Bangkok increased from 6.1 million units to 7.5 million units. On the other hand, the modal share of Mass Transit is estimated to increase from 5.8% in 2015 to 20.7% in 2029 (BMA), since the mass transit network will be expanded in Bangkok.

The increase of car use has caused various environmental degradation such as noise pollution, air pollution and increase of Green House Gas (GHG) emission. In fact, the transport sector is estimated to account for more than 30% of GHG emission in Bangkok in 2013. In addition, the percentage would increase in 2020, if an effective countermeasure would not be applied (The Bangkok Master Plan on Climate Change 2013-2023).



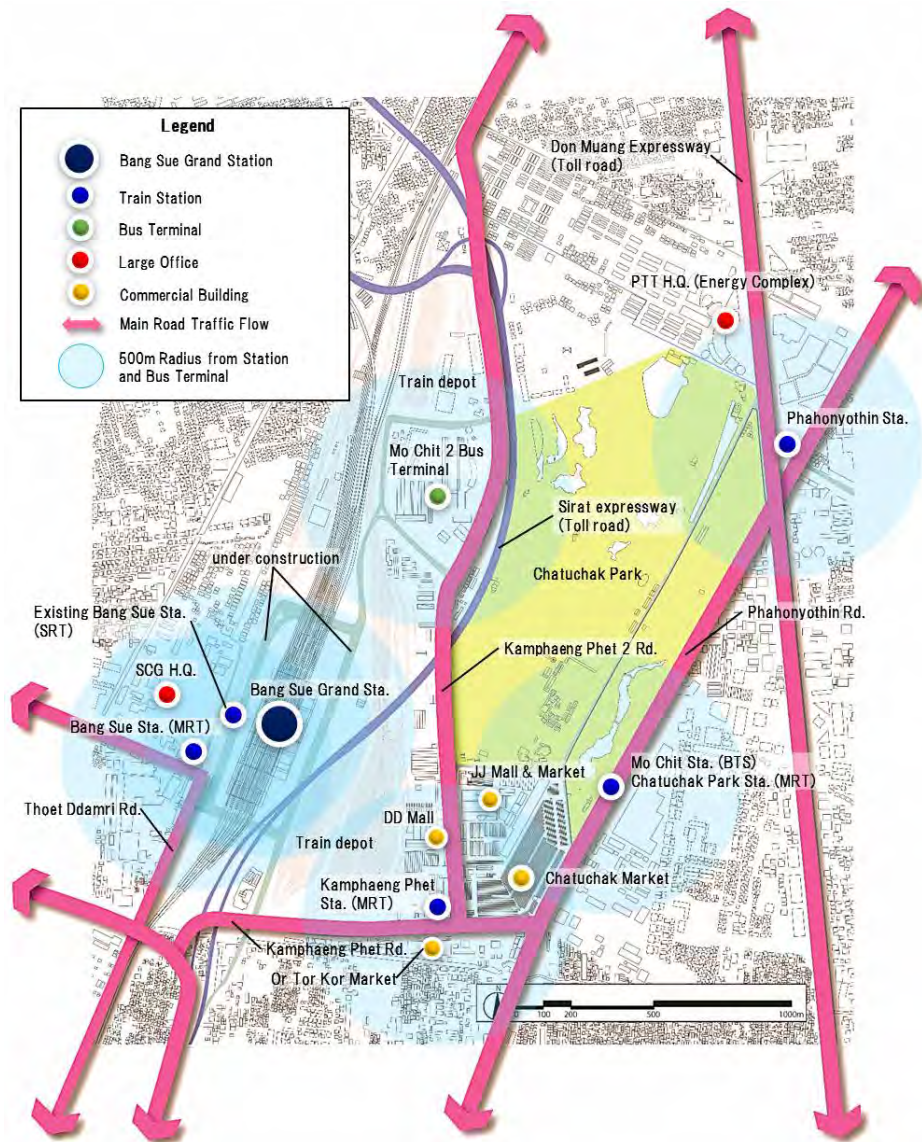
Source: JICA Study Team

Figure 4.12 Traffic congestion in Bangkok (left: near Asok Station, right: Bang Sue Area)

There are several important transport facilities around the Bang Sue Area. For instance, there are several operating railway stations, such as Bang Sue Station for local long distance trains of SRT; Bang Sue Station; Kamphaeng Phet Station and Chatuchak Park Station of MRT; and Mo Chit Station of BTS. According to the last JICA Study, Chatuchak Park Station and Mo Chit Station each have more than 40,000 passengers per day. Besides, the Mo Chit 2 Bus Terminal works as a terminal for both long distance and short-distance buses, operated by Transport Co., Ltd, a state company under the MOT. It has different bus routes to the northern and northeastern Thailand and neighbor countries. Bangkok Mass Transit Authority (BMTA) operates another terminal for

the buses of inner-city routes in the Mo Chit 2 Bus Terminal. The Mo Chit 2 Bus Terminal serves 38 million passengers and 2.3 million bus trips in a year (from October 2015 to September 2016). It means there are more than 100,000 passengers and 6,000 arrivals and departures of buses on average every day.

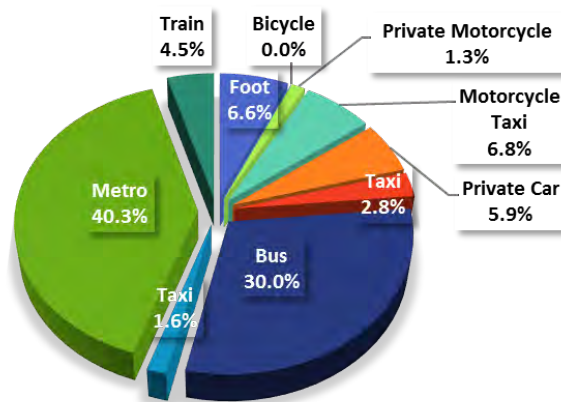
In addition, a number of trips is generated by office workers, residents and visitors around the Bang Sue Area. Head Quarters of PTT and SCG have many commuters on weekdays. Many people visit the Chatuchak market, Or Tor Kor Market and go shopping at commercial buildings such as JJ Mall, JJ Market and DD Mall, especially on the weekends. Furthermore, the Bang Sue Development Area includes some residential areas, which are Zone E (SRT Land) with 509 households and Zone G (KM11) with 1,931 households, according to SRT. The last JICA Study estimated that the numbers of residents are approximately 2,000 in SRT Land and 7,000 in KM11. Hence, regarding the transport to the Bang Sue Area and inner transport in the area, various people used different modes of transport, such as bus, MRT, BTS, Motorcycle Taxi, Private Car and Foot, for their different purpose. Main road traffic flow and facilities around the Bang Sue Area would be shown in the following figure.



Source: JICA Study Team

Figure4.13 Road traffic flow and key facilities around Bang Sue Area

The figure below indicates the modal share based on the interview survey in the Bang Sue Area implemented by OTP in 2016. Metro and bus seem to be often used to visit the area with the share of 40.3% and 30.0% respectively.



Source: OTP, 2016

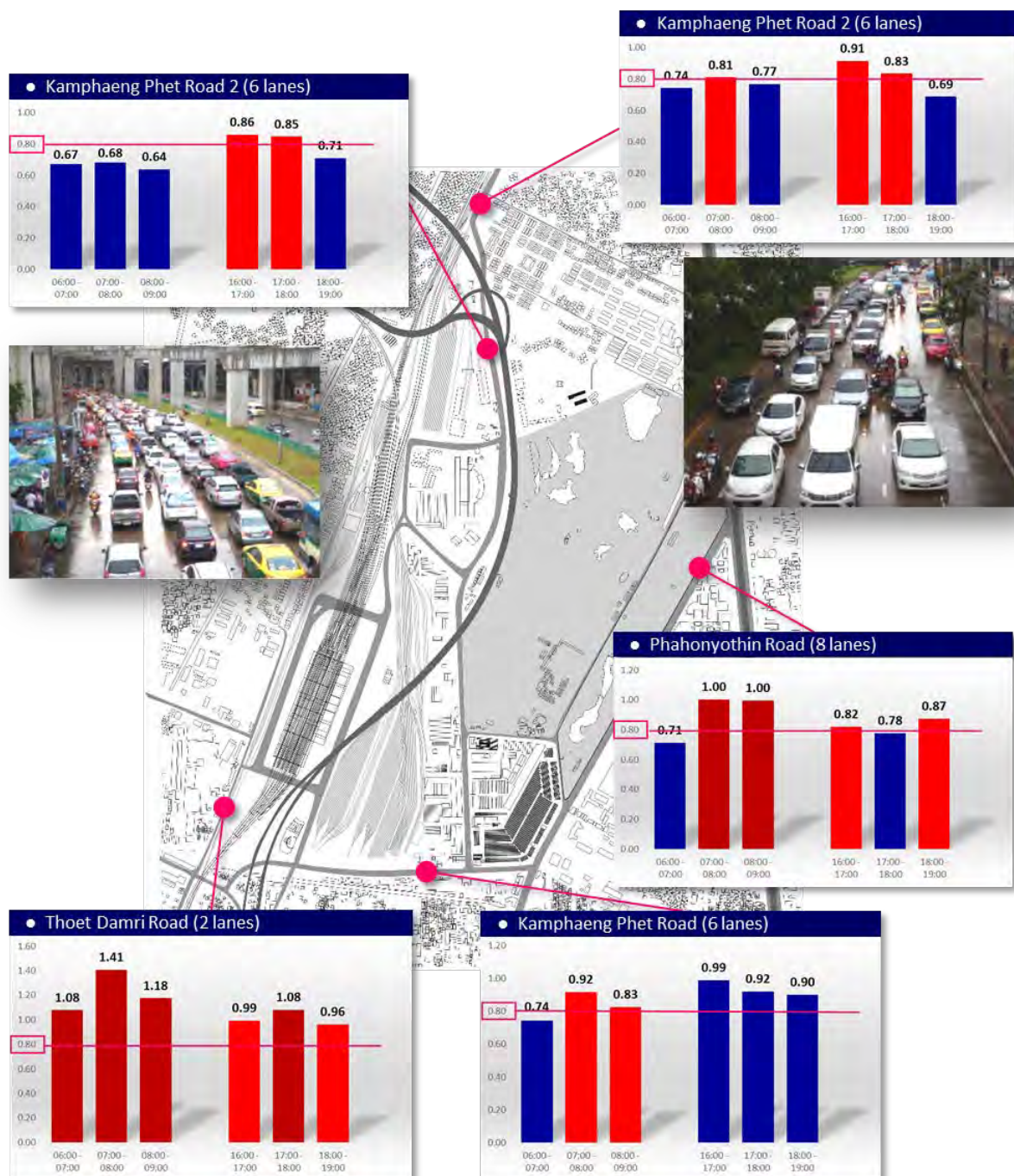
Figure4.14 Modal share in Bang Sue Area based on OTP interview survey (2016)

Regarding road traffic condition around the Bang Sue Area, there are arterial roads with a lot of daily traffic volumes. Kampaeng Phet Road with 6 lanes and Phahonyothin Road with 8 lanes are respectively located in the southern fringe and the eastern fringe of the Bang Sue Area. Kamparng Phet 2 Road longitudinally runs in the area with 6 to 8 lanes. These roads seem to have important roles not only for short trips but also long-distance traffic flows from the city-center of Bangkok to northern part of the city and north-western local regions.

The following figure shows the Volume-to-Capacity Ratio (VCR¹) of arterial roads around the Bang Sue Area in rush hours, calculated using the result of the traffic survey conducted by OTP in 2016. As shown in the figure, all arterial roads around the Bang Sue Area most likely have rush hours with traffic congestion, reaching more than VCR 0.8. Although those roads have more than 6 lanes, current number of vehicles are quite intensive. For instance, the traffic volume of Phahonyothin road reaches around 10,000 PCU in a peak hour. Kamphaeng Phet 2 Road has more than 6,000 PCU/hour in rush hours. Thoet Damri Road, a local road located in the western side of the Bang Sue Grand Station would be mostly congested in rush hours, as its VCR is remarkably high.

In terms of spatial characteristics of traffic flow on the ground level in the Bang Sue Area, it is noted that the whole area is separated in eastern-western direction by the Sirat Expressway, Kamphaeng Phet 2 Road and railways connecting train depots which lie north and south.

¹ VCR is one of the most used indicator to evaluate the level of service (LOS) of road traffic status for a roadway or an intersection. If VCR is greater than 0.8, traffic condition is likely inappropriate with traffic congestion.



Source: JICA Study Team based on the traffic survey by OTP in 2016

Figure4.15 Volume to Capacity Ratio (VCR) of arterial roads around Bang Sue Area



Figure4.16 Kamphaeng Phet Road (left) and Kamphaeng Phet 2 Road (right)

4.3.2 Future Transport Demand and Existing Mobility Plan

It is expected that there would be a vast amount of railway passengers using the Bang Sue Grand Station and other surrounding stations with the expansion of railway networks and the urban development. The table below shows the future demand of daily passengers for the Bang Sue Grand Station and other stations forecasted by OTP. According to the estimate, the passengers of the Bang Sue Grand Station would be about 1.2 million passengers per day by the year 2032.

Table4.5 Passenger demand of Bang Sue Grand Station and other stations estimated by OTP

Station		2022 (people/day)		2032 (people/day)		2037 (people/day)	
		Boarding	Alighting	Boarding	Alighting	Boarding	Alighting
Bang Sue Grand Station	Dark Red Line	105,600	106,100	185,200	185,100	217,100	218,000
	Light Red Line	65,400	65,900	89,000	88,500	96,900	96,900
	Long Distance Train	29,300	29,600	86,100	86,100	106,500	106,100
	High Speed Rail	38,600	38,600	69,200	69,100	85,700	86,100
	Airport Rail Link	30,700	30,800	48,400	48,600	60,300	60,100
	Blue Line	56,700	56,500	121,500	121,300	145,400	144,600
Subtotal		326,300	327,500	599,400	598,700	711,900	711,800
		653,800		1,198,100		1,423,700	
Kamphaeng Phet Station		33,000	33,100	67,000	67,300	82,900	82,900
Chatuchak Station		78,200	77,900	169,400	170,000	195,600	195,500
Mo Chit Station		95,600	95,500	170,600	171,200	184,900	185,700
Total		533,100	534,000	1,006,400	1,007,200	1,175,300	1,175,900
		1,067,100		2,013,600		2,351,200	

Source: OTP, 2016

Based on the study of Bang Sue development plan, passenger demand of the Bang Sue Grand Station is forecasted as shown in the following table by the previous JICA study. Although passengers of Blue Line is not included, the number of passengers is estimated at approximately 1.0 million. The future increase of passengers using the Bang Sue Grand Station will certainly cause the rapid rise of terminal trips around the Grand Station from inside and outside of the development area.

Table4.6 Passenger demand of Bang Sue Grand Station estimated by JICA

Station		2022 (people/day)		2027 (people/day)		2032 (people/day)	
		Boarding	Alighting	Boarding	Alighting	Boarding	Alighting
Bang Sue Grand Station	Dark Red Line	58,352	58,352	94,702	94,702	144,755	144,755
	Light Red Line	101,989	101,989	132,421	132,421	169,598	169,598
	Long Distance Train	13,389	13,389	14,303	14,303	14,954	14,954
	High Speed Rail	0	0	35,170	35,170	40,374	40,374
	Airport Rail Link	0	0	86,586	86,586	137,188	137,188
	Blue Line	-	-	-	-	-	-
Total		173,730	173,730	363,182	363,182	506,870	506,870
		347,460		726,364		1,013,740	

Source: Data Collection Survey on Urban Redevelopment in Bang Sue Area in the Kingdom of Thailand, 2017, JICA

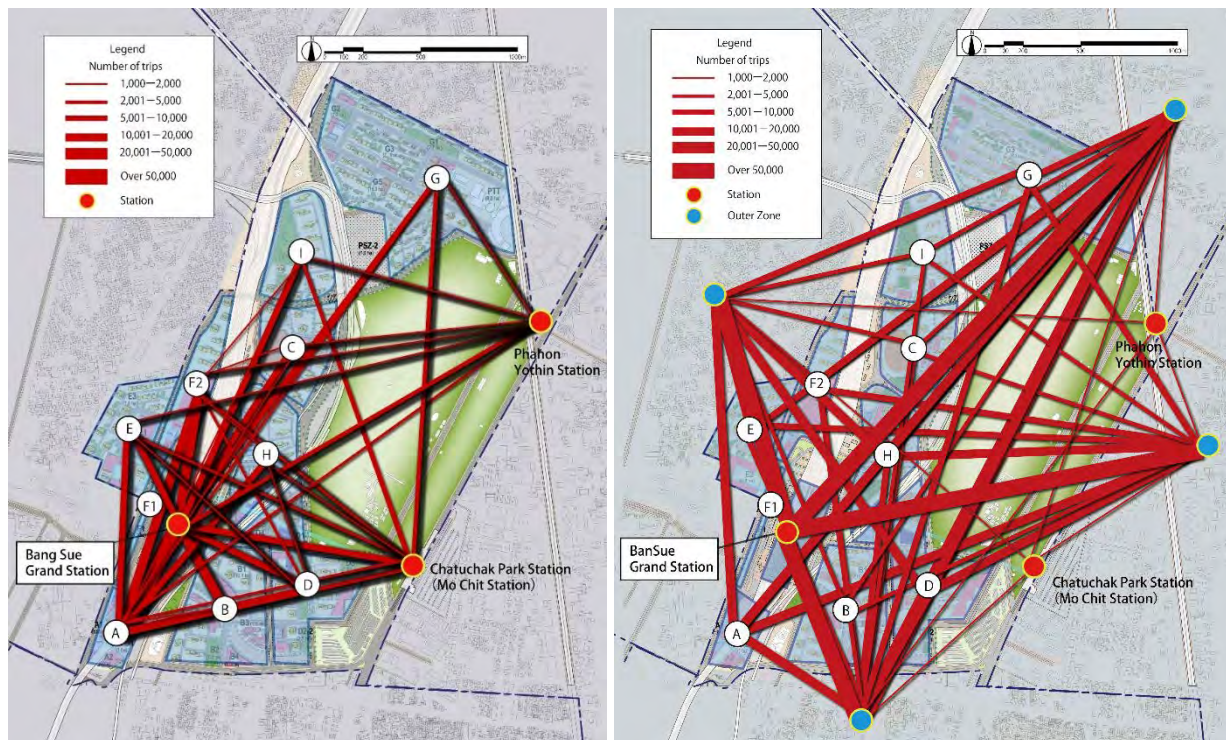
Additionally, the number of trips between inside and outside of the Bang Sue Area and between

inner zones of the Bang Sue Area will increase through the Bang Sue development. The following table indicates the number of generated trips in the Bang Sue Area in each development phase predicted by the previous JICA study². Based on this prediction, more than 600,000 trips per day will be generated in the area in 2032. The figure below describes transport flows between inner zones and flows between inner zones and outer zones in 2032. As shown in the figure, traffic movement around the Bang Sue Grand Station would be highly intensive with a large number of trips which has different characteristics such as short or long distance trips. For example, the trips between Zone A and the Bang Sue Grand Station in 2032 is estimated at more than 600,000 trips per day, whereas the total transport volume of the links between Zone A and the station will be more than that, due to the trips piling up between Zone A and other northern zones.

Table4.7 Generated Trips in the Bang Sue Area

Zone	2022 (trips/day)	2027 (trips/day)	2032 (trips/day)
SRT Land & Zone F	113,600	233,800	233,800
Zone A	17,500	17,500	17,500
Zone B	0	0	97,600
Zone C & Zone I	0	49,800	67,400
Zone D	4,500	4,500	117,400
Zone H	0	0	36,300
KM11	0	54,000	54,000
Total	135,600	359,600	624,000

Source: Data Collection Survey on Urban Redevelopment in Bang Sue Area in the Kingdom of Thailand, 2017, JICA

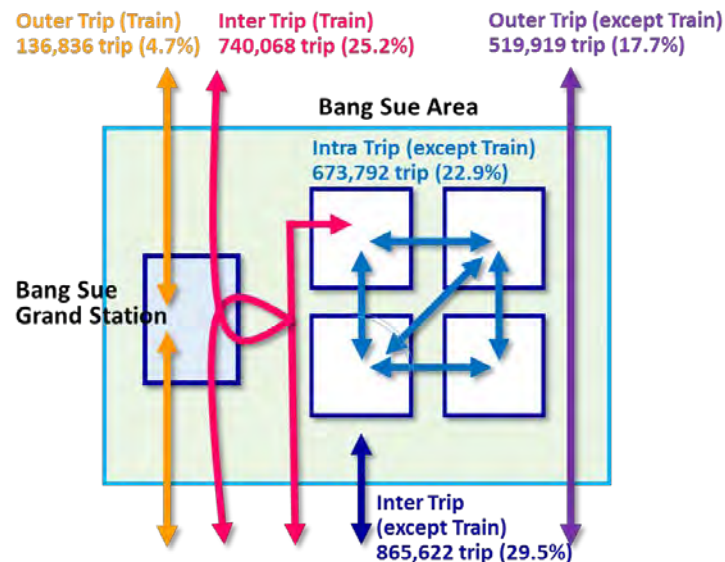


※ Walking and BRT trips in the area and railway trips are excluded, since those OD trips were not predicted in the previous JICA study.
Source: JICA Study Team (Result of demand forecast by Data Collection Survey on Urban Redevelopment in Bang Sue Area in the Kingdom of Thailand, 2017, JICA)

Figure4.17 Transport flows between inner zones(left) and transport flows between outer zones and inner zones (right) per day in 2032

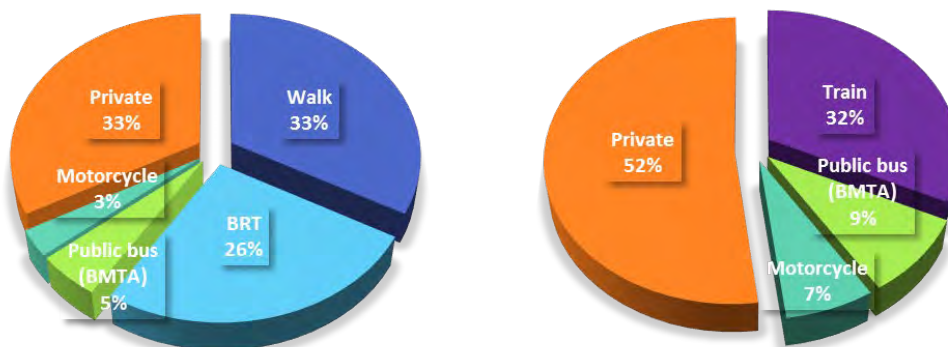
² In the previous JICA study, the number of generated trips were calculated based on the planned floor area in the development plan. In the Bang Sue development plan, the relocation of the Mo Chit 2 bus terminal from Zone C to the neighbor land of the Mo Chit station of BRT is taken into account.

The trip numbers in the Bang Sue Area including trips by passing through vehicles and modal share in 2032 were estimated by the previous JICA study as shown in following figures. According to the prediction, more than 800,000 inter trips and more than 500,000 outer trips are forecasted for 2032. In addition to the intra trips, these large movement needs to be considered for the Bang Sue development. Regarding the modal share, while both walk and private account for 33% of inner trips, private occupies more than 50 % of inter trips, since inter trips tend to be more long distance movement than inner trips.



Source: JICA Study Team (Result of demand forecast by Data Collection Survey on Urban Redevelopment in Bang Sue Area in the Kingdom of Thailand, 2017, JICA)

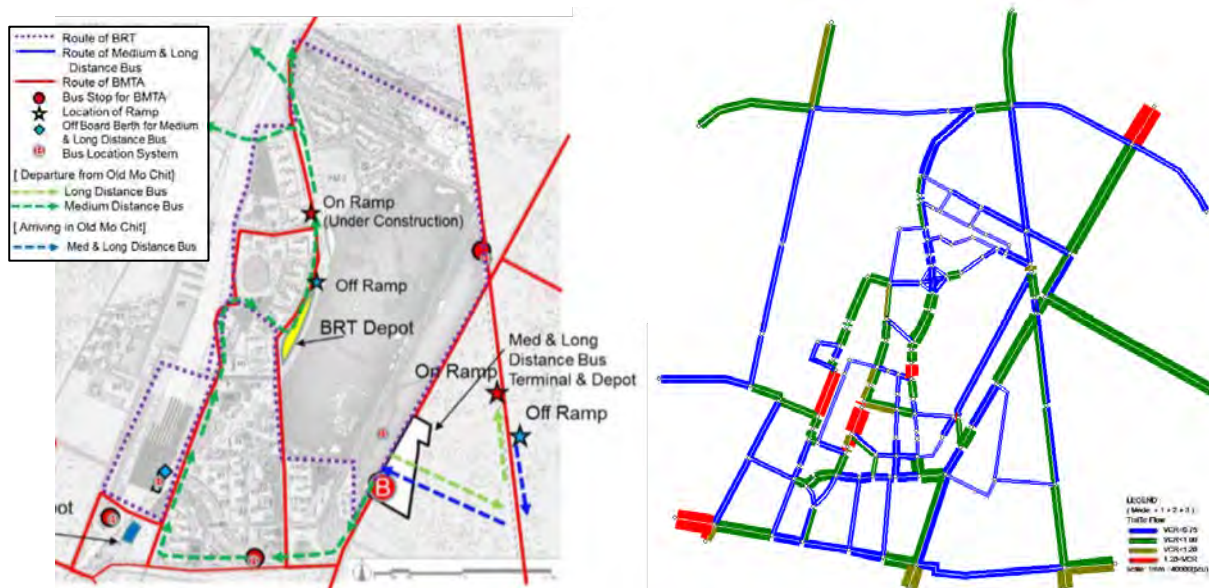
Figure4.18 Trip number in Bang Sue Area in 2032 estimated by previous JICA study



Source: JICA Study Team (Result of demand forecast by Data Collection Survey on Urban Redevelopment in Bang Sue Area in the Kingdom of Thailand, 2017, JICA)

Figure4.19 Inner trip modal share (left) and inter trip modal share of Bang Sue Area in 2032 estimated by previous JICA study

In order to manage the increasing traffic, the public transport planning including the BRT network plan for the Bang Sue Area was considered in the previous JICA study. However, based on the result of traffic assignment by the study, even if the BRT plan is implemented, traffic congestion of the road network, particularly around the Bang Sue Grand Station, seems to still remain as shown in the following figure.



Source: Data Collection Survey on Urban Redevelopment in Bang Sue Area in the Kingdom of Thailand, 2017, JICA

Figure 4.20 Public transport planning (left) and result of traffic assignment in 2032 for the Bang Sue Area in previous JICA study

4.3.3 Mobility Issues for Bang Sue Development

Based on the above situation and analysis of future traffic demand, following mobility issues would be highlighted.

(1) Management of increasing traffic

The development of the Bang Sue Grand Station and the Bang Sue Area will cause dramatic increase of traffic demand around the area. The mobility for different people, who move to/from the Bang Sue Grand Station and developing facilities, such as commuters and residents of development zones and railway users need to be considered. On the other hand, existing road network is already suffering with traffic congestion. Therefore, if effective countermeasures are not implemented, those increasing traffic will seriously deteriorate the traffic condition not only in the Bang Sue Area but also the surrounding areas. In addition to the road network plans and transport services for inside the area, the connectivity between inside and outside of the Bang Sue Area needs to be well considered. Furthermore, comfortable last/first one mile transport system and network connecting zones and stations should be developed.

(2) Securement of accessibility inside the Bang Sue Area

The circulation lines of people in the Bang Sue Area would be split in eastern-western direction by railways of different levels, elevated expressways and Kamphaeng Phet 2 Road, which run north and south. Moreover, distances between each zone seem to be fundamentally larger than the walking sphere, which is roughly assumed around 400m or five minutes by walking. These characteristics of the existing transport network and traffic conditions could hinder the circulation of urban activities. Thus, the securement of accessibility between zones and facilities in the area, in particular in eastern-western direction, should be tackled in order to vitalize urban activities and realize the integrated Bang Sue development. In addition, for general roads in Bangkok,

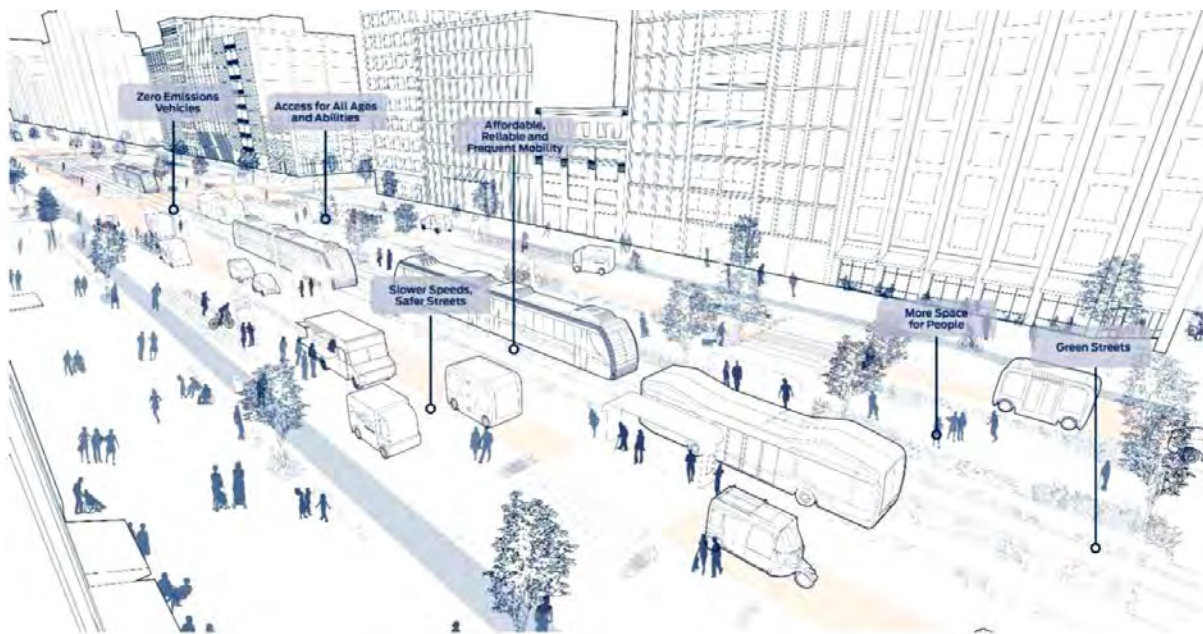
pedestrian spaces are not sufficiently secured, and pedestrians are often unable to walk comfortably. Responding to an aging society is also an important social problem, and it is necessary to develop a barrier-free traffic environment that allows everyone to walk comfortably and move.

(3) Response to staged development of the Bang Sue area

Since the development of the Bang Sue area is promoted in stages by dividing the development zones, it is necessary to flexibly and carefully examine the treatment of existing facilities and the prospects of traffic demand in accordance with the gradual development plan. Traffic systems that require large-scale infrastructure development, such as monorails and track systems such as AGT, for example, need to be carefully considered because it is not considered easy introducing them in accordance with such phased development.

(4) Creation of attractive mobility and urban space

As a New Gateway of Bangkok and the platform for innovation, one of the key development issue for the Bang Sue area is how to realize the attractive urban environment in terms of urban activity, living and economic investment. Therefore, creative and attractive mobility and urbanism which contribute to increasing the city value and enhancing the regional economy need to be pursued for the Bang Sue Area. Recently, new street design and urban planning principles considering autonomous vehicles has been developed worldwide. For instance, as shown in the following figure, principles of new urban planning proposed by National Association of City Transportation Officials (NACTO) in 2017 includes ensuring several transport choice through the city, street design considering autonomous vehicles, real-time traffic operation and management, constraints of car use in the area and so on.



Source: NACTO, (2017). Blueprint for autonomous urbanism

Figure4.21 Blueprint of street design with new mobility systems proposed by NACTO

(5) Pursuing affordable, flexible, comfortable, reliable and safe transport

In Thailand, there are different types of transport modes in terms of size, affordability and flexibility of movement. Each mode has its role in supporting the daily lives of the local people. In addition, comfortability, reliability and safety of transport system are also important factors. Hence, affordable, flexible, comfortable, reliable and safe transport system and infrastructure for all of the people visiting the Bang Sue area need to be pursued.

(6) Building a transportation system that is friendly to the natural environment and urban environment

Increase of traffic movement could affect the natural environment and urban environment, through greenhouse gas emissions, air pollution and noise issues. In the development of the Bang Sue area, which aims to be a model of other cities as a smart city, low carbon and environmentally-friendly transport system should be promoted for the Bang Sue Area.

(7) Establishment of economically sustainable urban transportation system

In order to realize an economically sustainable transport for the Bang Sue Area, it would be indispensable to consider the development and implementation structure and financial scheme for the mobility system in the Bang Sue Area. A sustainable structure could be realized only through the collaboration and partnership of related actors including public and private sectors. This is because the quality of service and the financial feasibility of the mobility would often face a trade-off. In addition, it is important to establish a structure which can continually improve the transportation system by reflecting opinions of diverse stakeholders such as end users and local residents.

4.3.4 Concept of Smart Mobility for Bang Sue Development

These urban transportation issues in the Bang Sue area cannot be solved by simple measures such as introducing a new mode of transportation. In addition to considering urban traffic policies that have been mainstream, such as road planning, BRT and mobility management, it is necessary to pursue an integrated and innovative traffic system that meets the challenges of the Bang Sue area.

In addition, various technological advances and changes have been made in recent years regarding urban mobility, and it is important to examine the mobility in view of the trends in the world and future possibilities. Global trends in urban mobility include the development and introduction of new technologies and concepts such as automated-driving, ride-share, and MaaS³, the expansion of applications (such as Grab and Uber), electronic toll collection (E-payment), the development of public transport-oriented development (TOD), the analysis of big data, and the development of real-time traffic control technology.

In this context, 'smart mobility' in the Bang Sue area is considered as a comprehensive concept: " the sustainable mobility balanced socially, environmentally and economically which provide solutions for urban transport challenges in the Bang Sue development, using remarkably advancing technologies ." The following shows the direction of smart mobility to overcome

³ MaaS, Mobility as a Service, is a notion to provide a more comfortable mobility service through integrating different transport modes by using advancing technologies, recognizing mobility as a service, originated from Finland.

mobility challenges in the Bang Sue area.

- a) Creating attractive urban place, public transport network and pedestrian network
- b) Realizing affordable, flexible, comfortable, reliable and safe mobility for all of the people with consideration for innovative transport systems such as MaaS and autonomous vehicles
- c) Ensuring several transport choice through the Bang Sue area including innovative mobility
- d) Promoting low carbon travelling and decreasing environmental impact
- e) Incorporating utilization of real-time dynamic data of urban activities and transport movements using IoT technologies into management and planning of the city and mobility
- f) Establishing sustainable structure and financial scheme for the mobility

From the point of view of smart mobility, the following key concepts of the Bang Sue area are proposed.

- A city where people can walk around comfortably and safely: Walkable City
- A city where people can move comfortably, easily, and environmentally-friendly
- A city where people can enjoy the abundant space with proper management of multimodal transportation systems

4.3.5 Concept of Smart Mobility for Bang Sue District

Smart mobility for the Bang Sue Development is not only to introduce a new mobility system using advancing technologies, but also to create sustainable transport and attractive urban places, managing traffic increase by the development. In order to realize this, it would be important to accurately analyze the regional characteristics, future demand, and traffic problems of the Bang Sue area using advanced IoT technology. Then, the detailed transport plan of the Bang Sue area needs to be examined. Measures such as transport demand management as well as hardware measures such as roads and urban traffic infrastructure should be addressed with consideration for utilization of advanced technology.

In this section, the concept and measures of smart mobility in the Bang Sue area will be examined as a concept design. Based on the results of this study, it is recommended to conduct more detailed surveys and analyses in order to precisely implement road traffic flow analysis including road networks outside the Bang Sue area and future transport demand forecasts. In addition, it is important to formulate detailed measures and plans and to promote various actions comprehensively.

Based on the urban vision to be aimed at from the viewpoint of smart mobility mentioned above, the main concepts on smart mobility in the Bang Sue area are set as follows:

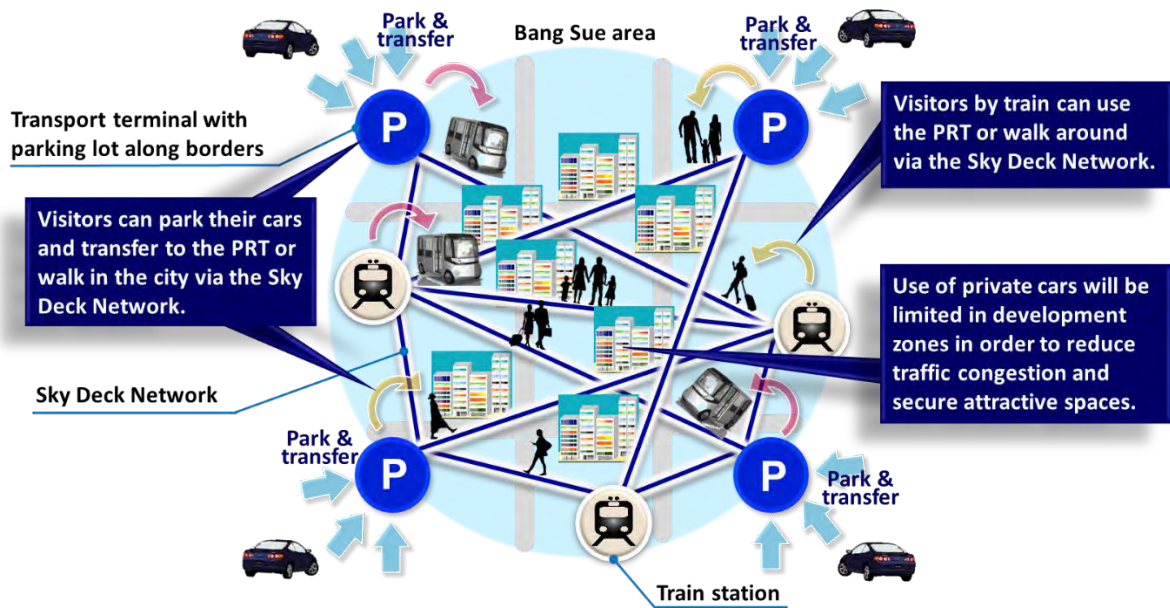
- Development of multilayered transport infrastructure and introduction of environmentally-friendly regional public transportation services
- Congestion alleviation and expansion of public spaces by developing parking lots at boundary areas and managing traffic flow in the area
- Traffic management using IoT

In order to respond to traffic demand that increases with development and to alleviate traffic congestion, to separate moving lines by automotive traffic from pedestrians and public transport, to realize a Walkable City that is easy for everyone to move, and to establish last one mile transport, a sky deck network will be developed to connect the Bang Sue Grand station, development zones, and transport bases.

On top of this, an automated driving system called PRT (Personal Rapid Transit) could be

introduced on the sky deck in the future, and public transport services using small, environmentally friendly EVs could be established using IoT. In addition, a parking lot will be installed at the outer edge of the development area, and visitors from outside the area will stop their private cars there and be able to move inside the Bang Sue area by foot or PRT. On the other hand, for roads in zones, the congestion of roads will be alleviated by suppressing the inflow of automobiles and promoting the use of public transportation.

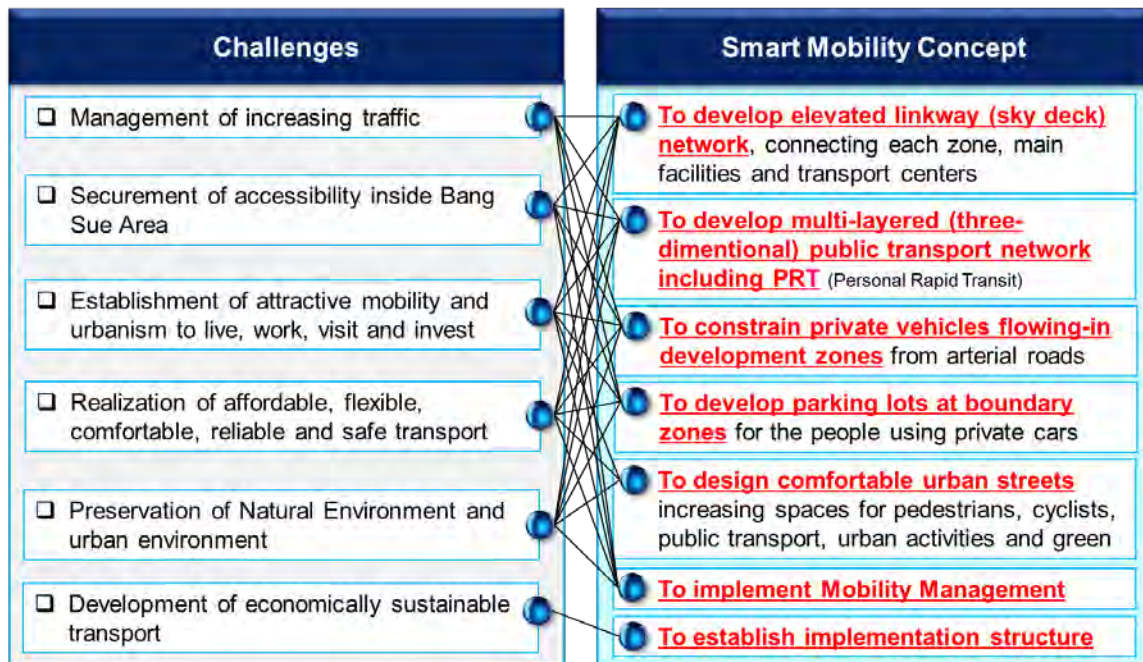
Roads in zones with reduced traffic volume due to vehicle inflow restraint form attractive urban spaces by redistributing road spaces and expanding spaces for pedestrians, bicycle roads, public spaces, and green planting belts. The following figures show images of the main concept of smart mobility in the Bang Sue area.



Source: JICA Study Team

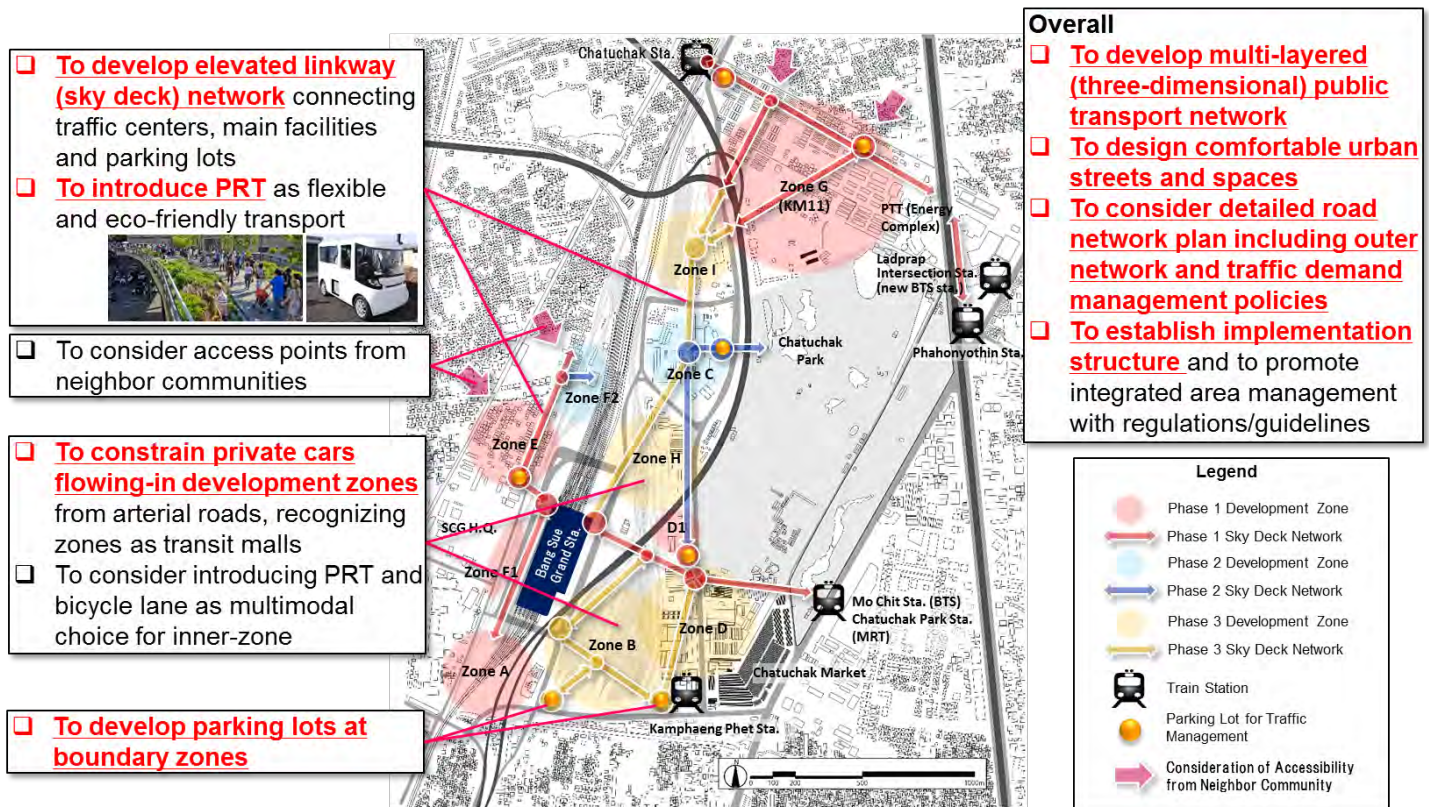
Figure4.22 Conceptual Image of Smart Mobility in the Bang Sue Area

The following figure indicates the correspondence between urban transport challenges and smart mobility initiatives in the Bang Sue area.



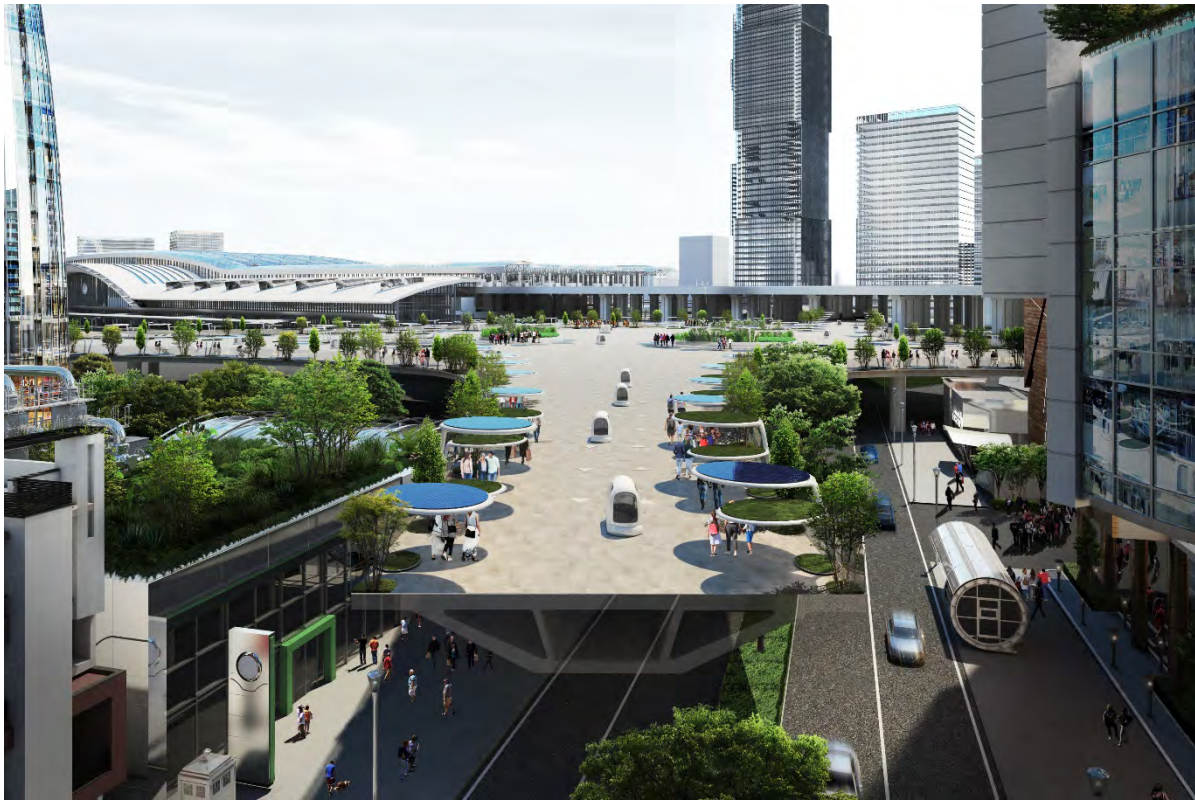
Source: JICA Study Group

Figure4.23 Transport Challenges and Smart Mobility Concept of Bang Sue Development



Source: JICA Study Team

Figure4.24 Concept of Smart Mobility of Bang Sue Development



Source: JICA Study Team

Figure4.25 Conceptual Image of Sky Deck Network and PRT

The following shows the concept design of the main smart mobility policies.

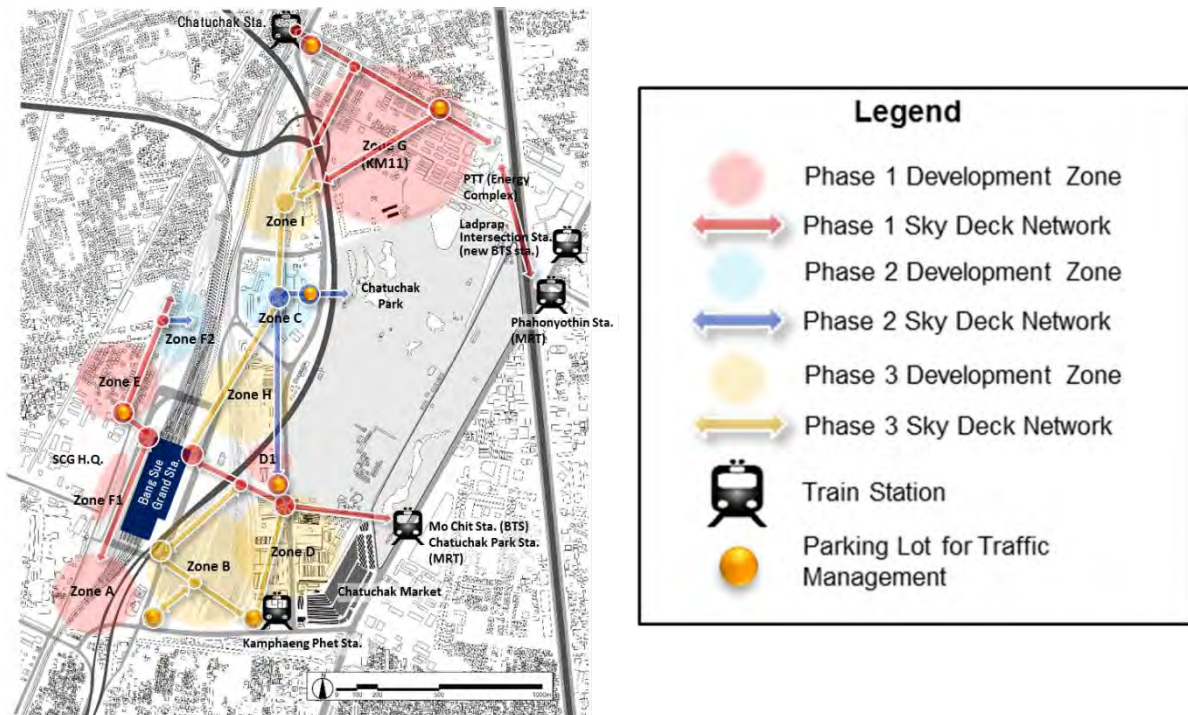
(1) Sky Deck network

As described above, traffic demand in the Bang Sue area will increase as a result of development. In particular, there are concerns that traffic congestion will deteriorate and traffic services will decline in the future. In addition, since the circulation in the development area would be separated by the Sirat expressway and the Kamphaeng Phet 2 Road and railways, the east-west connectivity should be enhanced to realize integrated development for the Bang Sue Area.

As a solution for these issues, “the development of elevated linkway network as a sky deck network connecting transport centers, main facilities and parking lots located in boundary zones is proposed”. Then, “modes on sky deck network could be limited in pedestrians, bicycles and new small transport”. The sky deck network will enable to vertically segregate automobiles and pedestrians and to realize smooth inter-and-inner zone trips as a ‘Walkable City’. The main functions and roles of the sky deck network are as follows. The detailed basic policy of the plan is described in the Development Project Plan on Chapter 5.

- Forming traffic lines that enable people to move safely and comfortably as a Walkable City, by separating car and pedestrian traffic lines and alleviating road congestion on the ground
- Connecting Bang Sue development zones, strengthening access between zones and facilities, and enhancing the convenience and real estate value of the entire development area
- Introducing an environmentally friendly public transport system on the sky deck network to provide flexible and comfortable transport services that can be used by everyone
- Promoting the use of public transport and other transport modes by creating a traffic environment that does not depend on the use of automobiles on roads

- Enhancing barrier-free mobility that is easy for everyone to move, such as the elderly and disabled
- Contributing to the creation of attractive urban spaces by utilizing them as greenery spaces and lively activities



Source: JICA Study Team

Figure 4.26 Conceptual Design of the Sky Deck Network



Source: JICA Study Team

Figure 4.27 Good Example of Pedestrian Network in Bangkok (National Stadium Station)



Source: JICA Study Team

Figure4.28 Conceptual Image of Bang Sue Development and Sky Deck Network: Night View

(2) Smart Public Transport: PRT (Personal Rapid Transit)

In the Bang Sue area, enhancement of public transport system would be indispensable in order to manage the trips from stations and parking lots at fringe areas to development zones and inter-zone trips. The following table shows the comparison of the functions of each urban transport system. This study proposes the introduction of an environmentally friendly compact EV called PRT system on a sky deck network, based on the characteristics and challenges of Bang Sue development described above and the comparison of urban transport systems.

Track-based public transport systems such as monorails and AGT are considered to be difficult to cope with gradual development in the Bang Sue area because of the large construction cost, construction period and the difficulty of partial introduction. Furthermore, since the route is only on the track to be constructed, it is not suitable for public transport which bears short-distance traffic demand and last mile mobility deployed in the area. There is a high possibility that the BRT system will be in conflict with the road traffic. Chronic road congestion could reduce service levels and could easily lead to new traffic congestion. Installation of special lanes may ensure a certain level of service, but in this case, the construction cost and construction period may increase, and it may become a new factor that spatially divides the whole town.

On the other hand, introduction of the PRT system on the sky deck network has a low overall introduction cost and a short introduction period even considering the construction cost of the Sky Deck. It can be introduced in accordance with the gradual development, and it is also possible to provide the traffic service to flexibly respond to the traffic demand which differs depending on the development situation and the time zone.

Table4.8 Comparison of Urban Public Transport Systems

	MRT	Monorail/AGT	LRT	BRT	PRT
Image					
Quick-Deliverability	✓✓	✓✓	✓✓	✓	✓
Construction Cost, Time	Heavy construction & long time are needed (×)			✓	✓✓
Phased Development	×	×	✓	✓✓	✓✓
Operation Flexibility	×	×	×	✓	✓✓
Transport Maximum (PPHPD*)	✓✓ 60,000	✓✓ 18,000 - 26,000	✓ 14,000	✓ 2,500 - 4,000	✓ 7,200 - 9,600
Cover Distance	Long	Long-Middle	Middle	Middle	Short
Eco-friendly	✓✓	✓✓	✓✓	✓	✓✓

*PPHPD: Passenger Per Hour Per Direction

Source: JICA Study Team

The main functions and roles of the PRT installed on the sky deck network are shown below. The basic policy of the plan and the draft plan in accordance with the phase development plan shall be described in detail in the Development Project Plan, Chapter 5.

- By separating car and public transport flow lines, alleviating road congestion on the ground and safe and providing comfortable moving flow lines and transport services
- Along with the development of the sky deck network, connecting development zones, increasing the accessibility between zones and facilities, and improving the convenience and real estate value of the entire development area
- Providing flexible, comfortable and affordable transport services that can be used by anyone
- Promoting the use of public transport and other transport modes by creating a traffic environment that does not depend on the use of automobiles on roads
- Enhancing barrier-free mobility that is easy for everyone to move, such as the elderly and disabled
- Improving future service levels while incorporating advanced technologies such as autonomous driving technologies
- Providing efficient public transport services in response to demand, such as platoon-driving services with specified routes for routes and time zones where demand is high, and demand-responsive services for time zones where demand is low
- Becoming a symbol of smart mobility
- Convenient payment service using e-payment will be introduced

It should be noted that the PRT system is considered as one of environmentally friendly and desirable transport mode as a public transport system not only on the sky deck network but also on the road. Especially, in a road section in which a vehicle inflow restriction is performed, which will be described later, it is considered as a transport mode flexibly corresponding to a short distance trip demand.

(3) Restriction of Vehicle Inflow into Development Zones and Development of Fringe Parking Lots

Traffic congestion is already occurring on roads in the vicinity of the Bang Sue area, and there is a concern that further deterioration will occur due to the increase in traffic demand associated with urban development. Especially, the existing transport plan is supposed to be most likely insufficient to secure smooth traffic in the road network around the Bang Sue area. In order to cope with such problems, it is considered necessary to investigate and study wider-area road network plans and to examine measures to promote the use of public transportation in the future. For example, it would be important to consider the development of a bypass, the development of an underpass for passing traffic, and the improvement of crossing points at bottlenecks of the road network as medium-and long-term solutions.

Meanwhile, traffic condition in the development area is also concerned about road congestion as a result of the development of each zone. In this study, restrictions on the inflow of automobiles into development zones and the development of fringe parking lots at the outer edges of the development area along main roads are proposed, in order to respond to such increased traffic demand to development districts, alleviate traffic congestion in the zones, and create attractive urban spaces.

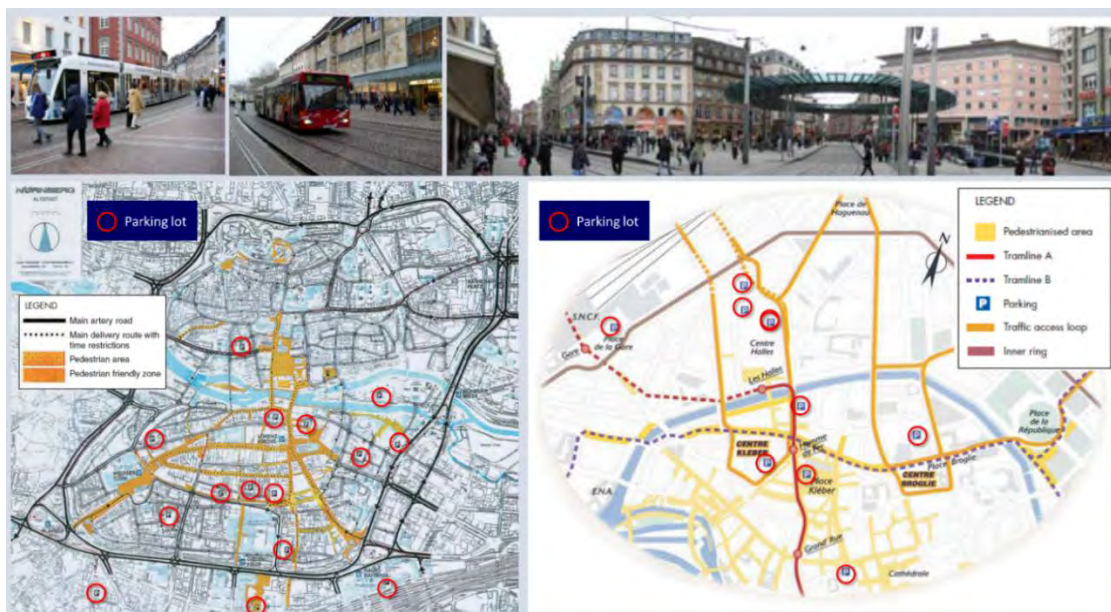
It is assumed that restrictions on the inflow of automobiles into the development area are mainly applied to ordinary visitors, except residents, disabled persons, logistics vehicles, emergency vehicles, maintenance and construction vehicles of in-zone facilities, and waste collection vehicles. In addition, it is important to promote the use of public transport by restraining the use of automobiles through package measures which consist of fringe parking lots, sky deck network development, provision of public transportation services. Furthermore, it would not be necessary to regulate the passage of the Kamphaeng Phet 2 road and the Kamphaeng Phet road, which are currently responsible for a large number of traffic passes, however it is important to suppress the inflow of traffic from existing arterial roads into development zones. It is assumed that automatic gates are installed at the entrances to and from roads in the development zone so that pre-registrants can smoothly enter and exit. Besides, it is necessary to formulate rules to promote these mechanisms in cooperation with related actors.

In addition to restricting the inflow of automobiles into the zone, a fringe parking lot will be installed as a facility for receiving automobile traffic of ordinary visitors inside and outside the zone and for switching to other transport modes. In order to prevent traffic congestion in the vicinity of a parking lot, priority shall be given to the location of parking lot buildings, real-time information provision systems for parking conditions, user registration systems, automatic gates, electronic toll collection systems, and traffic countermeasures in the vicinity of parking gates. Moreover, when introducing these measures, it is necessary to reconsider the way of the mandatory parking lot to be attached and design improvement policies in town development guidelines and zone development plans. Main functions and roles of restricting the inflow of automobiles into the development zones and developing the fringe parking lot are shown below.

- Reducing traffic congestion around the development area by suppressing the inflow of passing traffic visitors by private vehicles into development zones
- Reducing the use of vehicles by visitors and promote the use of public transport through the development of fringe parking lots, tariff measures, sky deck network and provision of public transport services which support last mile trips from parking lots as a package of measures
- Examining the restrictions of inflow traffic, the reduction in the number and width of lanes, and

the reallocation and design of road spaces, and considering roads in the development zones as urban place for abundant urban activities

The policy which constrain the traffic inflow to the urban center developing parking lots at fringe zones of the center was implemented in many cities, especially in European region such as Strasbourg, France; Munich, Nuremberg; and Freiburg, Germany. The following figure shows pedestrian areas limiting car use in Nuremberg and Strasbourg. Strasbourg, for example, developed LRT network and banned car use at the center of the city. A number of parking lots along the LRT and at fringe zones of the car restraining area was delivered through public-private partnership. As a result, “the removal of cars from the city center allow space for pedestrians and cyclists has improved the quality of life everyone, for those living and working in the city, and tourists” (European Commission, 2004).



Source: European Commission, (2004). Reclaiming city streets for people: Chaos or quality of life (Edited by JICA Study Team)
 Top photograph: 2 left; Transit mall at Freiburg, Germany (MLIT, Japan), right; Pedestrian area at city center of Strasbourg, France (The Prince's Foundation, (2015). Strasbourg: Regaining the public realm)

Figure4.29 Pedestrian area with limitation of car use in Nuremberg (left) and Strasbourg (right)



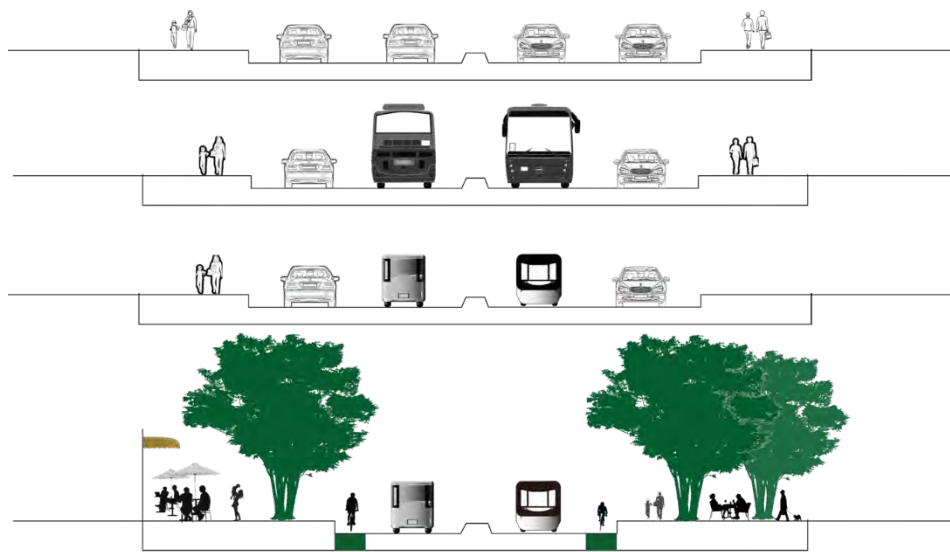
Source: JICA Study Team

Figure4.30 Conceptual image of fringe parking lot

(4) Street design

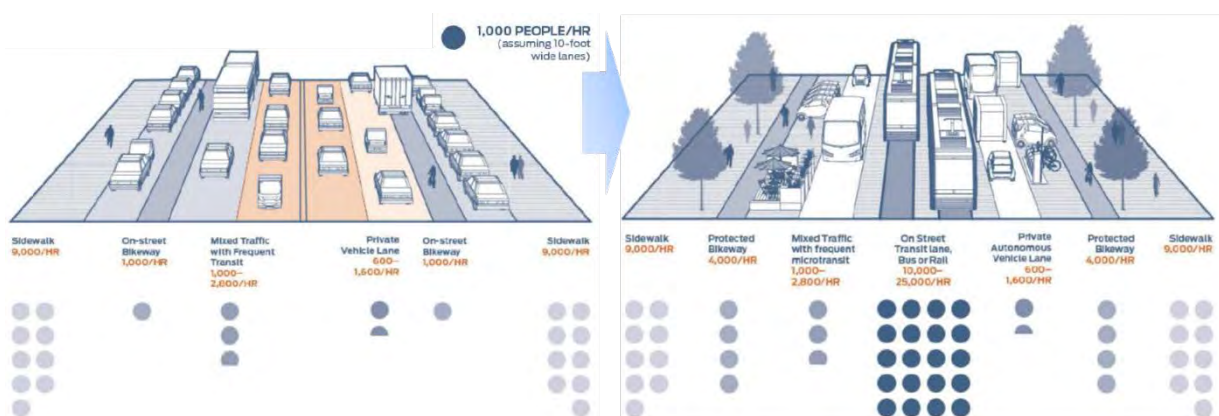
By restricting the inflow of automobiles, the spaces for road traffic in the Bang Sue area could be reallocated and redesigned from traffic oriented road to urban public places for connecting people to people, society, green and so on. On the basis of this road space reallocation, more comfortable urban streets increasing spaces for pedestrians, cyclists, public transport, different urban community activities and green spaces, decreasing spaces for private vehicles should be addressed.

The following figures show images of road space reallocation and redesign. Constraining private vehicles and introducing the fittest transport mode corresponding to the trip demand by routes and areas, more green and human places can be created.



Source: JICA Study Team

Figure4.31 Image of reallocation of road space



Source: NACTO, (2017). Blueprint for autonomous urbanism

Figure4.32 Redesign of roadside space by introduction of MaaS and autonomous vehicle

(5) Other Smart Mobility Related Measures

1) Transport information management system

In addition to monitoring and managing local transport information in real time through GPS and CCTV, the introduction of transport information management and provision systems that provide traffic information to users in real time will be sought. Details are summarized in the Smart City Platform section along with other information management systems.



Source: JICA Study Team

Figure4.33 Smart City Center managing urban transport information in Seoul City

2) Bicycle lanes and personal mobility lanes

Many roads in Bangkok City do not have sufficient road space for bicycle using, and it seems that bicycle use is not much at present. However, the potential demand for bicycle use as an environment-and health-friendly urban transport mode like green mobility may increase in the future. Actually traffic measures such as Share Cycling are expanding worldwide, and are also set in the Thai government's smart criteria. Besides, not only bicycles, but also small-sized personal mobility such as electric kickboards, electric scooters and segways are spreading rapidly.

In the Bang Sue area, which aims to become a gateway of new technology development, it would be essential to develop new personal mobility and technology development related to these sharing services, and to improve traffic environments with a view to future development. Therefore, it is proposed to address the transport environment of bicycles and other personal mobility by providing a personal mobility lane in the road space.

3) Car sharing and ride share

It is expected that the promotion of car sharing and ride share will contribute to the decrease of traffic congestion and effective utilization of urban space by reducing the ownership of automobiles, restraining the use of automobiles, reducing the number of parking facilities, and increasing the use of other transport modes. In the Bang Sue area, the experimental introduction could be examined for zones where the housing development which the resident expects to demand is promoted at high density.

4) Sustainable implementation structure and area management of smart mobility

In order to promote smart mobility measures in the Bang Sue area, cooperation among various related organizations is indispensable. On the one hand, it would be necessary to establish an organizational structure for implementing and managing the smart mobility policies on a proactive basis and to establish a framework and rules for the implementation. Besides, it would be also important to consider not only smart mobility but also the entire development of the Bang Sue area as a whole, in order to establish such an implementation system and framework. The implementation structure proposed in this study and the mechanism for financial procurement and management will be described later in the Development Project Plan, Chapter 5.

5) Exploration of detailed road and urban transport plans and implementation of necessary measures

In the future, traffic congestion is expected to worsen in road networks including areas around Ban Sue Grand station and outside the Ban Sue area due to the increase in traffic demand caused by the Bang Sue development. On the other hand, as the development of each zone is going to proceed, consideration of necessary countermeasures would be an urgent issue. On top of that, it is recommended that Thai government carefully carries out transport demand forecasting in more detail with survey and analysis of latest conditions in the future. Based on the proposal of smart mobility in this study, it would be important to formulate comprehensive and detailed measures and plans, and to promote various actions comprehensively.

4.3.6 Evaluation of Smart Mobility Policies by Traffic Simulation

(1) Outline of Traffic Simulation

Traffic simulation analysis was carried out for the Bang Sue area in order to quantitatively evaluate smart mobility policies. Target policies to be evaluated were development of sky deck network, introduction of PRT system, restriction of vehicle inflow into development zones and development of fringe parking lots. Effects of these measures on road traffic flow at peak times and alleviation of traffic congestion were examined.

The year to be evaluated is 2032, when the development of each zone and the development of infrastructure were expected to be completed. Traffic simulations are performed for the following three scenario cases, and the results are compared and analyzed to verify the effect.

- Case 1: Without smart mobility measures in 2032
- Case 2: Sky deck network and PRT system installed in 2032
- Case 3: Sky deck network and PRT system, vehicle flow restrictions into development zones and fringe parking installed in 2032

(2) Conditions for Traffic Simulation

Setting of basic conditions of traffic simulation is shown in the following table.

Table4.9 Basic condition for traffic simulation

Item	Setting basic conditions
Target year	• 2032
Target time	• 1 hour at peak in the morning (assuming that the peak rate is 6% based on the actual situation of road traffic in Bangkok) ⁴
Scenario	• Case 1: Without Smart Mobility Measures in 2032 • Case 2: Sky Deck Network and PRT system installed in 2032 • Case 3: Sky Deck Network and PRT system, Vehicle Flow Restrictions into Development Zones and Fringe Parking Installment in 2032
Zoning	• Traffic zone setting are based on previous JICA study (see Chapter 7 of the previous report)
OD Table (Distributed Transport Volume)	• Established based on the results of previous JICA study (see Chapter 7 of the previous report) • Supplementary predictions were made for OD table by transport modes which was estimated in the previous JICA study (refer to the following table in detail).
Traffic network	• Established for roads in and around the entire Bang Sue Development Area, assuming that the road network in the development plan has been developed.

Source: JICA Study Team

With respect to OD data by transport estimated in the previous JICA study, supplementary predictions were made since OD tables (traffic volume distribution) of walking trips and BRT were not predicted in the development areas in the previous JICA study, and the OD table data as a base was prepared. Based on this assumption, OD table data for each scenario was prepared and used as input data. The following table describes the setting conditions for each complementary prediction including PRT and each scenario.

⁴ Set based on interviews with Thai traffic planning consultants (around 10% in urban areas of Japan in many cases; however, throughout-day traffic including night time tends to be large in Bangkok).

Table4.10 Complementary forecasting method for distributed transport volume (OD table)

Item	Complementary method
1) OD table of BRT	- In the previous JICA study, BRT was estimated to have a trip share of 26% in the Bang Sue area. - For this reason, the number of BRT trips for each OD pair is calculated in proportion to the total number of trips for each OD pair of automobiles, motorcycles, and route buses for which data are available, using the total number of trips of 26% of the total number of trips in the district as the total number of trips.
2) OD table of PRT	- The Smart Mobility Plan of this study proposes the introduction of PRT, not BRT, as a means of local public transportation, but assumes that the role and use characteristics of PRT are close to those of BRT. - It is also assumed that the PRT is responsible for the OD trip of the complementary BRT as described above because of the lack of data for constructing the traffic sharing rate model, etc.
3) OD table of Walking	Estimated number of OD trips on foot using the pedestrian share curves ($y=-0.464\ln(x)+3.5309$) examined in the previous JICA study, and corrected the total number of known pedestrian trips as a control total.

Source: JICA Study Team

Table4.11 Setting Conditions for Traffic Simulation by Scenario

Scenarios and items		Setting condition
Case 1	OD table	- For trips within the development area, the amount of distributed traffic supplemented by the method described above is applied. - Distributed traffic volume of PRT is distributed according to the ratio of automobiles, motorcycles, and route buses. - Domestic and external trips are based on the data estimated at the time of the previous survey.
	Network	Network in which the road network in the development plan has been developed
Case 2	OD table	- It is assumed that the traffic environment of pedestrians is greatly improved by the development of the sky deck network, and that the number of walking trips between zones increases by 30%, and the number of trips is converted from automobile trips by the same amount. - Assuming that the development of sky deck networks and the introduction of PRT will increase the speed and comfort of movement in the development area, it is assumed that 20% of automobile trips between inside and outside development area will be converted to railway trips. - For external trips, the estimates from the previous JICA survey are applied.
	Network	Network in which the road network in the development plan has been developed
Case 3	OD table	- For internal trips, it is assumed that the number of walking trips between zones increases by 30% when there is no sky deck, as in the case of Case 2, and the number of trips changes from car trips. - Assume that 30% of the remaining inter-zone vehicle and motorcycle trips are converted to PRT because of restrictions on vehicle use within each zone. - For trips between in and outside development area, it is assumed that the development of sky deck networks and the introduction of PRT will increase mobility within the development area. In addition, it is assumed that the use of automobiles is restricted in each zone, parking lots will be developed in the fringe area (parking lot fee measures will be considered at the same time), and road space will be reallocated in the vehicle inflow control section. Assume that 40% of automobile trips between in and outside the development area will be converted to railway trips by such urban development that prioritizes pedestrians and public transport. - At this time, it is assumed that 70% of the vehicle trips in the development area and the vehicle trips between in and outside the developed area are restricted from flowing into the zone (26% of the residential population according to the type of facilities in the previous JICA study) and that the parking lot in the fringe area of each zone is used to accommodate those trips (in the zone where the fringe parking lot plan is planned, 70% of the vehicle trips in which the inflow is restricted are set as trips to the fringe parking lot (sub-zone)). - For external trips, the estimates from the previous JICA study are applied.
	Network	- Network in which the road network in the development plan has been developed - Set fringe parking lots in the basic development plan (set as sub-zones) - Establishment of automobile inflow control section described in the basic development plan (see Chapter 5)

Source: JICA Study Team



Case 1



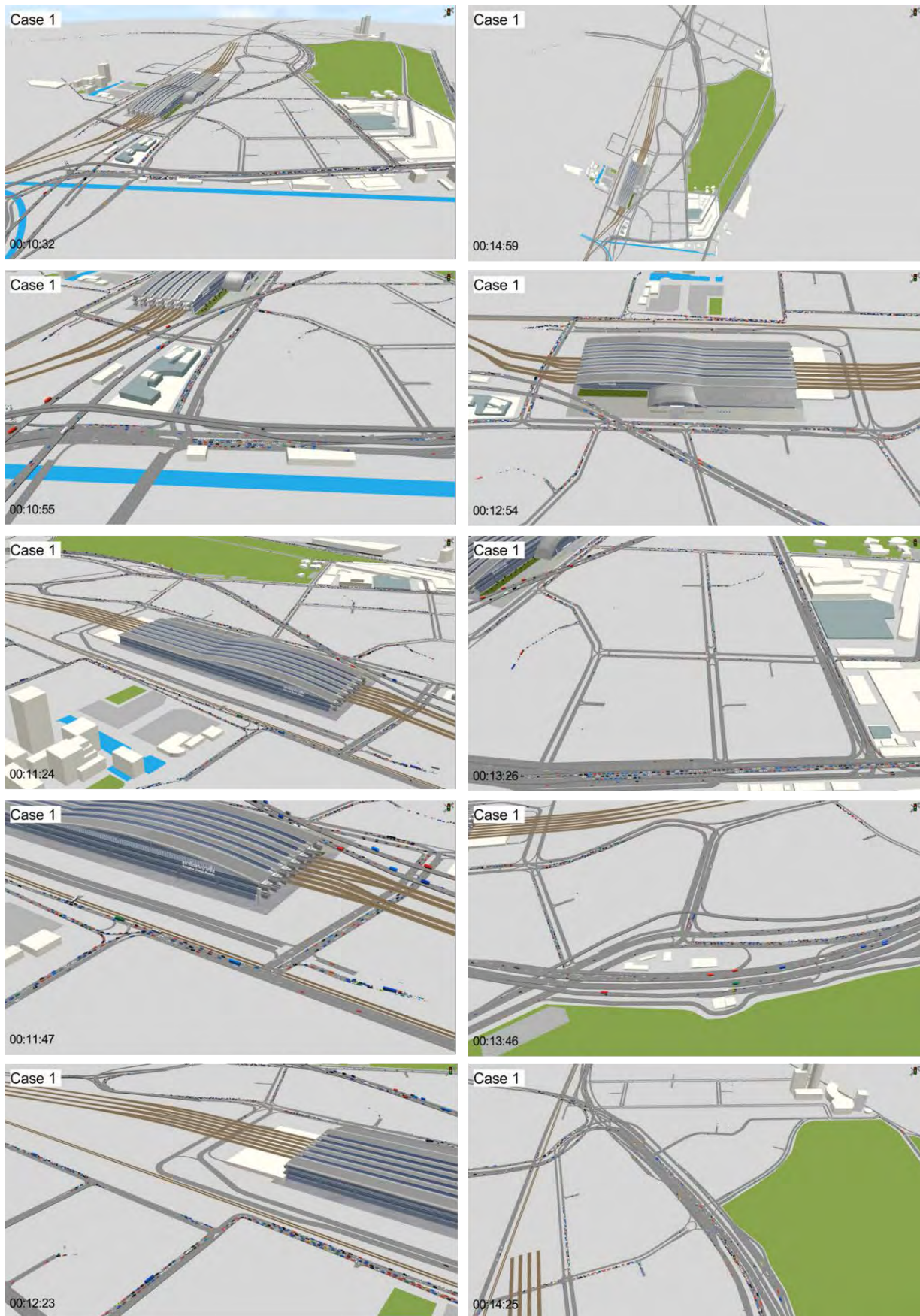
Case 3



Source: JICA Study Team

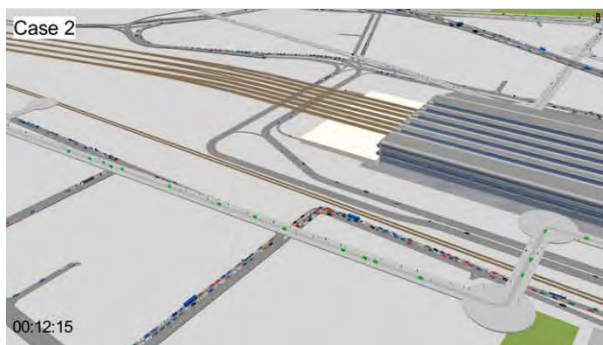
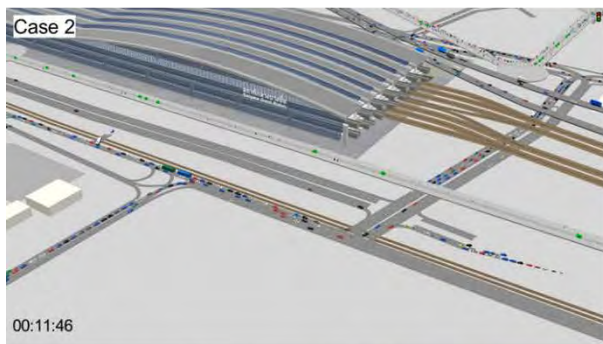
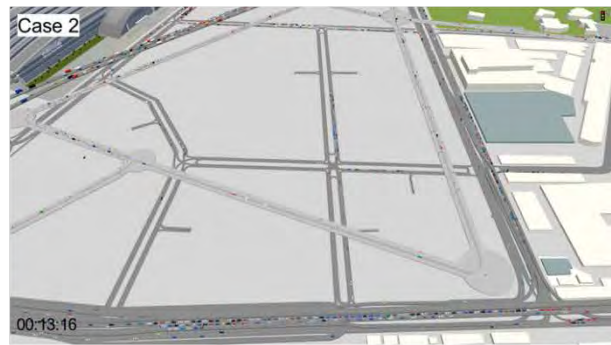
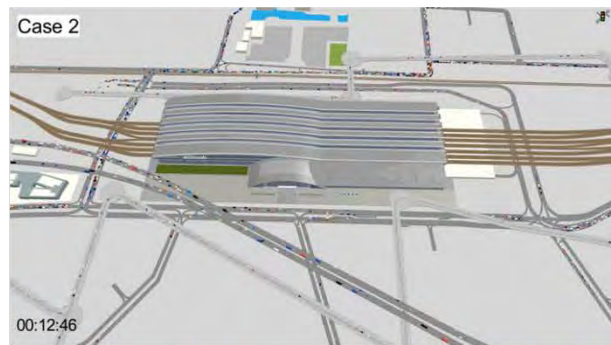
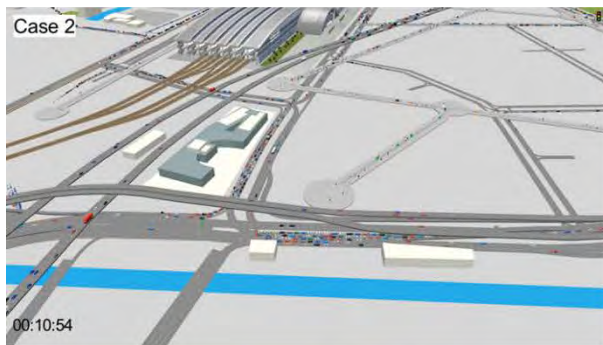
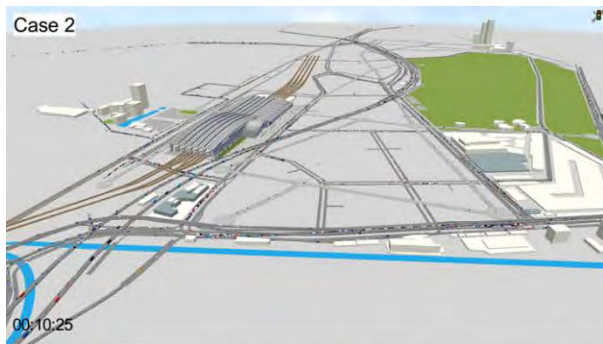
Figure4.34 Formulation of Traffic Simulation Network

(3) Traffic simulation results



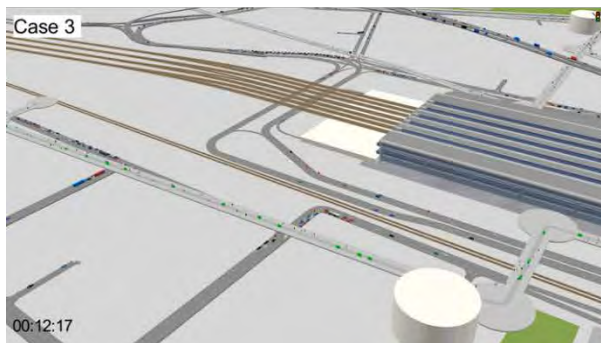
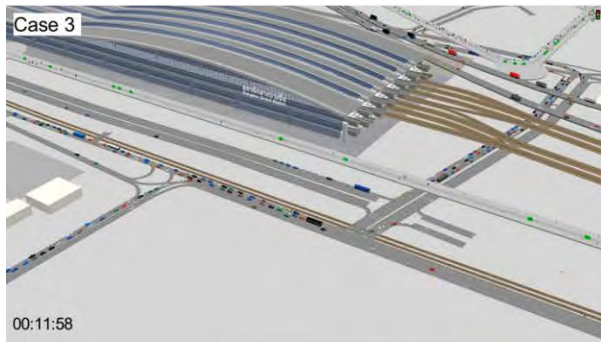
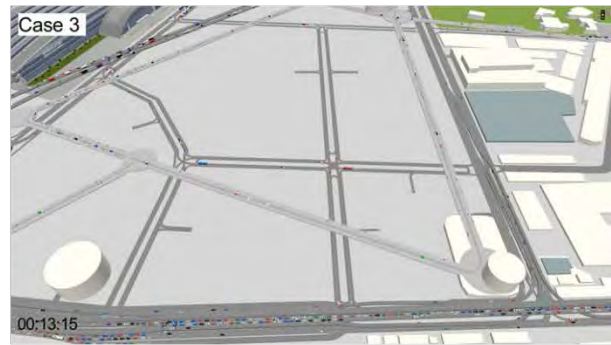
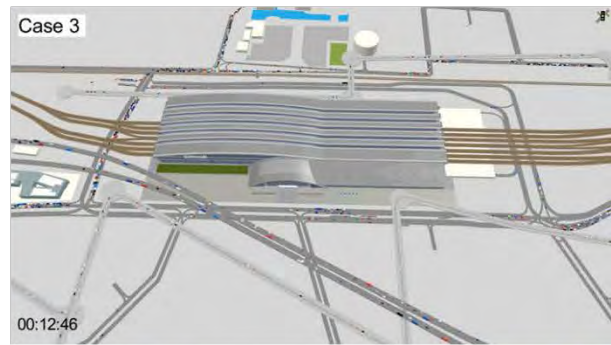
Source: JICA Study Team

Figure4.35 Traffic Simulation (Case 1)



Source: JICA Study Team

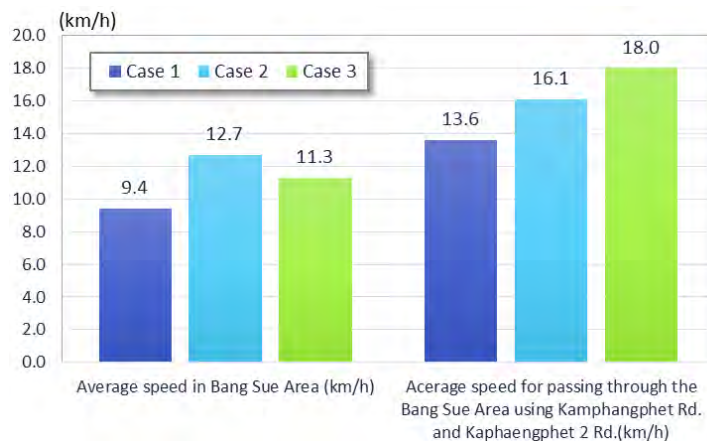
Figure4.36 Traffic Simulation (Case 2)



Source: JICA Study Team

Figure4.37 Traffic Simulation (Case 3)

A comparative graph of the average travel speed according to the result of the traffic simulation is shown in the figure below. Looking at the average travel speed of cars in the Bang Sue area (left in the figure below), the travel speed increased more in Case2 • Case3 than in Case1. Travel speed of Case2 is higher than Case3, this is because the vehicle inflow control sections in zones are installed in Case3, and the traffic congestion alleviation circumstance differs depending on the place. As shown in the right side of figure below), average travel speeds at the time of north-south crossing of the Bang Sue area on the main roads (Kamphaeng Phet road and Kamphaeng Phet 2 road) are 16.1km/h for Case2 and 18.0km/h for Case3 compared to 13.6km/h for Case1. The Case3 scenario is designed to restrain the use of automotive traffic in cities and aim for high-quality urban spaces and Walkable City. In addition to these effects, it is expected that traffic congestion will be alleviated.



Source: JICA Study Team

Figure4.38 Comparison of average travel speed (average speed in Bang Sue area (left) and average speed for north and south passing through the area (right))

The following figure indicates the average travel speed chart for each road section. There are many sections with low travel speeds in Case 1, and chronic traffic congestion occurs in sections with low travel speeds of 10km/h or less. On the other hand, in Case2 and 3, the average travel speed is improved in many sections.



Source: JICA Study Team

Figure4.39 Comparison of average travel speed in each section

Comparison of the area around the Bang Sue Grand station is shown in the figure below. In the roads around the Bang Sue Grand station, the decrease in travel speed due to traffic congestion was remarkable in Case1, however in Case3 in particular, the decrease in travel speed section is reducing. It can also be seen that traffic congestion on roads in the development zone has been almost eliminated by restraining the inflow of vehicles into development zones, particularly in Case3. Travel speeds on Kamphaeng Phet2 roads have also been improved in Case 3.



Source: JICA Study Team

Figure4.40 Comparison of average travel speed by scenario (around Bang Sue Grand station)

In order to grasp the traffic problem in the Bang Sue area and to obtain the implications for future countermeasures consideration, the road traffic congestion points were verified on the basis of the result of the Case1. As shown in the figure below, traffic congestion is a concern particularly in road sections around the Bang Sue Grand station. As described above, the promotion of smart mobility policies can be expected to have a positive effect of alleviating areal traffic congestion, while it is not possible to eliminate all of these bottleneck points. Therefore, it is important to

formulate a road network plan including a traffic network outside the development area and a comprehensive transport master plan including measures to promote the public transport use in line with a detailed development plan in the future.



Source: JICA Study Team

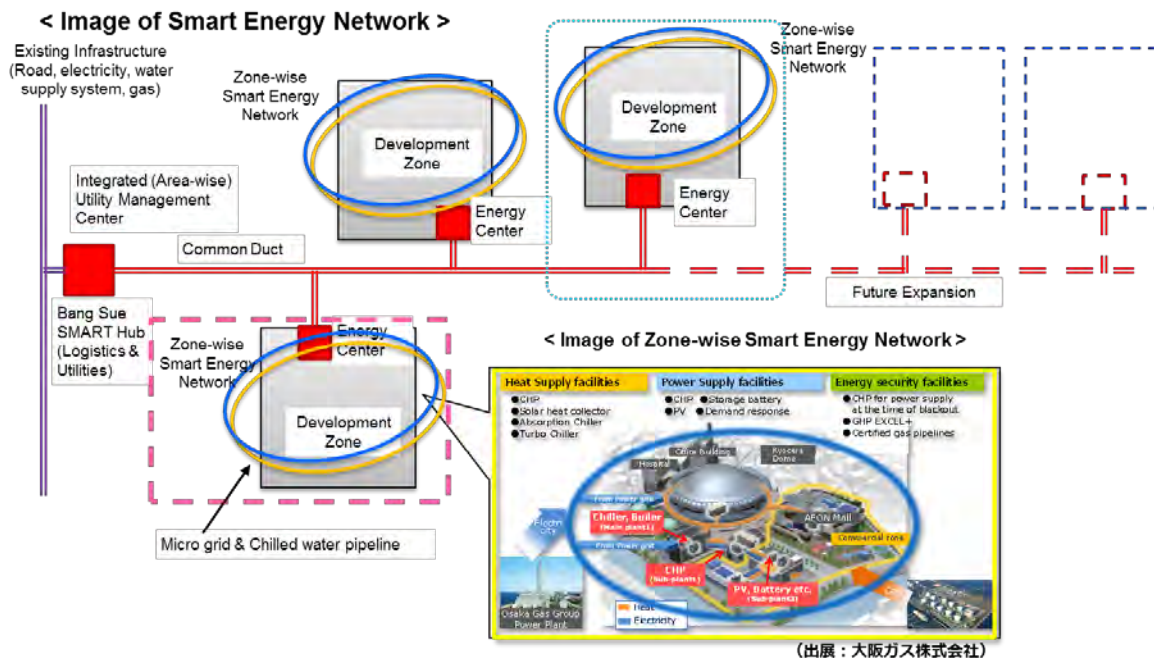
Figure4.41 Assumed road traffic bottleneck points

4.4 Smart Energy

4.4.1 Overview

As PTT-owned gas pipeline has already been installed underground near the existing SRT railroad in the Bang Sue area, the establishment of urban-type power supply/cold heat supply network is expected as an energy source from gas pipeline.

This urban-type power supply/cold heat supply network system, as shown in the following figure, includes the development of urban infrastructure by zone including energy supply points or power network and cold water pipeline, on the sidelines of stepwise development plans in the Bang Sue area. In this system, these energy supply points will be connected, as a network, to power network and cold water pipelines in the future to make the entire area function more effective with energy-saving efforts, aiming to build an energy supply system favorable for smart city.



Source: JICA Study Team.

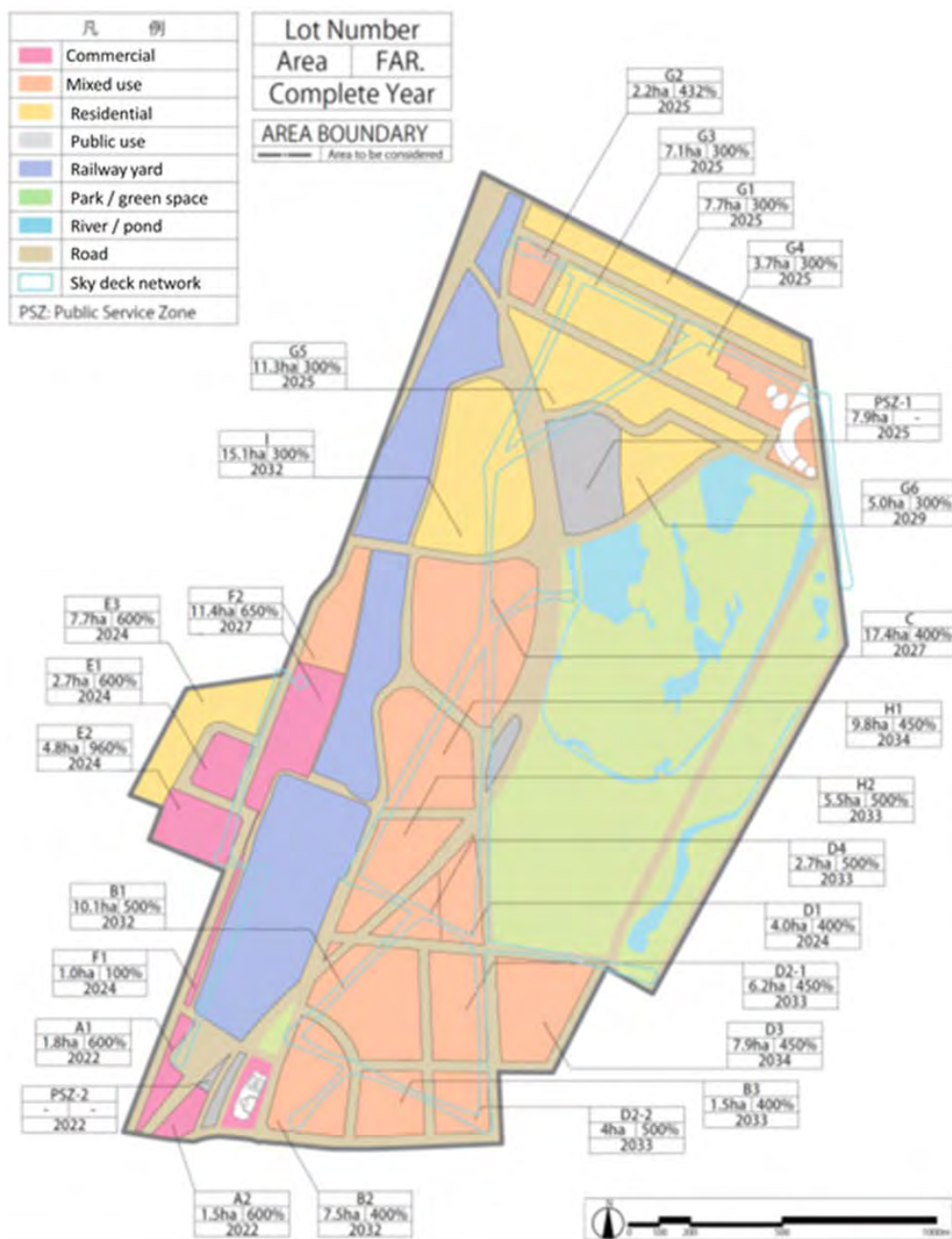
Figure4.42 Smart Energy Network Image in Bang Sue

4.4.2 Conditions for Plan

Planning conditions are organized for urban development in the Bang Sue area before examination on smart energy network in Bang Sue.

(1) Plan for Land Use

Multiple land use is planned on approximately 100 ha of the Bang Sue area, consisting of commercial, business and complex facilities, and residential houses, etc. Figure4.43 shows a land use plan in Zones A to H considered in the study in the past fiscal year.



Source: JICA Study Team.

Figure4.43 Land Use Plan

Figure4.44 shows a layout plan by building use in the Bang Sue area considered in the study in the past fiscal year.



Source: Report produced in the past fiscal year

Figure4.44 Layout Plan by Building Use

(2) Total Development Floor Area by Use

The following table shows the total development floor area by use, drawn up in each zone of the Bang Sue area.

Table4.12 Total Floor Area by Use (m²)

Zone	Office	Retail	Residential	Hotel	Public Facility	Total of floor space according to the zone
ZONE A	80,000	20,200	13,800	50,400		164,400
Subtotal	80,000	20,200	13,800	50,400	0	164,400
ZONE B1	80,000	40,000	257,900			377,900
ZONE B2	39,900	30,020	154,430			224,350
ZONE B3		44,100				44,100
ZONE B4		32,400				32,400
Subtotal	119,900	146,520	412,330	0	0	678,750
ZONE C		29,600	493,000		50,000	572,600
Subtotal	0	29,600	493,000	0	50,000	572,600
ZONE D1			45,360	73,000		118,360
ZONE D2-1		59,850	109,620	41,400		210,870
ZONE D2-2	30,090	20,000	44,100	0		94,190
ZONE D3		60,000	145,060	60,000		265,060
ZONE D4	35,020		64,260			99,280
Subtotal	65,110	139,850	408,400	174,400	0	787,760
ZONE E1 (SRT LAND)	80,080	83,400				163,480
ZONE E2 (SRT LAND)	201,000	50,700	213,900			465,600
ZONE E3 (SRT LAND)			344,320			344,320
Subtotal	281,080	134,100	558,220	0	0	973,400
ZONE F1		9,700				9,700
ZONE F2	119,700	195,130	335,800	90,240		740,870
Subtotal	119,700	204,830	335,800	90,240	0	750,570
ZONE G1		5,000	168,640			173,640
ZONE G2	64,500	6,000				70,500
ZONE G3		5,010	154,750			159,760
ZONE G4		5,000	80,020		6,000	91,020
ZONE G5		5,000	249,870		8,400	263,270
ZONE G6		5,000	107,940			112,940
Subtotal	64,500	31,010	761,220	0	14,400	871,130
ZONE H1	80,000	10,000	239,210			329,210
ZONE H2	75,620	10,050	73,080	50,400		209,150
Subtotal	155,620	20,050	312,290	50,400	0	538,360
ZONE I		5,000	335,580			340,580
Subtotal	0	5,000	335,580	0	0	340,580
Total Amount	885,910	731,160	3,630,640	365,440	64,400	5,677,550

Source: JICA Study Team on the basis of the report produced in FY2018.

(3) Zone Development Schedule

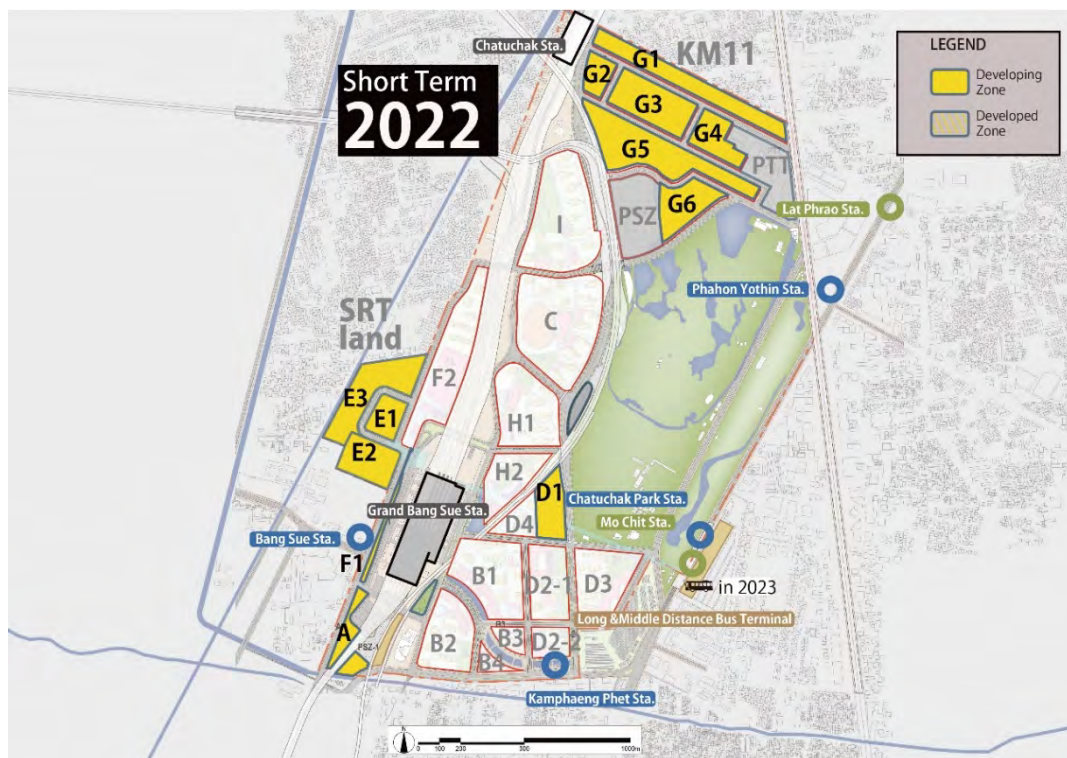
As stepwise development is planned in Phases 1 to 3 in Bang Sue, as shown in Figure4.45, Figure4.51 and Figure4.52, development policies and consideration points are summarized in accordance with development for each phase.

1) Development Plan for Phase 1 (from 2022 onwards)

In Phase 1 to start business by 2022, SRT publicly solicited Zone A developers in July 2019 and future development work includes Grand Station set to open in 2022, Zone E covering SRT head office and Zone F1 near Zone E. In Grand Station, development work for central air conditioning system (2,000 USRT x 5 = 10,000 RT, 1 unit for spare), as cooling system of each building and for emergency generator has been started. When smart energy network is considered in the Bang Sue area, it is effective to examine the entire energy collaboration method with BCP measures for key facilities in mind.

Zone D1, located in the southwest side of Chatuchak Park, east of Bang Sue Grand Station, is to be leased to Department of Medical Services (DMS), Ministry of Public Health, which has promoted the procedure for the development of complex facility “DMS Medical Complex,” consisting of a specialized medical center, a small-scale shopping mall, a restaurant district, etc.

In addition to the above, in Zone G (KM 11), located in the north side of the Bang Sue area, the development schedule has been changed from Phase 2 to Phase 1 and thus its development concept is being considered by SRT. As this Zone G has a certain distance with Zones A, E, F1 and D1 to be developed at the same time with Zone G, economic or geographical restrictions need to be considered at the time of reviewing smart energy network development. Figure4.45 shows development zones scheduled for Phase 1.



Source: JICA Study Team.

Figure4.45 Development Plan in Phase 1

① Bang Sue Grand Station

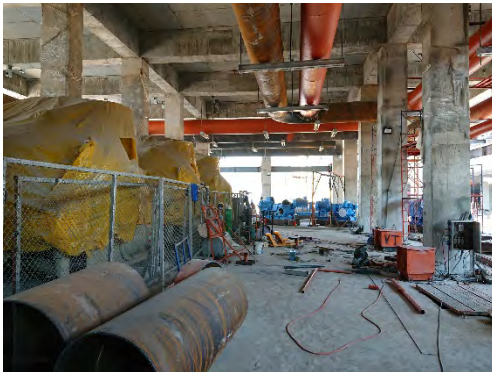
The following photos taken in December 2018 show construction work status for heat source equipment for Bang Sue Grand Station. The machine room is to be constructed in the west side of Bang Sue Grand Station with refrigerating machines to the tune of 10,000 USRT in total.



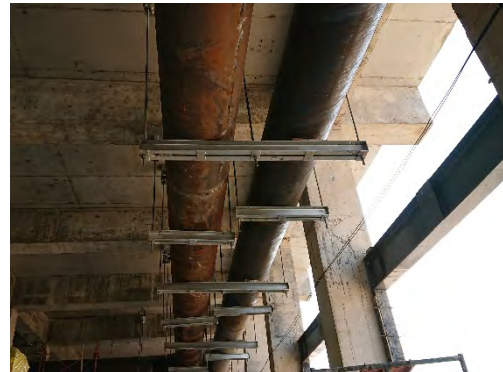
Main entrance in the east side of the station



Exterior of the machine room



Status in the machine room



Pipework for cold water



Motor-driven turbo chiller
(2,000 USRT x 5 units)



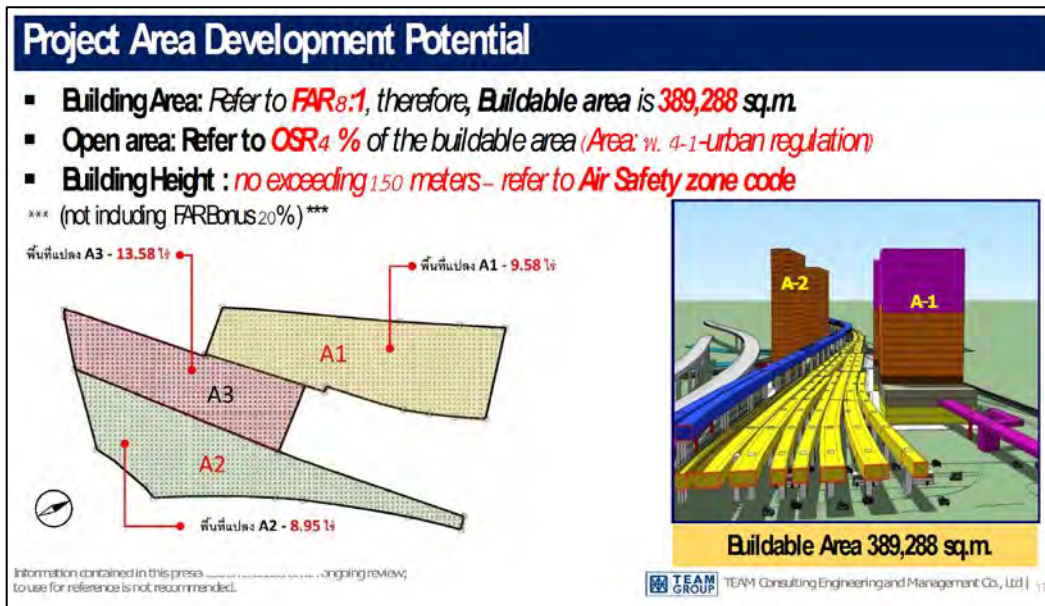
Water pump

Source: JICA Study Team.

Figure4.46 Construction status of Bang Sue grand station

② Planning Overview for Zone A

A 5.1-ha area in Zone A is to be developed as a smart business complex facility. In this zone, commercial facilities, hotels and office buildings are to be built and the zone is closer to Bang Sue Grand Station with possibly high energy demand and to Zone E to be developed coincidentally with Zone A. Therefore, Zone A development can be recognized as a touchstone for the development of wider energy network through zone collaboration.



Source: Material for Zone A market sounding study held on Wed., Oct. 17, 2018

Figure4.47 Development Outline for Zone A (as shown earlier)

③ Planning Overview for Zone E

In Zone E, a 19.2-ha area, located in the west side of Bang Sue Grand Station, is planned to be developed. As this area is close to SRT's head office or other offices, commercial facilities, relatively high-rise housing and SRT's company residence are to be developed.

As SRT's head office is located as a landmark for Bang Sue redevelopment in Zone E, the central function operation, even in the redevelopment process of the Bang Sue area, is expected, consisting of the smart city center controlling the entire city as a core function, together with its head office function, and Smart Energy Management Center (SEMC), integrating and managing energy supply system.



Source: Material for Pahon Yothin Zone E market sounding study

Figure4.48 Development Plan for Zone E (As shown earlier)



Source: Material for Pahon Yothin Zone E market sounding study

Figure4.49 Image Perspective for Zone E

④ Planning Overview for Zone D1

Zone D1 development plan includes a medical complex facility “DMS Medical Complex,” consisting of a small-scale shopping mall and a restaurant district. The medical complex will accommodate around 510 beds for hospital patients and address 2,500 outpatients per day, and equip emergency power source from cogeneration equipment. The following figure shows an image perspective supplied by Thai’s authorities.



Source: Concept paper on “DMS Medical Complex” supplied by OTP.

Figure4.50 Image Perspective on Medical Complex Facility in Zone D1

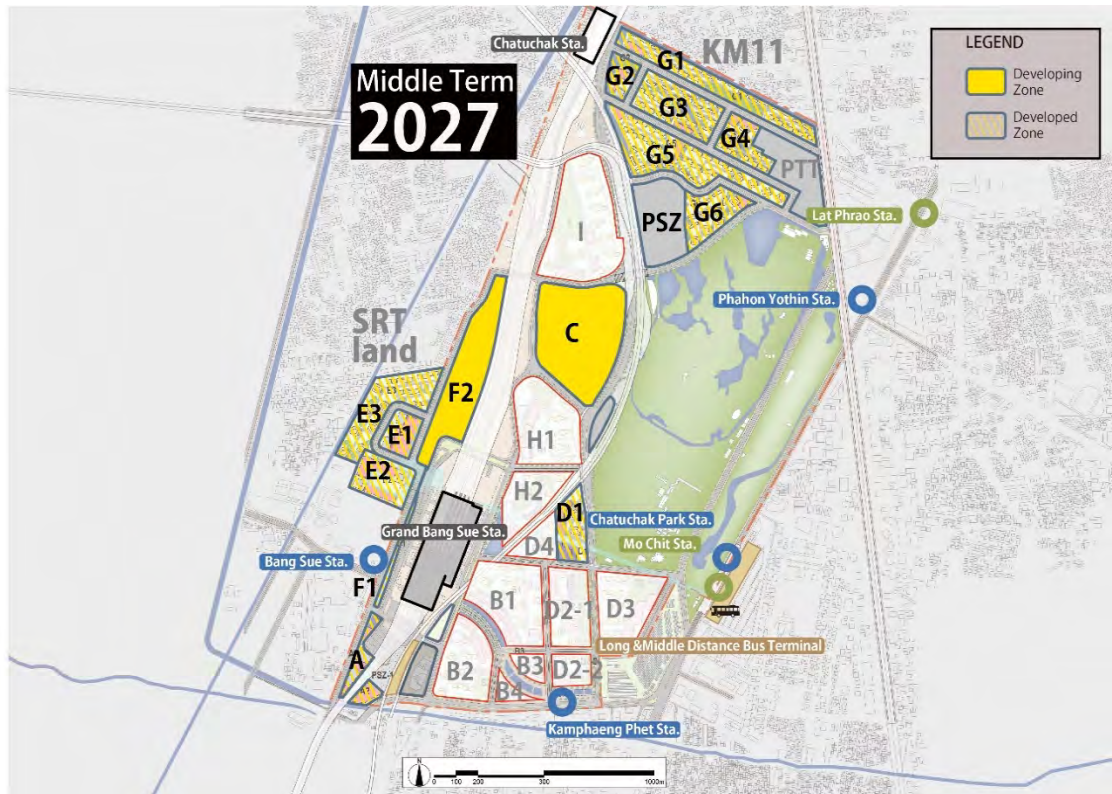
2) Phase 2 (From 2027 onwards)

Phase 2 to start business by 2027 includes Zone F2 with relatively large development work,

located in the west side of Bang Sue Grand Station and Zone C with the current bus terminal in the west side of Chatuchak Park.

In Phase 2, considering zone location features or geographical restrictions and energy demand concentration, etc., the expansion method for energy supply infrastructure (gas pipeline, conduit pipe for cold water, power transmission and distribution network) to be supplied by the energy plant developed in Phase 1 or the location of new energy supply plant need to be considered if necessary.

Figure4.51 shows scheduled development zones for Phase 2.



Source: JICA Study Team.

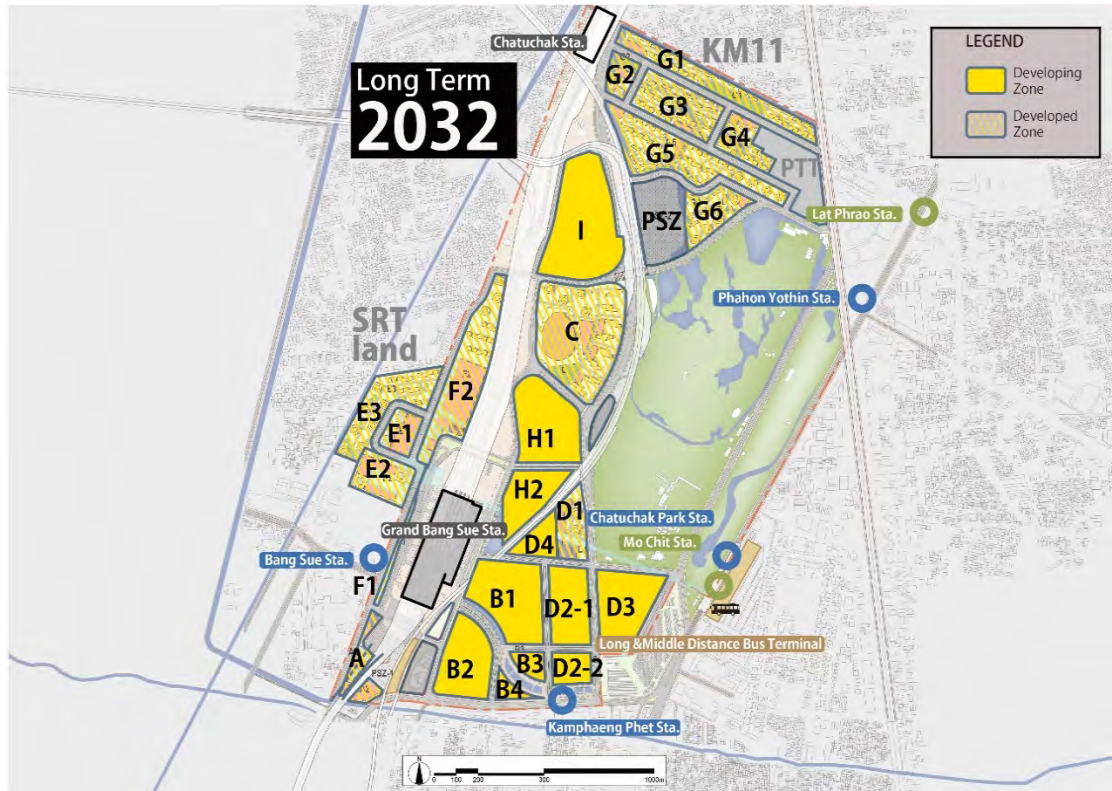
Figure4.51 Development Plan in Phase 2

3) Phase 3 (From 2032 onwards)

Phase 3 development plan to start business by 2032 mainly covers the east side of Bang Sue Grand Station.

Phase 3 plan includes many business or commercial facilities with relatively high energy demand in Zones B or D2 (D2 to D4). Therefore, if this area can collaborate energy network with the areas in Zones 1 and 2 which have already completed development, it is possible to achieve more efficiency across the entire Bang Sue area.

Figure4.52 shows scheduled development zones for Phase 3.



Source: JICA Study Team.

Figure4.52 Development Plan in Phase 3

4) Planned Total Floor Area for Each Phase

Table4.13 shows total floor areas by use to be developed in each phase. In the subsequent considerations, energy demand and others are calculated, based on zone description in the red frame of the table.

Table4.13 Planned Total Floor Area on Basis of Land Use Status for Each Phase (m²)

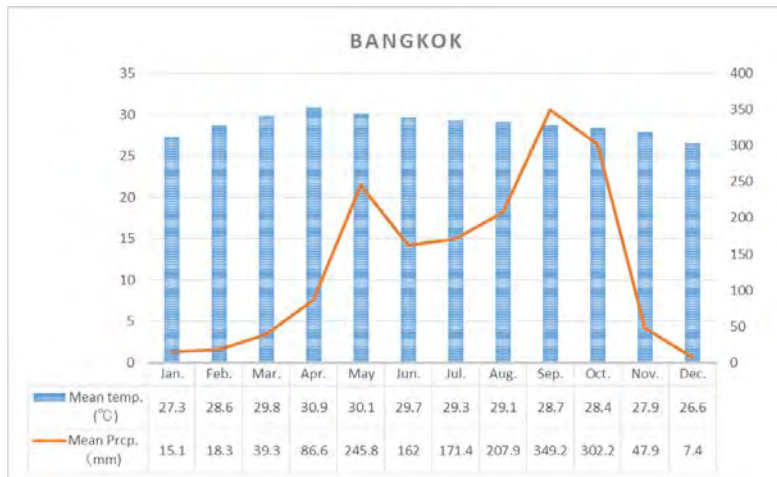
	Zone	Office	Retail	Residential	Hotel	Public Facility	Total of floor space according to the zone
Phase 1	Zone A	80,000	20,200	13,800	50,400		164,400
	Zone D1			45,360	73,000		118,360
	E1 (SRT LAND)	80,080	83,400				163,480
	Zone E	201,000	50,700	213,900			465,600
	E2 (SRT LAND)			344,320			344,320
	E3 (SRT LAND)						
	Zone F1		9,700				9,700
	G1		5,000	168,640			173,640
	G2	64,500	6,000				70,500
	Zone G1		5,010	154,750			159,760
	G3		5,000	80,020		6,000	91,020
	G4		5,000	249,870		8,400	263,270
	G5		5,000	107,940			112,940
	G6						
	Phase1 Subtotal	425,580	195,010	1,378,600	123,400	14,400	2,136,990
Phase2	ZONE C		29,600	493,000		50,000	572,600
	ZONE F2	119,700	195,130	335,800	90,240		740,870
	Phase2 Subtotal	119,700	224,730	828,800	90,240	50,000	1,313,470
Phase3	B1	80,000	40,000	257,900			377,900
	B2	39,900	30,020	154,430			224,350
	ZONE B		44,100				44,100
	B3		32,400				32,400
	B4		59,850	109,620	41,400		210,870
	D2-1		20,000	44,100	0		94,190
	ZONE D2	30,090					
	D2-2		60,000	145,060	60,000		265,060
	D3	35,020		64,260			99,280
	D4	80,000	10,000	239,210			329,210
	ZONE H	75,620	10,050	73,080	50,400		209,150
	H1		5,000	335,580			340,580
	H2						
	ZONE I						
	Phase3 Subtotal	340,630	311,420	1,423,240	151,800	0	2,227,090
Phase 1+2+3 Total Amount		885,910	731,160	3,630,640	365,440	64,400	5,677,550

Source: JICA Study Team, based on study reports created in FY2018

(4) Location Features

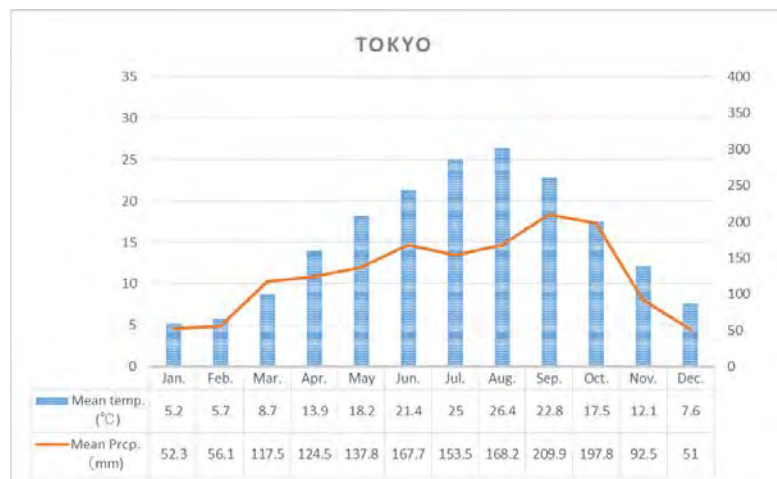
1) Weather Conditions

Thailand, classified as tropical monsoon climate, has three seasons: hot season from March to May, rainy season from June to October and dry season from November to February. Bangkok's climate features high temperature and high humidity with small annual temperature changes at an annual average temperature of 29 degrees C and an annual average humidity of 73%. Thailand has annual demand for cooling equipment, as its seasonal structure is different from that of Tokyo with autumn and spring seasons as moderate climate. The following charts show monthly average temperatures and precipitation amount in Bangkok and Tokyo.



Source: Produced on basis of statistics data sourced from Japan Meteorological Agency

Figure4.53 Weather in Bangkok City



Source: Produced on basis of statistics data sourced from Japan Meteorological Agency

Figure4.54 Weather in Tokyo

2) Insolation Conditions

The average insolation volume (241 W/m^2) in Bangkok City is about 1.4 times larger than that of Tokyo (169 W/m^2). Although care should be taken in consideration of cooling loads, etc. per unit floor area brought by transmission heat against the building, the potential for solar power generation as regional natural energy can be said to be high. Source: Solar GIS published by the World Bank

Figure4.56 shows isolation distribution in Thailand.



Source: Solar GIS published by the World Bank

Figure4.55 Isolation Distribution in Thailand

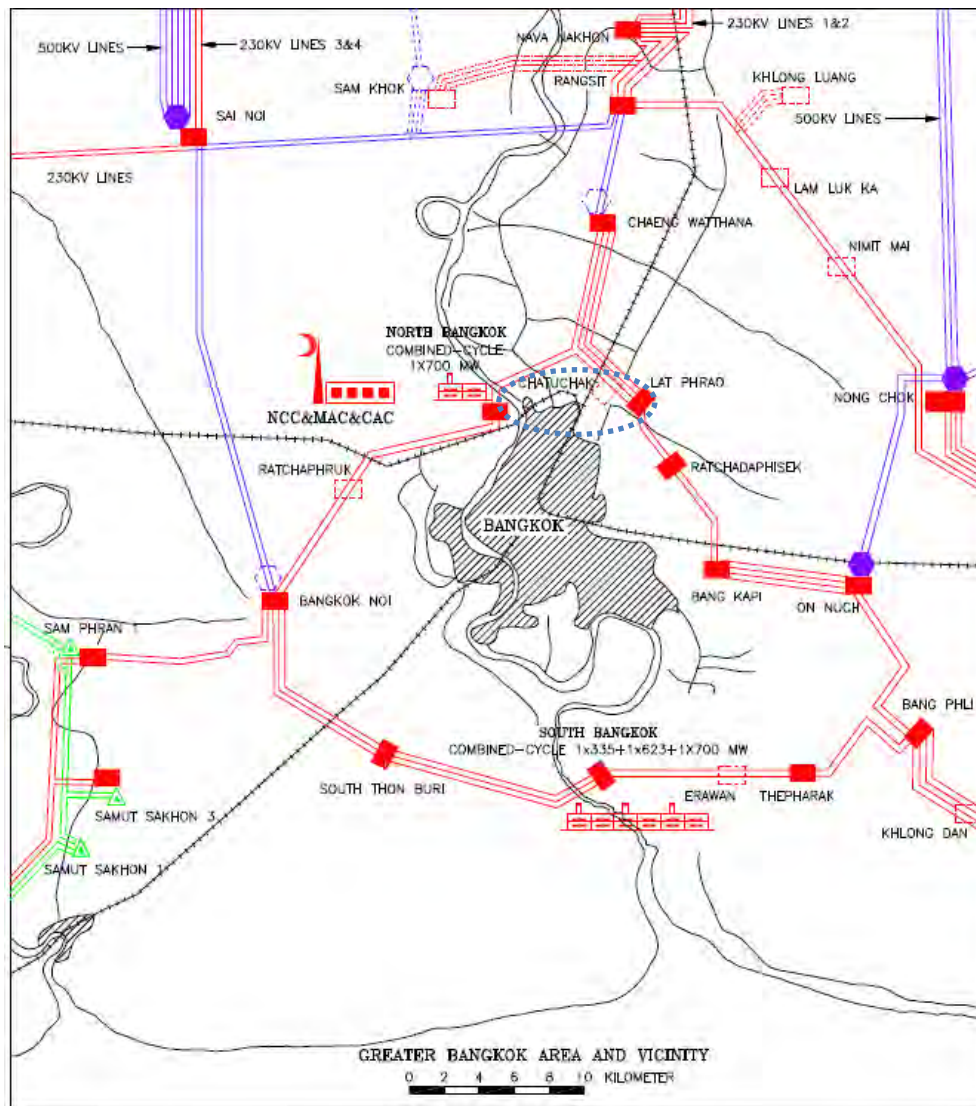


Source: Solar GIS published by the World Bank

Figure4.56 Isolation Distribution in Japan

3) Development Status for Electric Power Grid

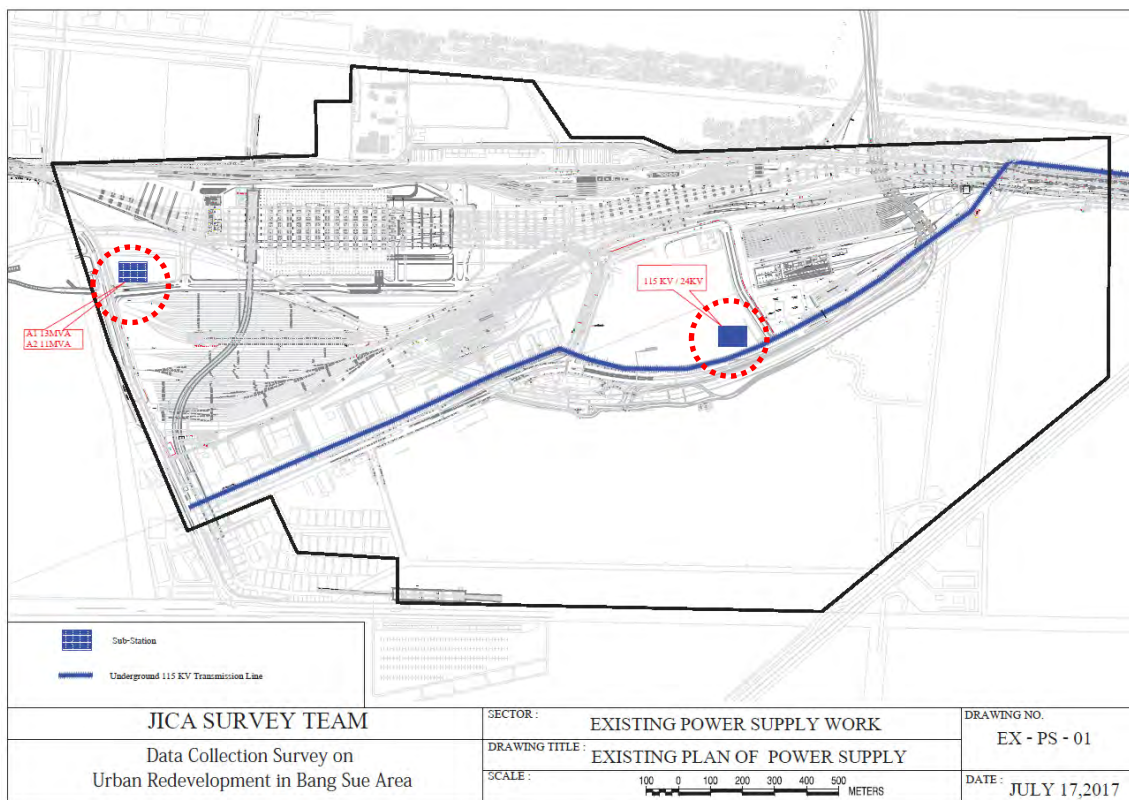
As shown in Figure4.57, 230 kV power grids are installed around Bangkok City and EGAT plans to develop Chatuchak substation near the Bang Sue area.



Source: Power Development Plan 2015 released by MOE

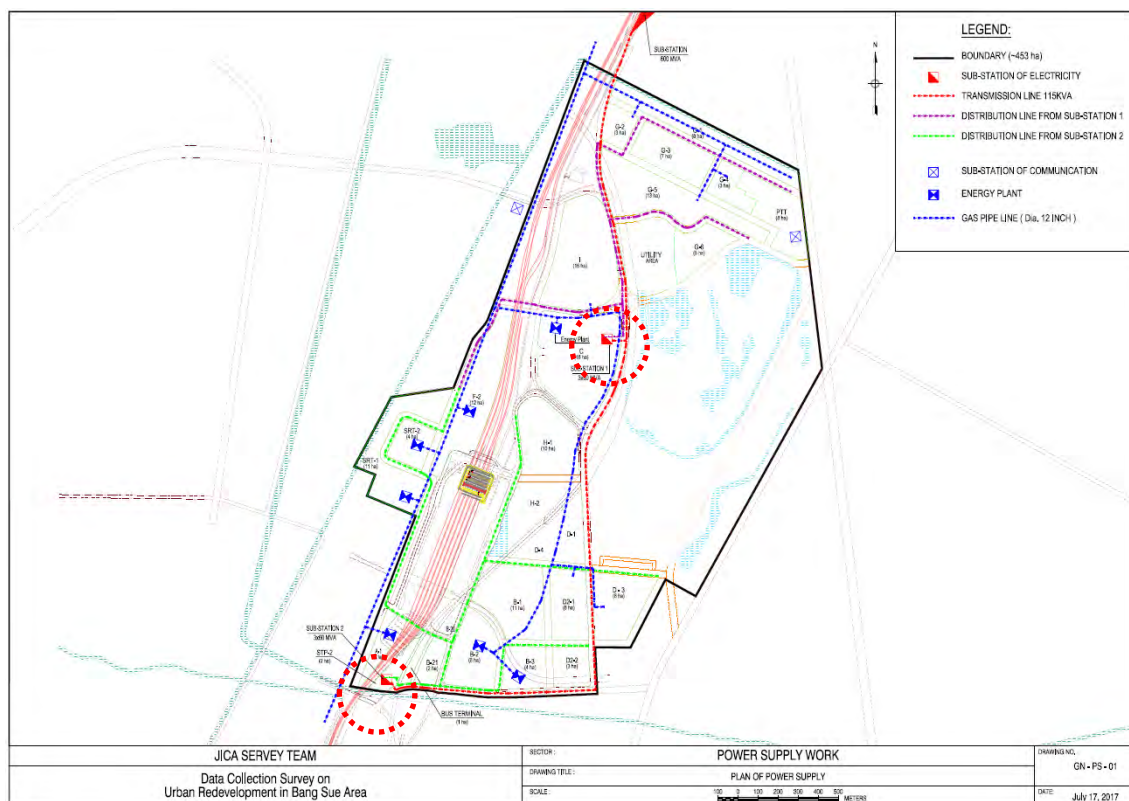
Figure4.57 Power Transmission Network around Bangkok City

In addition, two substations are to be developed for Zones A and C under the agreement between SRT and MEA in the Bang Sue area. Figure4.58 shows the location of substations planned by the MEA.



Source: JICA study reports produced in the past fiscal year, added partially by JICA Study Team.

Figure4.58 Substation Development Plan in Bang Sue (As built drawing)



Source: JICA study reports produced in the past fiscal year. (Location of energy plants in the Bang Sue area was considered at the time of studies done in the past fiscal year.)

Figure4.59 Substation Development Plan in Bang Sue (Drawing reflecting development zones)

Table4.14 Substation Development Status/Plan around Bang Sue Area

No.	Facility Name	Status	Volume	Operati on rate	Remarks
1	Lard Phrao Substation	In operation	40 MVA	50%	The total free space for two facilities is 40 kVA.
2	Chatuchak Substation	In operation	40 MVA	50%	
3	EGAT Chatuchak Substation	Planned		—	
4	MEA Substation (Redline, for ARL use)	In the process of producing detail plan	600 MVA	—	Started construction in 2017.
5	MEA Substation (for Bang Sue Station vicinity)	Planned	600 MVA (+300 MVA)	—	• +300 MVA as spare capacity • Electric power cables for Zones B, C and D are to be installed under the public road. • 115 kV for power cable

Source: JICA Study Team, based on study reports created in FY2018

4) Development Status for Gas Pipeline

PTT-owned oil and gas pipelines are installed underground in the Bang Sue area and the gas pipeline is laid near SRT's current railroad. Table4.15 indicates burial conditions of existing gas pipelines and Figure4.60 shows the location of oil and gas pipelines.

Table4.15 Burial conditions of existing gas pipelines

Category	owner	Burial conditions
Compressed natural gas pipeline	PTT	Buried underground pipe Diameter 300mm Pressure 300MMscfd (1.17MPa)

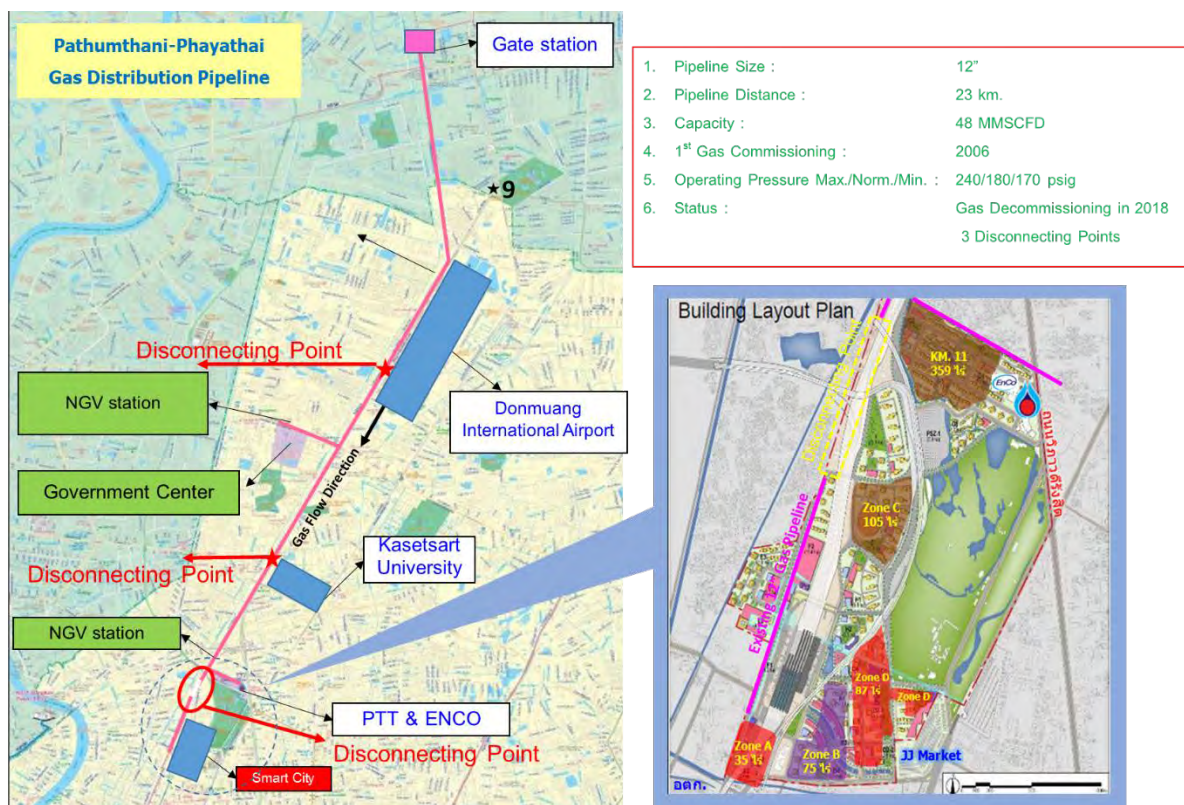
Source: JICA Study Team, based on study reports created in FY2018



Source: Report produced in the past fiscal year.

Figure4.60 Location of Oil/Gas Pipelines in Bang Sue Area

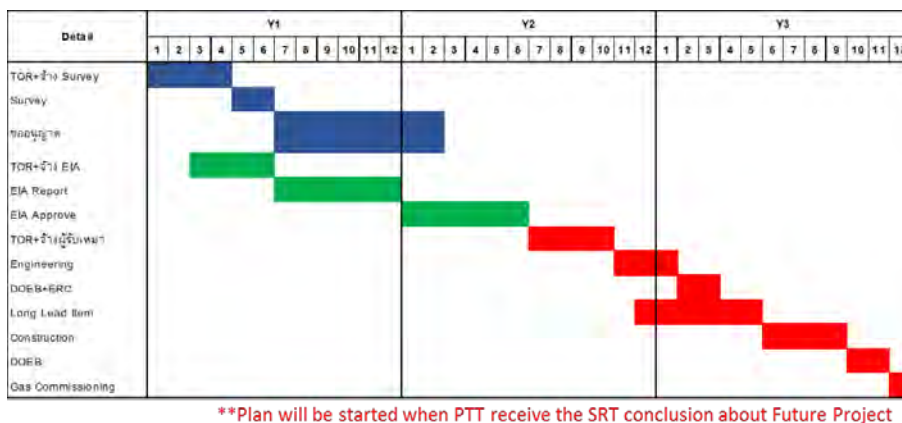
In addition, as the gas pipeline is diverged in the northwest side of the Bang Sue area, the gas pipeline can be brought into the Bang Sue area from the diverging point. However, according to PTT, as some of the gas pipeline routes are planned to be changed in the future, care should be taken. As detail surveys are possibly needed on reconnection and route change between Rangsit and Bang Sue due to construction work for Redline and high speed rail, coordination is needed with the SRT. But PTT mentioned that these gas pipeline routes can be utilized tentatively in the Bang Sue area. The branch points (Disconnecting Point) that can bring the gas pipeline into the Bang Sue area are shown below.



Source: Material supplied by PTT.

Figure4.61 Pathumthani-Phayathai Gas Pipeline

And furthermore, PPT points out that it takes about three years to bring gas pipeline to the Bang Sue area, including survey, design and environmental impact assessment, based on the current regulation. In Phase 1, especially, special measures are needed to facilitate the Bang Sue development plan in parallel with gas pipeline development through the mutatis mutandis application of Thai EEC system or special district certification. The rough schedule for the gas pipeline connection and installation is shown below.



Source: Material supplied by PTT.

Figure4.62 Pathumthani-Phayathai Gas Pipeline

4.4.3 Basic Policy and Concept

(1) Trend for Energy Policy and Urban-type Energy System

1) Policy Status in Thailand

In response to National Strategy “Thailand 4.0” released in May 2016 in Thailand, the country aims to develop smart city or smart grid under the banner of 1. Stable energy supply, 2. Well-balanced energy price and 3. Energy efficiency in the energy sector. And furthermore, a new Power Development Plan (PDP) has been published to advance the strategy in January 2019. This new PDP describes that renewable energy (hereinafter referred to as “RE”) accounts for 37% of the entire energy for 2037. (Approx. 15% as of 2018) Based on the new PDP, Thai Ministry of Energy (MOE) indicates that new construction of large-scale power plants is difficult due to growing environmental awareness in the country and small-scale power plant (SPP: Small Power Plant) will be a mainstream for future renewable energy or industrial complex, and also points out that systems need to be introduced to store or share excessive power.

And moreover, Energy Policy and Planning Office (EPPO) under the MOE has formulated Smart Grid Development Master Plan 2015-2036 and subsequently MEA, PEA and EGAT under the plan have produced a specific roadmap, which describes that smart grid will be achieved with the introductions of renewable energy or smart meter (AMI: Advanced Metering Infrastructure), power storage system (ESS: Energy Storage System), and electric vehicle (EV).

In addition, MOE considers a platform for renewable energy transactions or for power transactions with no restrictions through microgrid system, aiming to open up a power market furthermore in the future. As an advanced effort, the MEA has worked together with an Australian company to start a demonstration project for block chain technology in Bangkok and other smart city projects have been promoted under public-private collaboration.

2) Development Trend for Urban Energy System

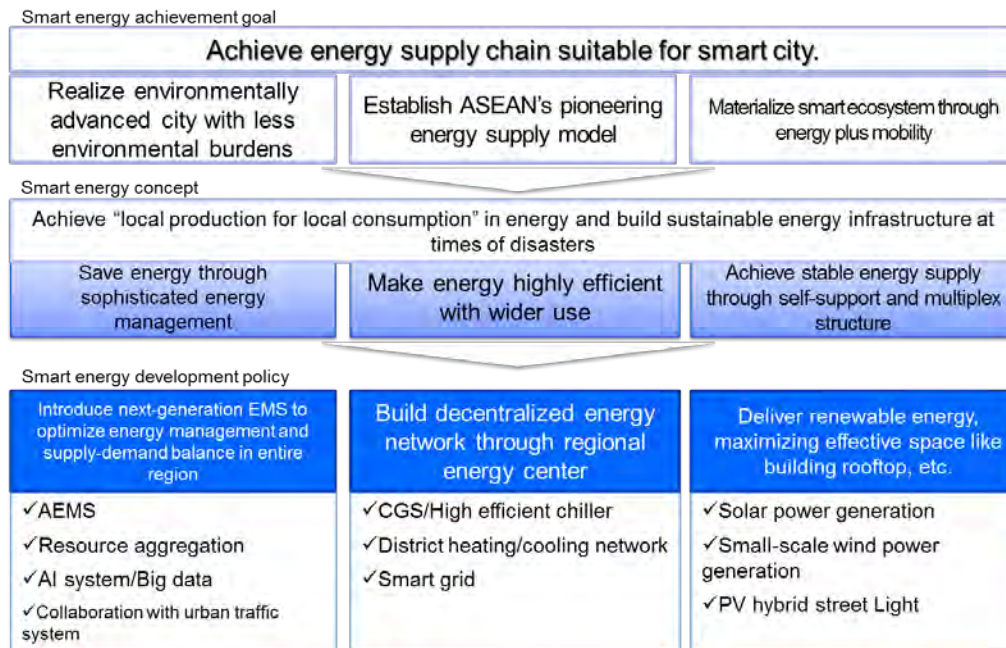
The global community tries to shift drastically to a low carbon society in order to tackle global environmental problems like global warming, climate change and environmental pollution. In the urban area with large energy consumption, in particular, demanded are a reduction in environmental loads through energy efficiency, promotion to introduce renewable or unused energy and sustainable energy supply system as reliable energy source at time of disasters.

As one method to achieve them, attention is drawn to the use of distributed energy system, including renewable energy as regional energy sources, in the area close to the consumption place, in addition to the traditional energy supply system. In the densely built-up urban area, especially, as the potential for renewable energy is not sufficient in most cases, cogeneration-based regional air conditioners play a pivotal role as a more energy-efficient mechanism to use energy across the entire area. Therefore, if distributed energy sources like renewable energy are combined with district cooling system through sophisticated management, the high-efficient, low carbon-based urban energy system will be frequently introduced with reliable supply in the future.

(2) Smart Energy Concept in Bang Sue Area

Based on the above, Figure 4.63 shows a smart energy concept and a development policy as a

basic policy for the development of smart energy network in Bang Sue in order to achieve an energy supply chain desirable for smart city.

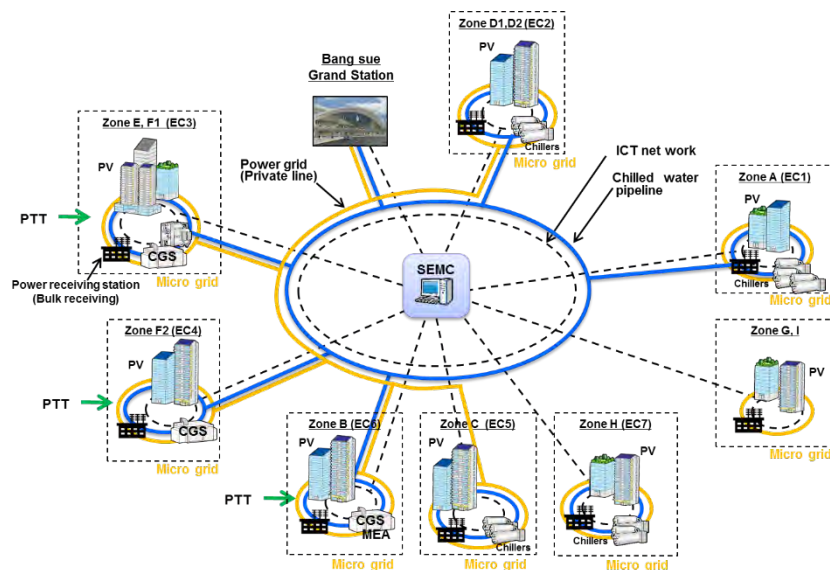


Source: JICA Study Team.

Figure4.63 Smart Energy Concept in Bang Sue

(3) Concept for Smart Energy Network

The Bang Sue area achieves a sophisticated management system for intraregional power supply network, including regional heat supply network and renewable energy, with ICT technology, and attains an urban energy system with high-efficient, reliable supply and less environmental loads. Figure4.64 organizes a basic concept for smart energy network to be achieved in the Bang Sue area.

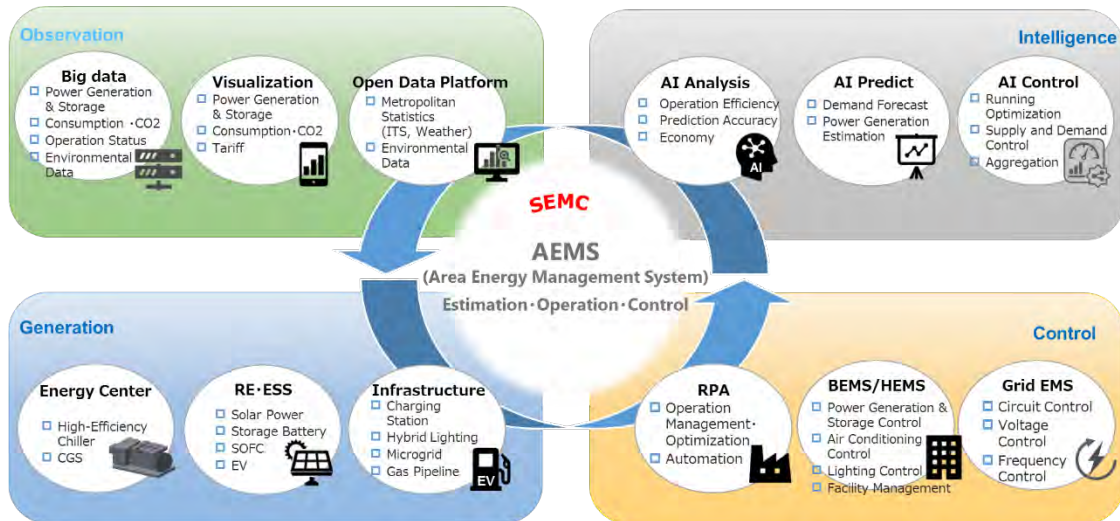


Source: JICA Study Team.

Figure4.64 Concept for Smart Energy Network

(4) Area Energy Management System (AEMS)

Smart Energy Management Center (SEMC) introduces Area Energy Management System (AEMS) to make sophisticated management of distributed energy resources like respective energy centers or renewable energy, and achieves optimal energy supply and demand with AI system in Bang Sue. Figure4.65 organizes a concept for AEMS.



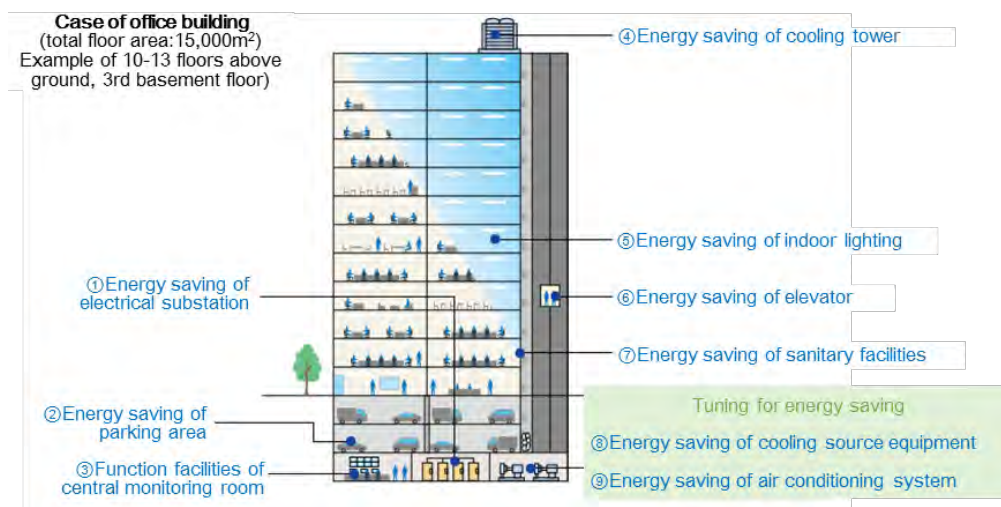
Source: JICA Study Team.

Figure4.65 Concept for AEMS

(5) Building Energy Management System (BEMS)

As many business facilities (office, commercial facility, hotel, public facility, etc.) are to be built in Bang Sue, Building Energy Management System (BEMS) is proactively introduced to manage energy by facility unit and save energy.

This BEMS system allows optimal control chiefly for air conditioner, heat source equipment and ventilatin volume, etc., and automated/optimal operation, including lighting intensity and adjustment/automatic lighting and lights-out for comfortability, in the entire facility, contributing to energy saving and labor-saving for facility managemnet. Figure4.66 shows BEMS overview.



Source: Published by Osaka Gas Facilities Corporation (English translation of JICA Study Team)

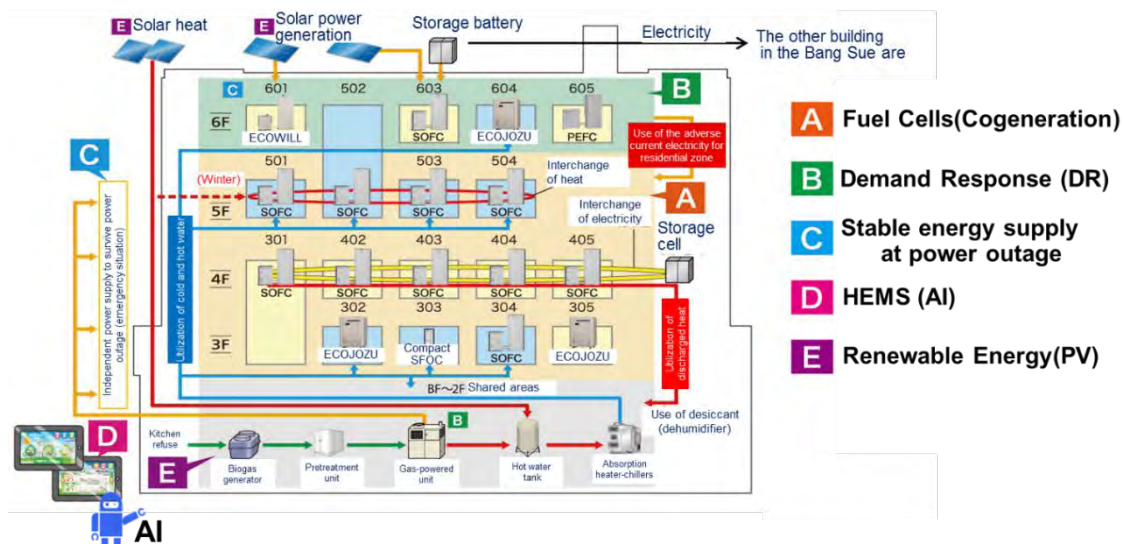
(<http://www.ogfa.co.jp/business/office-building.html>)

Figure4.66 BEMS Overview

(6) Home Energy Management System (HEMS)

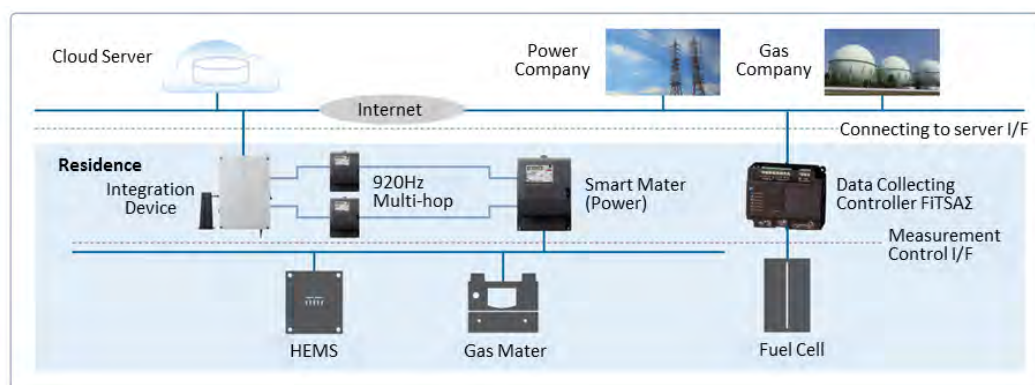
As many residential houses are located in the Bang Sue area, if energy consumption is efficient for each household, they can contribute to a low carbon society in the entire area. The use of Home Energy Management System (HEMS) can be considered as an effective energy management system for residential building. The introduction of HEMS allows each household to “visualize” power consumption or generation, reserve cell volume, gas/water consumption through management, and also to effectively manage or control smart household appliances for HEMS or energy resources like solar power or reserve cells. It is expected to raise awareness about energy-saving or reduce energy costs by monitoring energy consumption status in each household or the entire residential building.

The use of HEMS allows users to select power charge menus flexibly in collaboration with advanced metering infrastructure (AMI), collaborate with the open data platform with HEMS and obtain synergy effects with a wide range of services like surplus power trade. Figure4.67 organizes a concept for HEMS and Figure4.68 shows a system overview for remote metering with smart meters.



Source: NEXT 21 (experimental multi-family housing complex) tackled by Osaka Gas Co. Ltd.
<https://www.osakagas.co.jp/company/efforts/next21/index.html>

Figure4.67 HEMS Overview

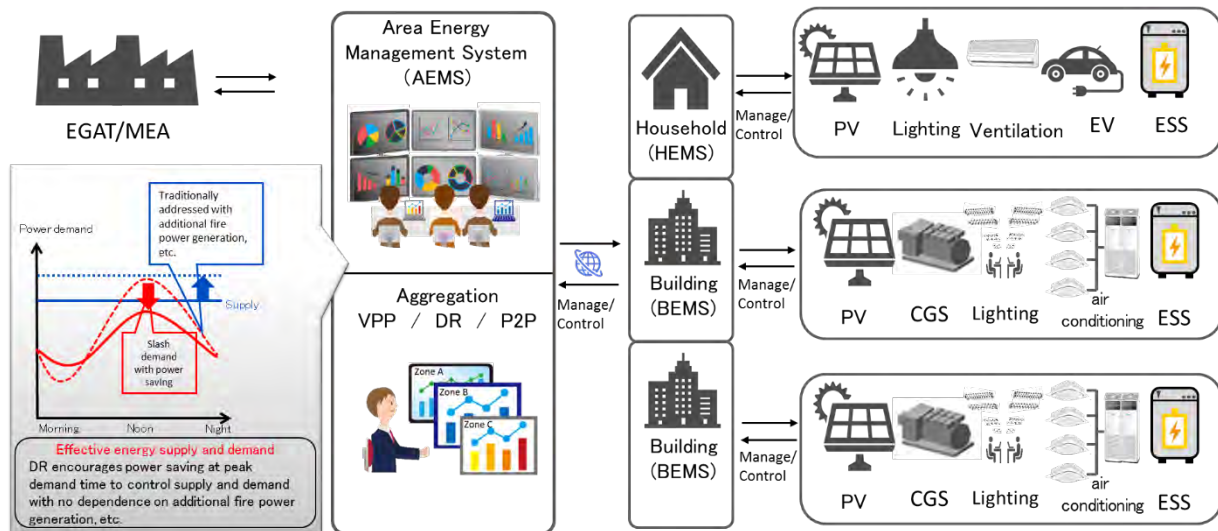


Source: Released by Fuji Electric Co., Ltd. (English translation of JICA Study Team)
<https://www.fujielectric.co.jp/products/whm/about/box/doc/61A1-J-0005.pdf>

Figure4.68 Remote Metering System with Smart Meter

(7) Collaboration between EMS and AEMS

If EMS for user facilities like BEMS or HEMS is collaborated with AEMS for energy management in the entire Bang Sue area, it can help optimize and stabilize supply and demand across the area through energy management for individual facilities, zone-based demand control (DR), virtual power plant (VPP) and peer-to-peer (P2P) energy trading. Figure4.69 shows an image for collaboration between EMS and AEMS for individual user facilities.



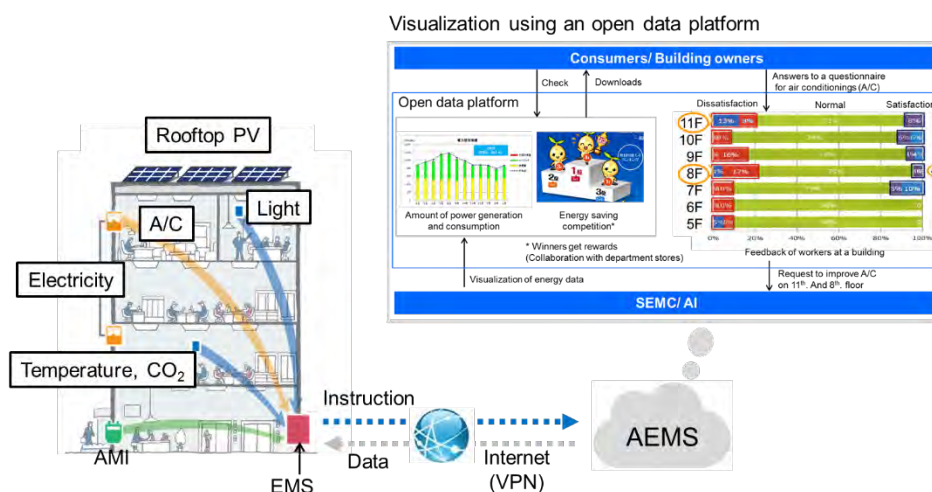
Source: JICA Study Team.

Figure4.69 Demand Control through Collaboration between EMS and AEMS in User Facilities

(8) Open Data Platform

Users can utilize energy data collected in the Bang Sue area to confirm energy consumption status or reduction goal.

In addition, data accumulated in the open data platform can be shared regionally and used for new innovation. Figure4.70 shows a concept to visualize energy with the use of the open data platform.

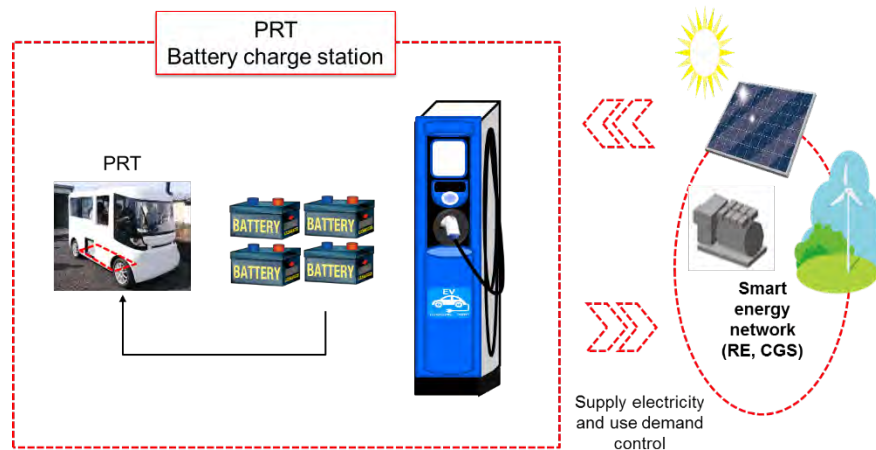


Source: JICA Study Team.

Figure4.70 Energy Visualization through Open Data Platform

(9) Establishment of Ecosystem

In order to collaborate smart mobility with smart energy to be considered in Bang Sue, distributed energy power sources in the area is used to charge a next-generation public traffic system PRT (EV) under consideration for the establishment of public traffic system with low environmental loads. Meanwhile, EV like PRT can contribute to energy efficiency or stability, if it is used as a reserve cell to store power instead of recognizing EV as mere traffic means. Therefore, with a focus on reserve cells for PRT, though PRT is used as power sources for the traditional traffic means for single use, it can be changed to multipurpose uses as energy resources to contribute to system stability, achieving the ecosystem.

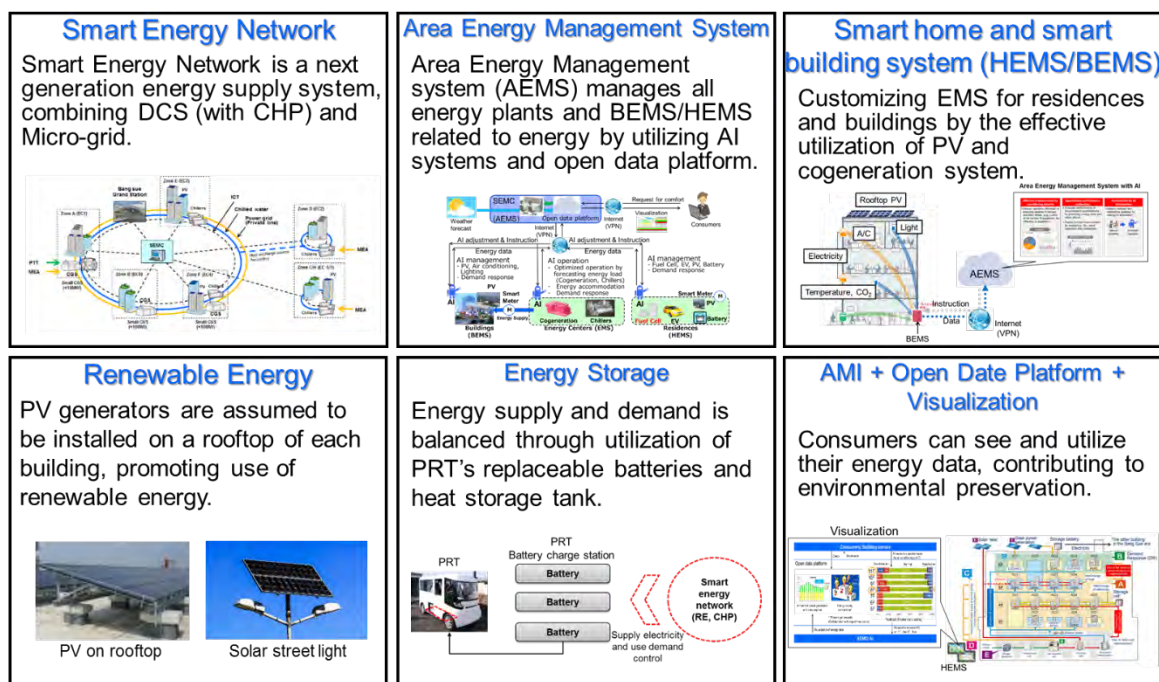


Source: JICA Study Team.

Figure4.71 Collaboration between Smart Energy System and Smart Mobility System

(10) Smart Energy Contents

Figure4.72 organizes smart energy contents in the Bang Sue area, based on the above considerations.



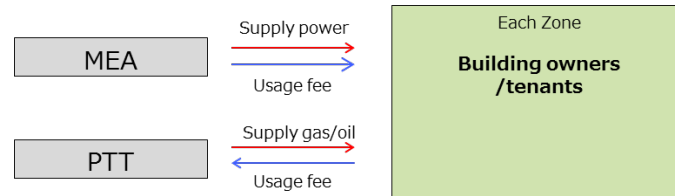
Source: JICA Study Team.

Figure4.72 Smart Energy Contents

(11) Energy Supply Model in Bang Sue Area

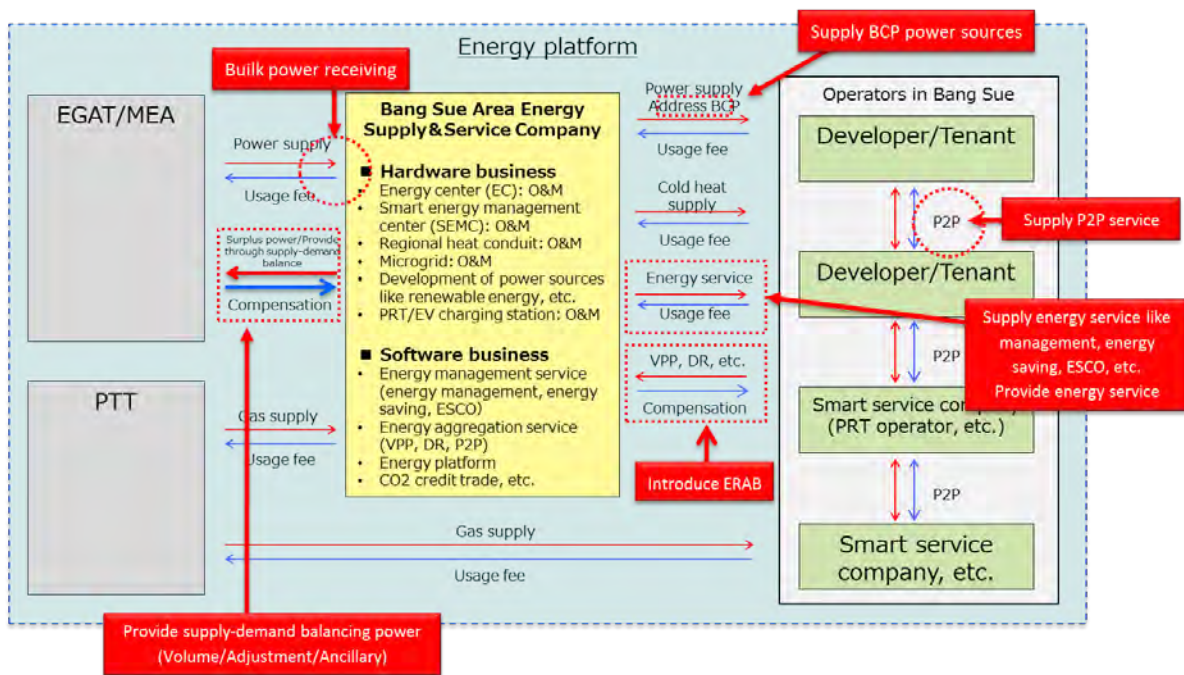
In order to achieve an energy supply chain suitable for smart city in Bang Sue, the establishment of new energy supply system, which is different from the traditional one, is needed.

Not only knowledge on energy supply hardware development, but also software-based service information need to be gathered to realize a new energy supply system. The traditional one-way energy supply model should be shifted to an interactive energy supply model with sophisticated hardware and software businesses combined, aiming at income diversification and innovation creation. This can facilitate electric power deregulation in Thailand, achieving pioneering business models in ASEAN.



Source: JICA Study Team.

Figure4.73 Traditional Energy Supply Model



Source: JICA Study Team.

Figure4.74 New Energy Supply Model in Bang Sue

4.4.4 Energy Demand Forecast (Power/Cooling) in Bang Sue

In this chapter, energy demand volume, expected for each zone, is calculated and is organized by development phase toward the development of smart energy network in the Bang Sue area.

(1) Energy Demand by Zone

Table 4.5 shows calculated results on expected power and cooling demand by zone in building use (office, hotel, commercial facility, public facility, residential house, etc.).

In this calculation, cooling loads are subject only to business/commercial facilities (office, hotel, commercial facility, public facility), and those for residential house is calculated as power load⁵.

As for Zones D and F where development periods are different in the same zone, Zone D1 to be developed for Phase 1 is separated from Zones D2 to D4 to be developed for Phase 3 (hereinafter referred collectively to as “D2”) and Zone F is divided into Zone F1 to be developed for Phase 1 and Zone F2 to done for Phase 2.

Table4.16 Demand Forecast for Power and Cooling Load

Zone	Site Area (m ²)	Power Load		Cooling Demand	
		Max. Load ⁶ (MW)	Annual Demand ⁷ (MWh/y)	Max. Load ⁸ (MW)	Annual Demand ⁹ (MWh/y)
A	164,400	5,898	24,722	15,465	50,675
B	678,750	25,118	68,398	32,878	95,338
C	572,600	18,247	31,097	8,922	23,763
D1	118,360	3,614	17,004	7,704	38,303
D2 (D2 to D4)	669,400	24,502	80,695	37,719	135,585
E	973,400	34,274	85,928	45,245	117,185
F1	9,700	572	2,766	1,475	4,925
F2	740,870	28,470	98,487	49,773	167,333
G	871,130	27,365	43,992	11,692	29,527
H	538,360	17,430	42,848	22,130	63,807
I	340,580	10,363	13,507	760	2,539
Total	5,677,550	195,854	509,444	233,761	728,978

Source: JICA Study Team.

⁵ In this consideration the central cooling system for residential use is excluded. The city area for many business or commercial use or the high-rise multifamily building for such multiple uses as business or commercial purpose achieves the reasonable central cooling supply system through the systems, including warmer environment improvement for smart housing, effective use of CGS heat waste, energy-saving demand control with HEMS/smart meter, application to flat-rate fees and simplified measurement. Consideration is desirable together with residents' intention surveys in the future in Thailand.

⁶ Max. Power Load = Σ (Floor area by use x Max. power load unit)

⁷ Annual power demand = Σ (Floor area by use x Annual power demand unit)

⁸ Max. cooling load = Σ (Floor area by use x Max. cooling load unit)

⁹ Annual cooling demand = Σ (Floor area by use x Annual cooling demand unit)

The respective load units shown above are set, based on exterior surface performance for building, ventilation power unit, calorific values gained inside equipment, elevator or escalator operation conditions, standby power and building type by use, etc.

(2) Energy Demand by Development Phase

As stepwise development is planned in Bang Sue, the energy supply plant needs to be developed and expanded in accordance with demand scale for each phase in an effort to build smart energy network. The following table shows calculated maximum power load and cooling loads for each phase.

Table4.17 Energy Demand by Development Phase

Phase	Developed Zone	Total Floor Area (m ²)	Max. Power Load (kW)	Max. Cooling Load (kW)
Phase1 (From 2022 onwards)	A	164,400	5,898	15,465
	D1	118,360	3,614	7,704
	E	973,400	34,274	45,245
	F1	9,700	572	1,475
	G	871,130	27,365	11,692
	Subtotal	2,136,990	71,724	81,580
Phase2 (From 2027 onwards)	C	572,600	18,247	8,922
	F2	740,870	28,470	49,773
	Subtotal	1,313,470	46,717	58,695
Phase3 (From 2032 onwards)	B	678,750	25,118	32,878
	D2	669,400	24,502	37,719
	H	538,360	17,430	22,130
	I	340,580	10,363	760
	Subtotal	2,227,090	77,413	93,487
Total		5,677,550	195,854	233,761

Source: JICA Study Team.

(3) Energy Demand Pattern by Development Phase

Figure4.75 and Figure4.77 show monthly and hourly demand volume patterns for power load by development phase.

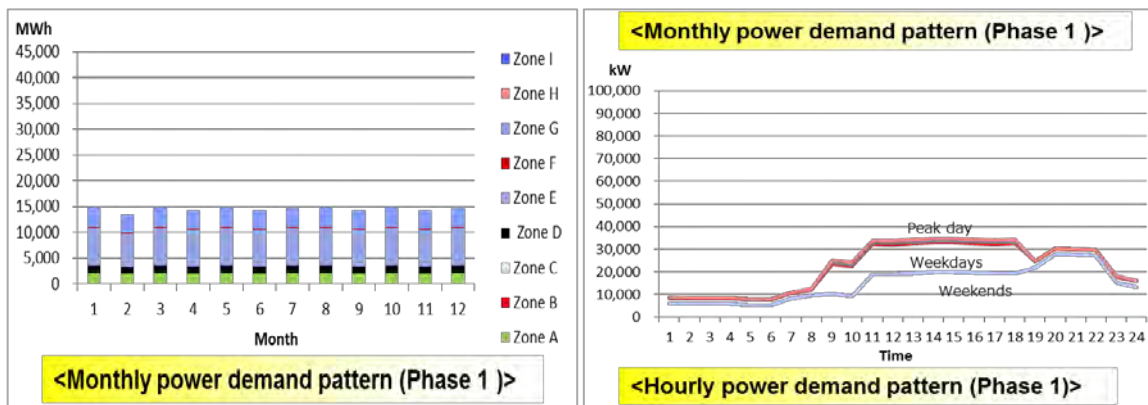


Figure4.75 Monthly/Hourly Demand Pattern for Power Load (Phase 1)

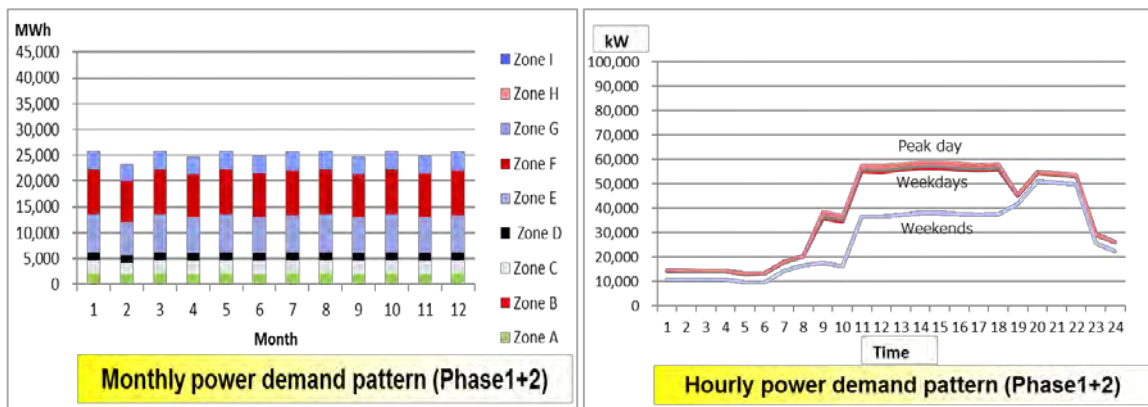


Figure4.76 Monthly/Hourly Demand Pattern for Power Load (Phases 1 + 2)

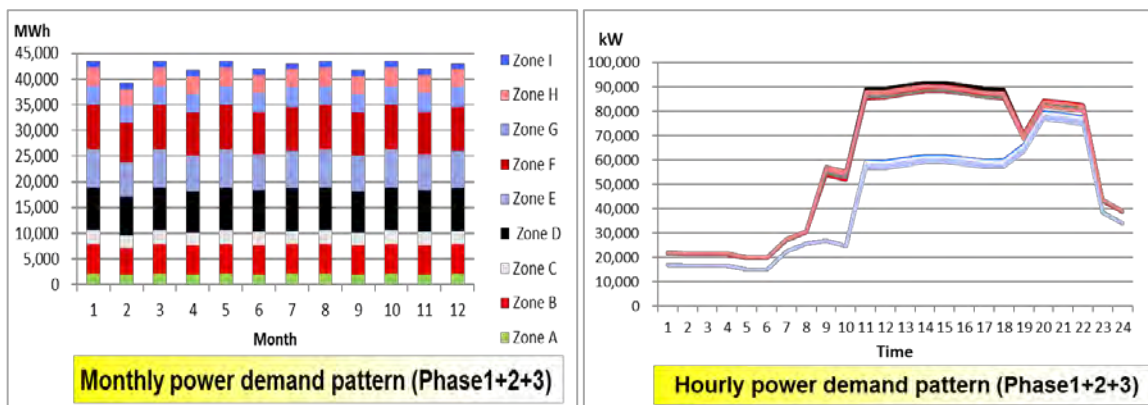
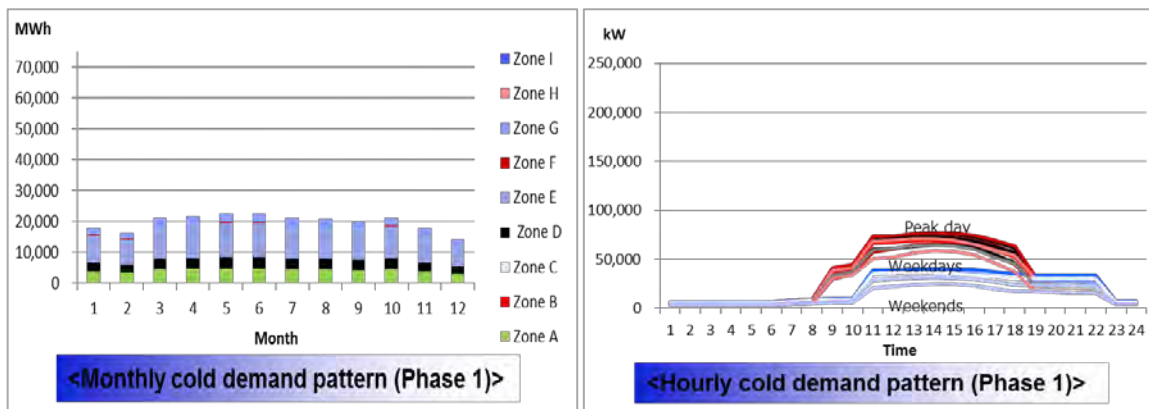


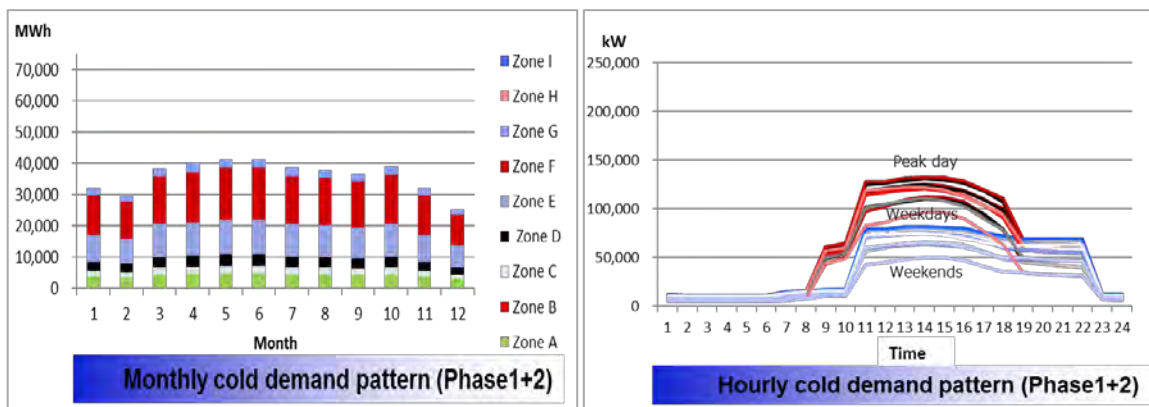
Figure4.77 Monthly/Hourly Demand Pattern for Power Load (Phases 1 + 2 + 3)

Figure4.78 and Figure4.80 show monthly and hourly demand volume patterns for cooling load by development phase.



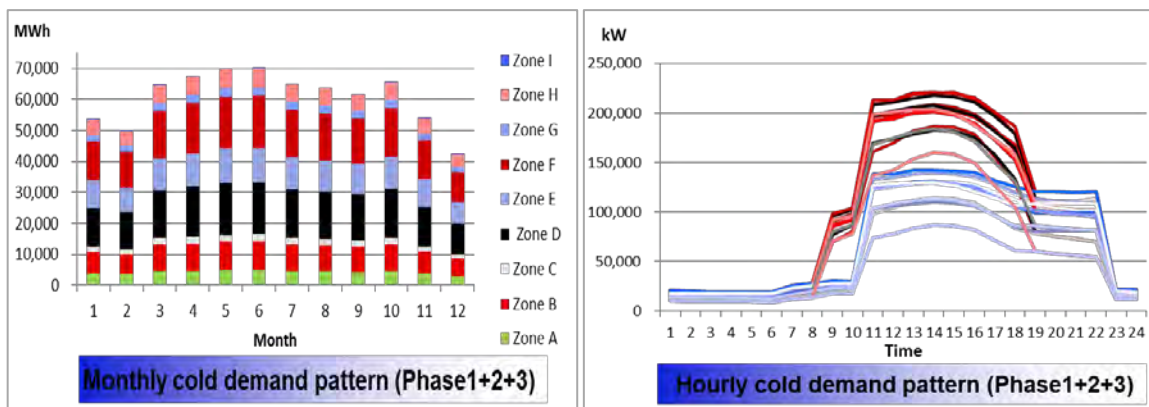
Source: JICA Study Team.

Figure4.78 Monthly/Hourly Demand Pattern for Cooling Load (Phase 1)



Source: JICA Study Team.

Figure4.79 Monthly/Hourly Demand Pattern for Cooling Load (Phases 1 + 2)



Source: JICA Study Team.

Figure4.80 Monthly/Hourly Demand Pattern for Cooling Load (Phases 1 + 2 + 3)

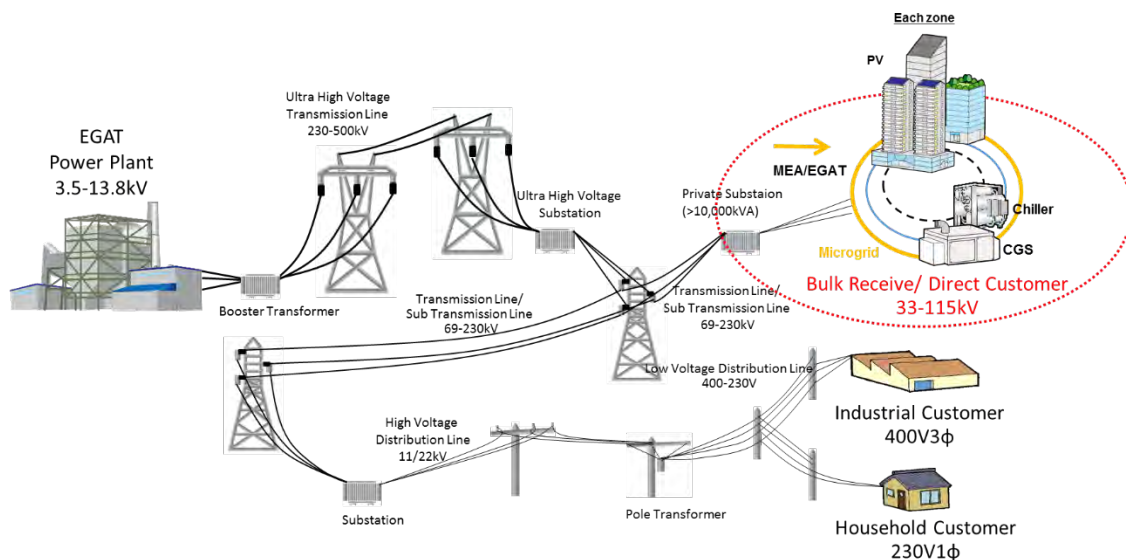
4.4.5 Proposed Development for Smart Energy Network

(1) Area Selection for Smart Energy Network

In order to develop a smart energy network, as shown in this chapter, energy supply plants need to be developed in accordance with the development scale for each phase and the network is built with energy supply plants for a new phase for smart energy network expansion. The following sections organize consideration results.

1) Target Area for Microgrid

Two substations to be developed by the MEA supplies power collectively to each zone in the Bang Sue area to build a cluster-type microgrid system by zone. This can optimize energy supply and demand with efficient management, and make energy supply and demand efficient and optimal across the area through the networked cluster-type microgrid system. Therefore, all the areas are subject to the microgrid system.



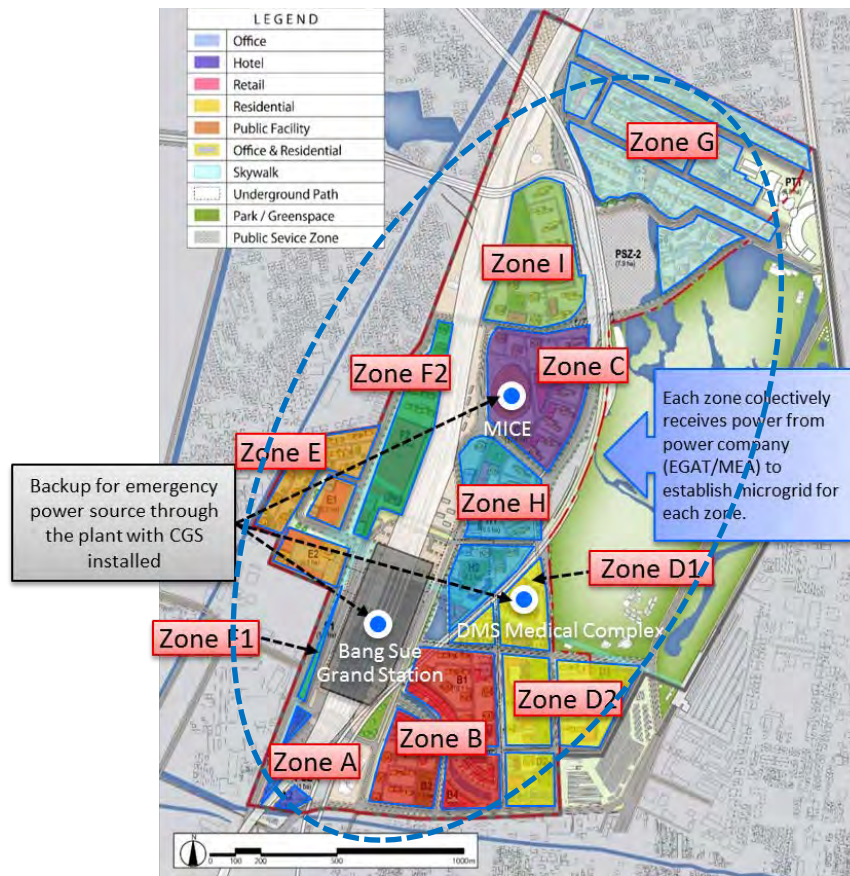
Source: JICA Study Team.

Figure4.81 Collective Power Distribution Image

And furthermore, as key public facilities like Bang Sue Grand Station is located in the Bang Sue area, a backup system for emergency power sources is developed in key facilities through cogeneration, not only from the perspective of efficient energy supply and demand, but also from that of business continuity plan (BCP) at time of disasters. As for the key facilities except for Bang Sue Grand Station, a medical complex (DMS) is to be built in Zone D1 and MICE facilities for many visitors are considered in Zone C. Therefore, as BCP measures are needed for these important facilities at time of disasters, the backup system for emergency power sources is established through cogeneration in order to enhance energy security.

In addition, regarding the backup for heat source and emergency power supply to Bang Sue Grand Station, it is required that prompt confirmation of design conditions and specifications of some facilities (substation, private power generator, heat source facility, etc.) that are planned to be installed into Bang Sue Grand Station which is currently under construction. Together with it, plan and design adjustment with Bang Sue Grand Station for systematic connection and operation

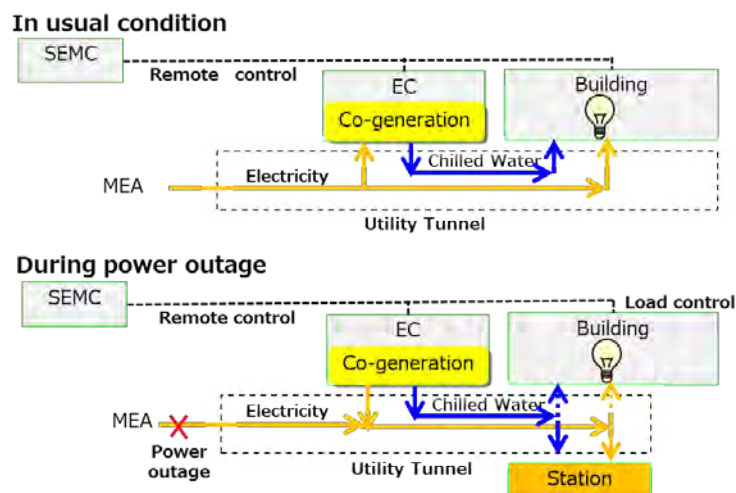
is also needed. In addition, as described later in Chapter 4.4.8, the operation management needs to be coordinated in the initial phase in order to shift, to SSC, the management on emergency power generation facilities and heat source equipment for Bang Sue Grand Station, from the efficient perspectives through integrated management operation.



Source: JICA Study Team, based on study reports for FY2018.

Figure4.82 Target Area for Microgrid

Figure4.83 shows a power supply flow in case of emergency through cogeneration.



Source: JICA Study Team.

Figure4.83 Sustainable Energy Supply Image by CGS

2) Target Area for District Heat Supply

In order to secure both energy efficiency and business profitability in the district heat supply business, preconditions are a certain degree of cooling demand and demand density in the target area. Table4.18 shows calculation results for energy demand in each zone.

Based on the calculation results, as cooling demand density is low at 0.08 GWh /m².h) and 0.02 GWh /m².h respectively for Zones G and I, the selection of common building-based cooling system is supposed, considering installation costs for cold water conduit pipe.

In Zones C and H, though a certain degree of cooling demand density is confirmed, it is not judged realistic to build a large-scale network with other zones, considering installation costs for cold water conduit tube. Therefore, “block cooling” system is selected for business and commercial facilities in the zones.

As Zone D includes two separate development phases consisting of Phases 1 and 3, “block cooling” system is selected in Zone D1 to be developed earlier for Phase 1 and “district cooling” system is done in Zone D2 to be developed for Phase 3. In Phase 3 when Zone D2 is to be developed, the renewal timing¹⁰ of heat source equipment is likely to get closer, facility volume is optimized at the time of the equipment renewal and the zone is connected with the district cooling network for more efficient planning.

As there are no legal requirements¹¹ on business division in Thailand, as shown in Heat Supply Business Act stipulated in Japan, in this report for the purpose of convenience, networking for heat supply business beyond the zone is defined as “district cooling,” and heat supply within the zone is done as “block cooling”.

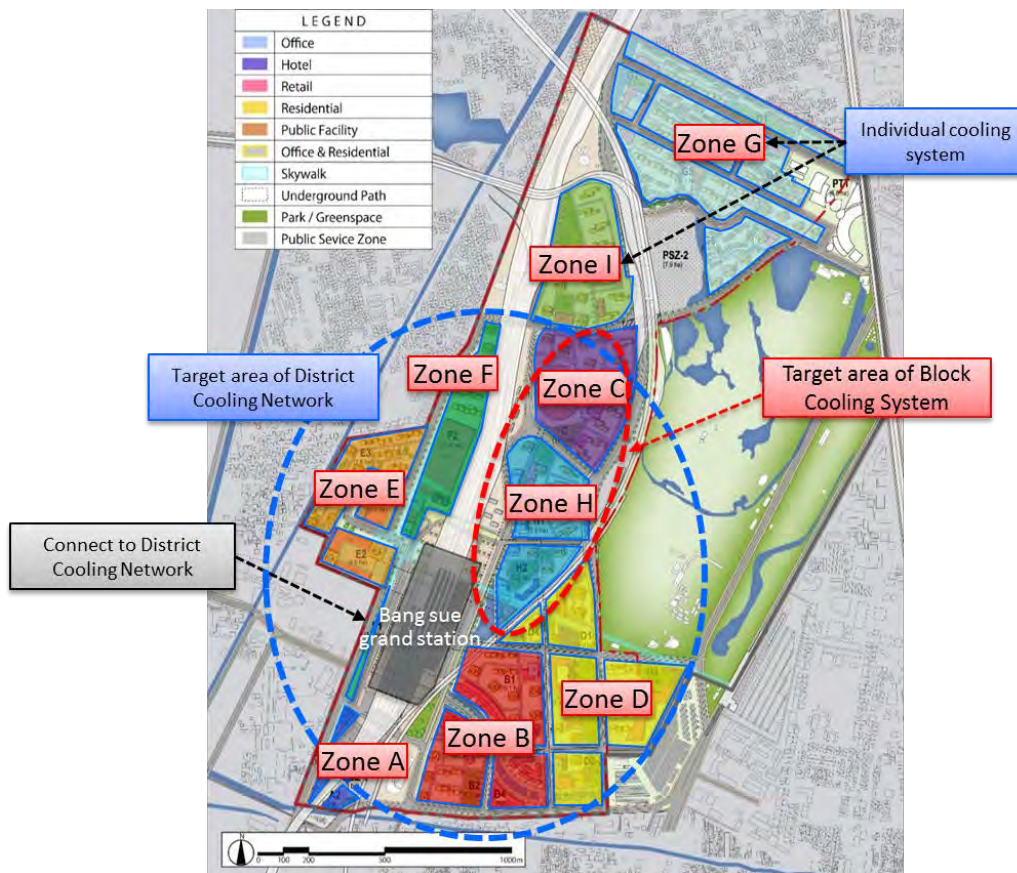
Table4.18 Cooling Demand Density and Cooling System by Zone

Zone	Site Area (m ²)	Cooling Load		Annual Cooling Load per Area (MWh/m ² ·y)	District Heat Supply		Building-based Cooling System
		Max. Load (kW)	Annual Demand (MWh/y)		District Cooling System	Block Cooling System	
A	27,300	15,465	50,675	1.86	Yes		
B	201,000	32,878	95,338	0.47	Yes		
C	174,400	8,922	23,763	0.14		Yes	
D1	39,500	7,704	38,303	0.97	(Scheduled)	Yes	
D2	192,400	37,719	135,585	0.70	Yes		
E	152,000	45,245	117,185	0.77	Yes		
F1	9,700	1,475	4,925	0.51	Yes		
F2	113,900	49,773	167,333	1.47	Yes		
G	370,800	11,692	29,527	0.08			Yes
H	152,900	22,130	63,807	0.42		Yes	
I	151,300	760	2,539	0.02			Yes
Total	1,585,200	233,761	728,978	0.46	—	—	—

Source: JICA Study Team.

¹⁰ The general renewal period for heat source equipment is considered to be 15 to 20 years.

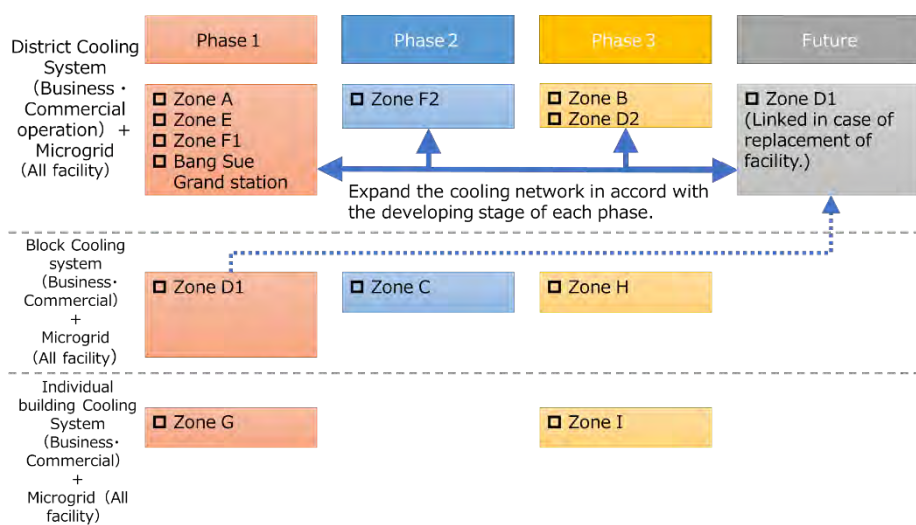
¹¹ Application to Heat Supply Business Act in Japan requires a general user operating a business to supply heat to two or more buildings with thermal capacity at 21 GJ/h or larger.



Source: JICA Study Team, based on study reports for FY2018.

Figure4.84 Target Area for District Cooling System

And furthermore, Figure4.85 organizes cooling system results for respective zones and expansion in accordance with development phases.



Source: JICA Study Team.

Figure4.85 Cooling System and Expansion by Phase

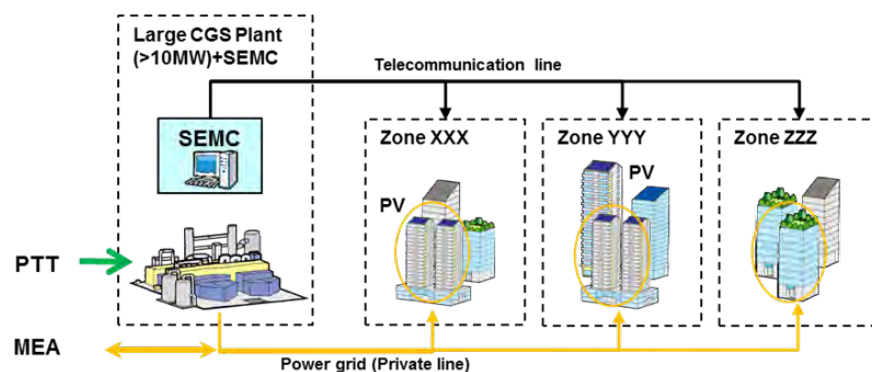
(2) Target Development Area for Cogeneration System (CGS)

1) Comparison between Centralized System and Distributed System through Cogeneration

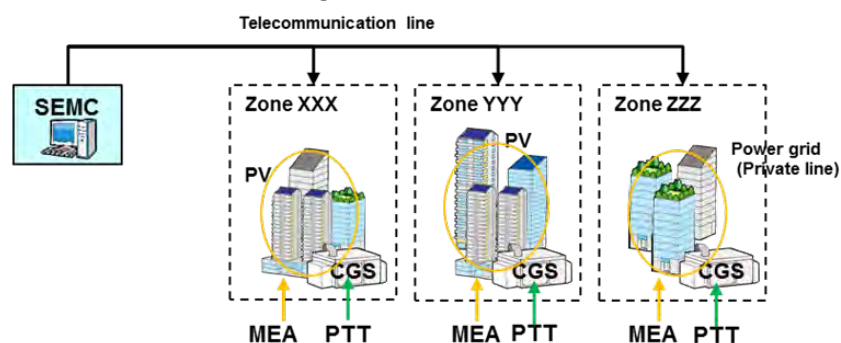
The Bang Sue area aims, as a smart energy network, to establish the cogeneration system and the highly effective energy supply system with power supply and waste heat-based cooling systems. And also, it tries to improve energy self-sufficiency rate and energy security, and needs to consider setting up the scale of cogeneration system.

The following figure compares, the collective centralized system to introduce large-scale cogeneration system into one plant, with the decentralized distributed system to introduce the cogeneration system to each zone.

<Collective centralized system>



<Decentralized distributed system>



Source: JICA Study Team.

Figure4.86 Centralized and Distributed Systems

The following table compares and considers the centralized system with the distributed one. As shown in Table4.19, stepwise development is planned. As a suitable scenario, it is considered that energy supply plants are to be developed by zone in accordance with the development scale for each phase and a smart energy network is expanded through networking with energy supply plants to be built for a new phase. Table4.19 organizes consideration results by comparing centralized and distributed systems for energy supply plants.

Table4.19 Comparison between Centralized System and Distributed System

	Centralized System	Distributed System
Outline	- Power is supplied collectively to the entire Bang Sue area and is supplied to each zone through self-employed power transmission and distribution network. - Cogeneration is operated at a rated value and excess power is sold to power companies.	Cogeneration system is dispersedly introduced to zones with a certain degree of cooling demand and profitability for power supply.
Consideration	- Excess power sales to power companies are not acceptable under the current regulation. Therefore, legal system change or special measure is needed for execution. - Environmental impact assessment is needed to introduce large-scale cogeneration at 10 MW or larger. (Need to have regional residents understood) - As the installation of cogeneration is illegal in the place except for industrial areas irrespective of size, legal revision is needed. (Challenging issue in common with distributed system)	- Sufficient power cannot be supplied to all zones at power outage. - As the installation of cogeneration is illegal in the place except for industrial areas irrespective of size, legal revision is needed. (Challenging issue in common with centralized system)
Continuity at Disaster	✓✓ Continuous power supply to the entire area is possible through cogeneration.	✓✓ (Limited) Continuous power supply is possible to key facilities (Bang Sue Grand Station, etc.) from the energy center with cogeneration system.
Introduction Cost	✓✓	✓
Feasibility	✓ - Excess power from cogeneration cannot be sold to power companies under the current regulation. (If power sales is possible, the feasibility is high.) - The business risk factor is huge, depending upon demand fluctuations.	✓✓ - It is possible to set up development volume in line with intraregional demand. - The business risk factor is small, depending upon demand fluctuations.
Suitability for Bang Sue Area	✓ - It takes longer time to conduct environmental impact assessment. - As Zone A development is proceeded earlier, its schedule cannot be possibly set at the same time with the development schedule for gas pipeline. - As there are obstacles for procedure and permit or approval, special district certification is needed as a precondition.	✓✓ - Development is realistically considered, as sequential expansion is possible in line with zone development schedule. - As power supply is possible for key facilities at emergency, operators' needs can be met within the zone.

Source: JICA Study Team.

2) Target Development Area for Cogeneration System (CGS)

Out of zones with district heat supply system, as cooling load density is relatively high in Zones A, B, D, E and F, considering the mutual distance with respective zones, the introduction of cogeneration is considered suitable in these zones. In Zone A, however, as the solicitation of developers has already been started, it is judged unrealistic to introduce the cogeneration system, considering a timeframe¹² for the development of gas pipeline.

In Zone D, too, as the development project is divided into Phases 1 (Zone D1) and 3 (Zone D2), it is judged unsuitable to introduce cogeneration.

Based on the above examination, the targeted development areas for cogeneration are Zones B, E and F. In the other district cooling areas, the energy supply system will be considered with high-efficient motor-driven turbo chiller as a major heat source. Waste heat from cogeneration is utilized in the zones which are planned to be networking by district cooling system,.

Table4.20 Targeted Development Area for Cogeneration System

Zone	Site Area (m ²)	Cooling Load		Annual Cooling Load per Area (MWh/m ² ·y)	District Heat Supply		Area to Introduce CGS
		Max. Load (kW)	Annual Demand (MWh/y)		District Cooling System	Spot Heat Supply System	
A	27,300	15,465	50,675	1.86	Yes		
B	201,000	32,878	95,338	0.47	Yes		Yes
C	174,400	8,922	23,763	0.14		Yes	
D1	39,500	7,704	38,303	0.97	(Scheduled)	Yes	
D2	192,400	37,719	135,585	0.70	Yes		
E	152,000	45,245	117,185	0.77	Yes		Yes
F1	9,700	1,475	4,925	0.51	Yes		
F2	113,900	49,773	167,333	1.47	Yes		Yes
G	370,800	11,692	29,527	0.08	—	—	—
H	152,900	22,130	63,807	0.42		Yes	
I	151,300	760	2,539	0.02	—	—	—
Total	1,585,200	233,761	728,978	0.46	—	—	—

Source: JICA Study Team.

(3) Proposed Development Plan for Energy Center and Cold Water Conduit

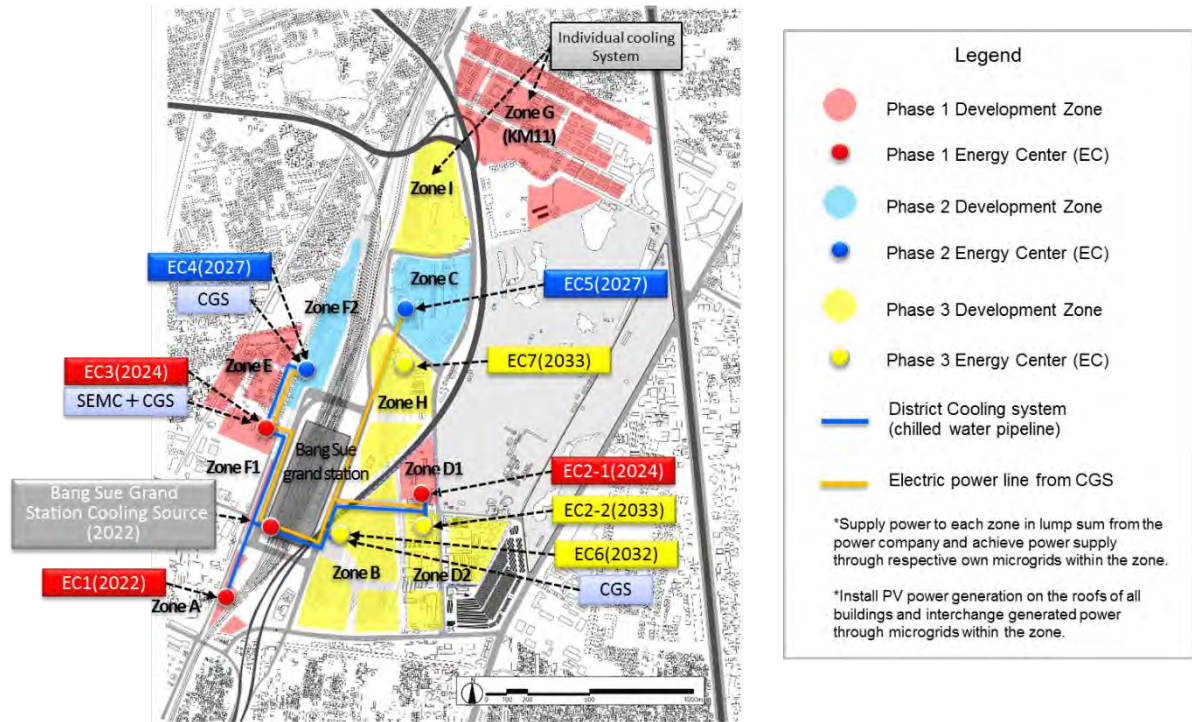
Based on the above consideration results, Figure4.87 organizes a proposed development plan for energy center layout and cold water conduit.

Energy centers are allocated respectively in Zones A, B, C, E, D1, D2, F2 and H. Cold water conduit network, as a district cooling system, is connected with Zones A, B, E, D1, D2 and F2, and a network is built with heat source equipment to be developed in Bang Sue Grand Station. In Zones C, D1 and H, meanwhile, the block cooling business is operated within respective zones, which does not need networking with cold water conduit beyond zones.

Cogeneration is also brought to Zones B, E and F2, from which through the cogeneration the

¹² PTT indicates that it takes about three years under the current regulation. See details on “4.4.2 (4) 4) Gas pipeline development status”.

backup system for emergency power sources is installed from BCP perspectives in Bang Sue Grand Station as a key facility for the area, the medical complex planned in Zone D1 and MICE in Zone C.



Source: JICA Study Team.

Figure4.87 Proposed Development Layout for Energy Supply Plant and Cold Water Conduit

Table4.21 organizes energy centers and supply areas.

Table4.21 Energy Center and Supply Area

Energy Center	Operati on Start	Supply Area	District Heat Supply		Area to Introduce CGS	Remarks
			District Cooling System	Block Cooling System		
EC 1	2022	Zone A	Yes			
EC 2-1	2024	Zone D1	(Scheduled)	Yes		Connect with district cooling network on the sidelines of future equipment renewal.
EC 2-2	2033	Zone D2	Yes			
EC 3	2025	Zones E, F1	Yes		Yes	Zone F is closer to Zone E, which supplies.
EC 4	2027	Zone F2	Yes		Yes	
EC 5	2027	Zone C		Yes		
EC 6	2032	Zone B	Yes		Yes	
EC 7	2033	Zone H		Yes		

Source: JICA Study Team.

(4) Supply Capability and Annual Supply Volume for Power and Cooling by Energy Center

1) Max. Power Supply Capability and Max. Supply Volume

Table4.22 and Table4.23 show max power supply capability and max supply volume by energy sector.

Table4.22 Max. Power Supply Capability by Energy Center

Energy Center	Operation Start	Supply Area	Max. Load (kW)	Simultaneous Usage Rate ¹³ (%)	Max. Supply Capability ¹⁴¹⁵ (kW)
EC1	2022	Zone A	5,898	94%	5,821
EC2-1	2024	Zone D1	3,614	61%	2,315
EC2-2	2033	Zone D2	24,502	93%	23,926
EC3	2025	Zones E, F1	34,847	78%	28,539
EC4	2027	Zone F2	28,470	88%	26,306
EC5	2027	Zone C	18,247	92%	17,627
EC6	2032	Zone B	25,118	87%	22,945
EC7	2033	Zone H	17,430	75%	13,726
—	2025	Zone G	31,263	92%	30,200
—	2032	Zone I	10,616	100%	11,147

Source: JICA Study Team.

Table4.23 Max. Power Supply Volume by Energy Center

Energy Center	Operation Start	Supply Area	Annual Demand (MWh/y)	Annual Transmission Loss ¹⁶ (MWh/y)	Max. Supply ¹⁷ (MWh/y)
EC1	2022	Zone A	24,722	1,236	25,958
EC2-1	2024	Zone D1	17,004	850	17,854
EC2-2	2033	Zone D2	80,695	4,035	84,729
EC3	2025	Zones E, F1	88,695	4,435	93,129
EC4	2027	Zone F2	98,487	4,924	103,412
EC5	2027	Zone C	31,097	1,555	32,652
EC6	2032	Zone B	68,398	3,420	71,818
EC7	2033	Zone H	42,848	2,142	44,990
—	2025	Zone G	53,834	2,692	56,526
—	2032	Zone I	14,353	718	15,071

Source: JICA Study Team.

¹³ Simultaneous usage rate is set at “peak load for each EC/total peak load for each building supplied by each EC” and the load pattern by time is considered and calculated by each building use.

¹⁴ As Zones G and I adopt a building-based cooling system, system COP to meet cooling demand is supposed as 3.0 and calculations are made.

¹⁵ Transmission loss (including loss in the transformer) is set at 5% across the board.

¹⁶ Transmission loss (including loss in the transformer) is set at 5% across the board.

¹⁷ As Zones G and I adopt a building-based cooling system, system COP to meet cooling demand is supposed as 3.0.

2) Max. Cooling Supply Capability and Max. Supply Volume

Table4.24 and Table4.25 show calculation results for maximum cooling supply capability and maximum supply volume by energy center.

Table4.24 Max. Cooling Supply Capability by Energy Center

Energy Center	Operation Start	Supply Area	Max. Load (kW)	Heat Loss ¹⁸ (kW)	Max. Supply Capability ¹⁹ (kW)
EC1	2022	Zone A	15,465	195	15,660
EC2-1	2024	Zone D1	7,704	14	7,718
EC2-2	2033	Zone D2	37,719	1,091	38,810
EC3	2025	Zones E, F1	46,719	105	46,824
EC4	2027	Zone F2	49,773	364	50,137
EC5	2027	Zone C	8,922	151	9,073
EC6	2032	Zone B	32,878	405	33,283
EC7	2033	Zone H	22,130	389	22,519

Source: JICA Study Team.

Table4.25 Max. Cooling Supply by Energy Center

Energy Center	Operation Start	Supply Area	Annual Demand (MWh/y)	Annual Heat Loss ²⁰ (MWh/y)	Max. Supply (MWh/y)
EC1	2022	Zone A	50,675	1,709	52,384
EC2-1	2024	Zone D1	38,303	120	38,423
EC2-2	2033	Zone D2	135,585	9,559	145,144
EC3	2025	Zones E, F1	122,110	917	123,027
EC4	2027	Zone F2	167,333	3,190	170,523
EC5	2027	Zone C	23,763	1,327	25,090
EC6	2032	Zone B	95,338	3,551	98,889
EC7	2033	Zone H	63,807	3,407	67,214

Source: JICA Study Team.

¹⁸ Piping ambient temperature for calculation is set at 30 °C for heat loss from district piping in the cold water supply system.

¹⁹ The simultaneous usage rate is set at 100% across the board.

²⁰ Piping ambient temperature for calculation is set at 30 °C for heat loss from district piping in the cold water supply system.

(5) Equipment Volume for Heat Source

1) Equipment Volume for Chiller

Table4.26 organizes chiller volume needed for respective energy centers and heat storage tank volume for cold water used for backup system.

Heat storage tanks are introduced to energy centers as a backup system for chiller from the perspectives of effective use of waste heat through cogeneration, fluctuation absorption of power loads and levelling of partial loads. The building frame under the installation space for heat source equipment, etc. is used, as a precondition, for the heat storage tank for cold water, and volume for heat storage tank is set at 10,000 USRTh, considering volume for possible installation.

Water for heat storage tank for cold water can also be used for fire-fighting or daily life water, contributing to enhanced disaster prevention functions in the urban area.

Table4.26 Chiller Volume

Energy Center	Operation Start	Supply Area	Max. Cooling Supply Capability (kW)	District Heat Supply <District Cooling/Block Cooling >	
				Chiller Volume ²¹ (USRT)	Heat Storage Tank for Cold Water for Backup ²² (USRTh)
EC 1	2022	Zone A	15,660	4,900	10,000
EC2-1	2024	Zone D1	7,718	2,500	10,000
EC2-2	2033	Zone D2	38,810	12,200	Share with EC2-1
EC 3	2025	Zones E, F1	46,824	14,700	10,000
EC 4	2027	Zone F2	50,137	15,700	10,000
EC 5	2027	Zone C	9,073	2,900	10,000
EC 6	2032	Zone B	33,283	10,500	10,000
EC 7	2033	Zone H	22,519	7,100	10,000

Source: JICA Study Team.

²¹ Allowance rate for chiller volume is set at 10% across the board.

²² Heat storage tanks are used for the backup use of district heat supply system.

2) Equipment Volume for Cogeneration System

The 4 MW-class gas turbine for cogeneration volume is set, considering effective use of waste heat, total device efficiency and equipment prices, in addition to boilers for backup use.

Table4.27 organizes overviews for cogeneration and boiler as backup use.

Table4.27 Cogeneration Volume

Energy Center	Operation Start	Supply Area	CGS Volume (kW)	Boiler Volume (t/h)
EC 1	2022	Zone A	—	—
EC 2-1	2024	Zone D1	—	—
EC 2-2	2033	Zone D2	—	—
EC 3	2025	Zones E, F1	4,440	10
EC 4	2027	Zone F2	4,440	10
EC 5	2027	Zone C	—	—
EC 6	2032	Zone B	4,440	10
EC 7	2033	Zone H	—	—

Source: JICA Study Team.

(6) Rough Area for Energy Center

Table4.28 organizes rough floor area needed for the installation of each energy center. SEMC overview is described later.

Table4.28 Area Needed for Energy Center and SEMC

Energy Center	Operation Start	Supply Area	Heat Source Equipment (m ²)	CGS (m ²)	Area for Heat Storage Tank ²³²⁴²⁵ (m ²)
EC 1	2022	Zone A	1,225	—	2,000
EC 2-1	2024	Zone D1	625	—	2,000
EC 2-2	2033	Zone D2	3,050	—	Share with EC2-1
EC 3	2025	Zones E, F1	3,675	1,500	2,000
EC 4	2027	Zone F2	3,925	1,500	2,000
EC 5	2027	Zone C	725	—	2,000
EC 6	2032	Zone B	2,625	1,500	2,000
EC 7	2033	Zone H	1,775	—	2,000
SEMC	2022	Subject to all areas	300		

Source: JICA Study Team.

²³ The pit height is set at 2 m across the board, considering construction costs.

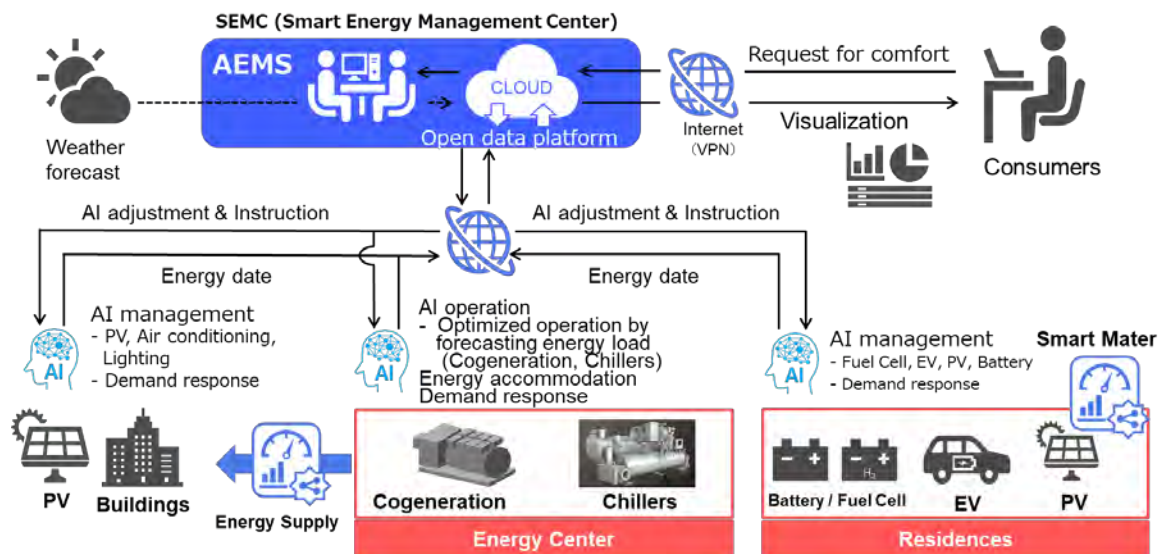
²⁴ Supply temperature for cold water is set at 7 °C and return temperature is set at 15 °C ($\Delta t = 8^\circ\text{C}$).

²⁵ Heat storage tank efficiency is set at 87%, assuming double-pit system.

(7) Overview of Smart Energy Management Center (SEMC)

1) Overview of Area Energy Management System (AEMS)

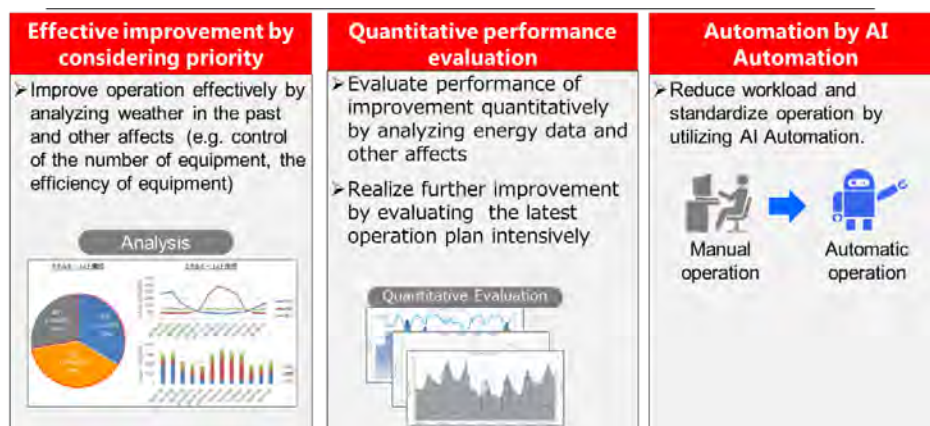
The Smart Energy Management Center (SEMC) adopts Area Energy Management System (AEMS) which manages operation for all energy centers and controls energy across the Bang Sue area. AEMS collects and analyses data including renewable energy from respective energy centers and solar power stations, energy from respective facilities and weather information in order to optimize the entire regional energy with AI system and visualize collected or accumulated energy data through the open data platform. Figure4.88 shows a function overview for AEMS.



Source: JICA Study Team.

Figure4.88 Concept for AEMS

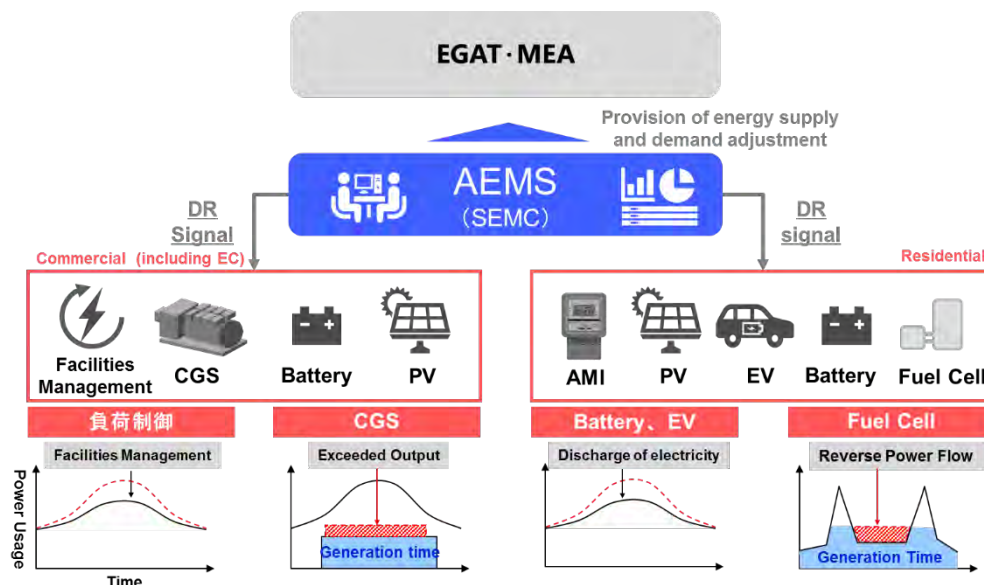
The AI system to be mounted on AEMS collects and analyses the past weather data and equipment operation data in an effort to optimize energy center operation and achieve labor-saving for operation supervision with robotic process automation (RPA). Figure4.89 shows a concept for energy improvement approach with the AI system in addition to optimal operation.



Source: JICA Study Team.

Figure4.89 Energy Management with AI System

Moreover, based on directions from Thai electricity authorities (EGAT/MEA), AEMS addresses supply and demand adjustment through virtual power plant (VPP) or demand response (DR) with intraregional energy resources, aiming to optimize energy across the Bang Sue area and make energy supply and demand effective and stable in a wider range. Figure4.90 shows a concept for AEMS demand control.



Source: JICA Study Team.

Figure4.90 Concept for Demand Control

2) Rough Area for Smart Energy Management Center (SEMC)

The SEMC is to be installed in or near the smart city center planned in Zone E. The SEMC includes an operation room, monitoring devices and servers²⁶ for AEMS operation in each energy center, together with an office room for operation managers, meeting rooms and a stockroom (devices, tools, etc.), and it needs an approximately 300 m²²⁷ space in total.

Table4.29 Rough Area for SEMC

	Operation Start	Needed Area (m ²)	
SEMC (Zone E)	2022	Operation room	100
		Office room for operation managers, meeting rooms, stockroom (device, tools), etc.	200
		Total	300

Source: JICA Study Team.

²⁶ Excludes servers for open data platform, which is included in the smart city center.

²⁷ Excludes area needed for head office functions (general affairs, finance, legal) for the smart service company.

(8) Introduction of EMS (BEMS/HEMS)

In order to visualize and save energy across the Bang Sue area through the open data platform, the EMS like BEMS/HEMS is introduced to facilities at a certain degree of scale or larger.

Although the BEMS is subject mainly to business facilities, its functions or requirements are not necessarily clarified. Therefore, the system is roughly divided into (1) energy data collection system and (2) energy control system. (1) is introduced to all facilities in the Bang Sue area and (2) implementation is handled as BEMS.

The way to consider the introduction of EMS like BEMS/HEMS is summarized and Table4.30 organizes the number of introduced facilities.

- Introduce business facilities at 50,000 m² or larger, considering cost-effectiveness for BEMS.
- Introduce HEMS to all residential facilities.

Table4.30 Number of Introduced Facilities for EMS

Phase	Zone	BEMS (No. of Buildings)	HEMS ²⁸ (No. of Houses)
Phase1 (From 2022 onwards)	A	2	197
	D1	1	648
	E	3	7,975
	F1	0	0
	G	0	10,875
	Subtotal	6	19,694
Phase2 (From 2027 onwards)	C	0	4,797
	F2	4	7,043
	Subtotal	4	11,840
Phase3 (From 2032 onwards)	B	2	5,186
	D2	0	5,890
	H	0	4,461
	I	0	4,794
	Subtotal	2	20,332
Total		12	51,866

Source: JICA Study Team.

(9) Introduction of Solar Power Generation

1) Potentiality for Solar Power Generation

In order to make effective use of empty space for unnecessary cooling towers by adopting district cooling system in the Bang Sue area, solar power generation is installed on the roofs of all buildings to achieve energy supply system with low environmental loads.

As the rooftop space for solar power generation is set at 80% of the standard floor area, possible power generation volume is calculated²⁹ on the basis of such condition.

²⁸ The figure 70 m² per house is used to calculate the number of houses. .

²⁹ The rooftop space is supposed to address solar power generation = building area by building x 0.8 in the study reports

The following table shows equipment volume for solar power generation by zone.

Table4.31 Solar Power Generation Volume

Phase	Zone	Building Area (m ²)	Solar Power Generation Volume (kW)	Renewable Energy Volume Ratio against Max. Power Load (%)
Phase1 (From 2022 onwards)	A	19,320	2,164	37
	D1	8,170	915	25
	E	56,780	6,359	19
	F1	9,700	1,086	190
	G	85,700	9,598	35
	Subtotal	179,670	20,123	28
Phase2 (From 2027 onwards)	C	51,600	5,779	32
	F2	383,450	6,149	22
	Subtotal	435,050	11,928	26
Phase3 (From 2032 onwards)	B	84,130	9,423	38
	D2	55,150	6,177	25
	H	32,560	3,647	21
	I	21,800	2,442	24
	Subtotal	193,640	21,688	28
Total		808,360	53,739	27

Source: JICA Study Team.

2) Business Model to Facilitate Solar Power Generation

Business models are compared and reviewed to facilitate solar power generation. Energy suppliers need to own solar power generation facilities and pay rental fees to the facility owners to advance solar power generation in the Bang Sue area.

Table4.32 Energy-Saving Effect and CO₂ Emission Reduction

The purchasers of Solar Panels	Building owners	ESP
Image		
Concept	- Building owners purchase solar panels - The power output is utilized in their own buildings primarily - The surplus of power output is sold to the ESP	- ESP invests solar panels instead of building owners - The power output is sold to building owners - The surplus of power is bought and sold to the other building owners by the ESP
Pros & Cons	- It is possible that building owners hate to install solar panels because of its installation cost - Building owners must maintain solar panels and repair them if necessary - Building owners fully enjoy the cost reduction obtained by solar panels	- Building owners need not invest the installation costs of solar panels - Building owners need not maintain solar panels - Building owners should share the cost reduction obtained by solar panels with the ESP

Source: JICA Study Team.

produced in FY2018 for the calculation of solar power generation output.

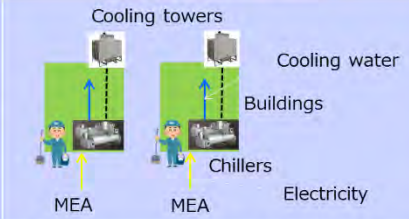
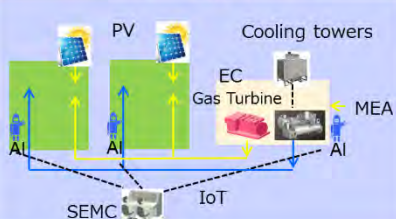
4.4.6 Comparison between Smart Energy Network and Conventional System

(1) Comparison between Smart Energy Network and Conventional System

The following table shows a comparison between the conventional system and the smart energy network. The traditional system needs the installation of heat source equipment tailored to demand for each building, and secures machine room or space for rooftop cooling tower, and arrangement for operators.

Meanwhile, as the smart energy network, suggested in the Bang Sue area, does not need heat source equipment for each building, the effective space is expanded, SEMC remotely monitors each EC status and manages day-to-day operation and maintenance for equipment in an effort to save labor in operation management. And also, AI system is used to optimize operation in the facility operation across the area.

Table4.33 Comparison between Smart Energy Network and Conventional System

	Conventional System	Smart Energy System
System Image		
Outline	- Building owners buy electricity from MEA. - Building owners have their own chillers in their building. - They operate and maintain them by themselves.	- Explained previously

Source: JICA study team.

(2) Energy-Saving Effect and CO₂ Emission Reduction

Table4.34 shows calculation results on energy saving effects and CO₂ emission reduction through the introduction of smart energy network. Based on the calculation results, approximately 28% of CO₂ emission is expected to be reduced in comparison with the traditional building-based cooling system.

In this calculation, considerations are made on high-efficient district heat supply system and energy-saving brought by solar power generation and by the EMS³⁰.

Table4.34 Energy-Saving Effect/ CO₂ Emission Reduction

		Phase1	Phase1+2	Phase1+2+3
Energy Consumption with Traditional Building-based Cooling System (MWh/y)		254,618	447,901	752,437
Energy Consumption at Adoption of Smart Energy Network	Power Consumption (MWh/y)	181,275	346,443	501,012
	Gas Consumption (MMBTU/y)	458	458	1,299
CO ₂ Reduction (t-CO ₂ /y)	Power	- 41,512	- 57,425	- 142,306
	Gas	23,177	23,177	65,733
	Total	- 18,334 (Reduction 7%)	- 80,602 (Reduction 18%)	- 208,039 (Reduction 28%)
CO ₂ Emission Unit		Gas 50.6 t-CO ₂ /MMBTU Power 0.566 t-CO ₂ /MWh		

Source: JICA Study Team.

Table4.35 shows expected equipment volume for the traditional building-based cooling system to compare with the smart energy network for reference.

Table4.35 Chiller Volume in Case of Building-Based Cooling System (Reference)

Energy Center	Operation Start	Supply Area	Cooling Supply Capability (kW)	Traditional System <Reference>	
				Chiller Volume ³¹ (USRT)	Backup ³² (Cold Source Equipment USRTh)
EC 1	2022	Zone A	15,660	4,900	1,000
EC2-1	2024	Zone D1	7,718	2,500	500
EC2-2	2033	Zone D2	38,810	12,200	2,500
EC 3	2025	Zones E, F1	46,824	14,700	3,000
EC 4	2027	Zone F2	50,137	15,700	3,200
EC 5	2027	Zone C	9,073	2,900	600
EC 6	2032	Zone B	33,283	10,500	2,100
EC 7	2033	Zone H	22,519	7,100	1,500

Source: JICA Study Team.

³⁰ Energy-saving effects brought by EMS is set here at 10% across the board, referring to Japan's case (Survey research report on energy-saving effects brought by IT, released by Japan Electronics and Information Technology Industries Association).

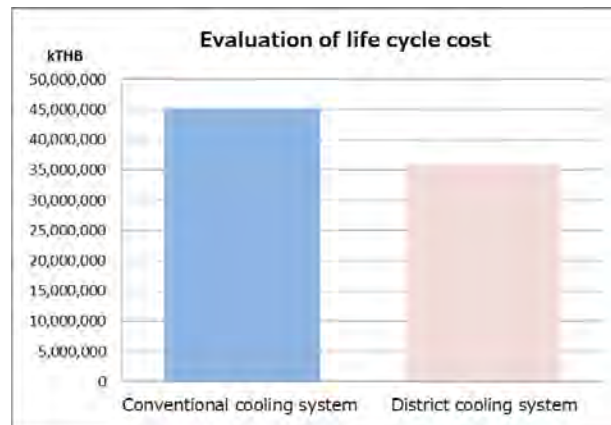
³¹ Allowance rate is set at 10% across the board, as done in the smart energy network.

³² The traditional system with backup devices is set at 20% of chiller volume, considering allowance rate.

(3) Advantage in Smart Energy Network

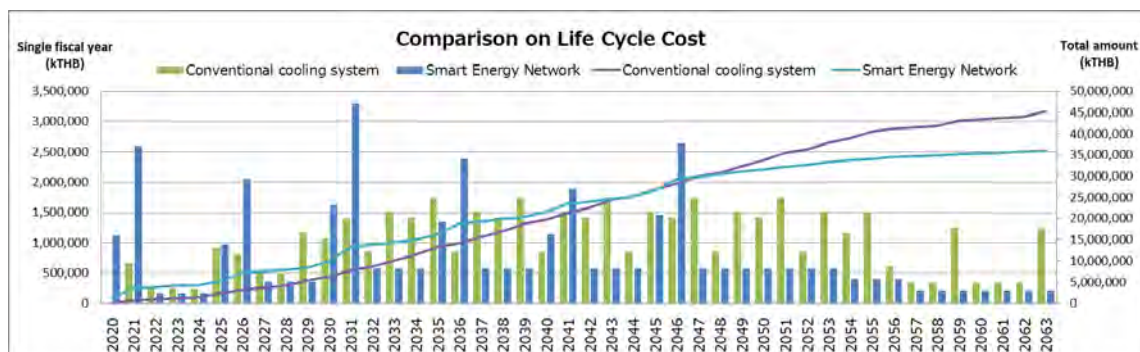
1) Energy Conservation/Environmental Performance/Life Cycle Cost

The district cooling system features better life cycle cost performance and higher energy consumption efficiency than those of individual heat source system and less impact on the environment like air pollution. The following figure compares the case of district cooling system and conventional cooling system in the Bang Sue are.³³ ..



Source: JICA Study Team.

Figure4.91 Comparison on Life Cycle Cost ①



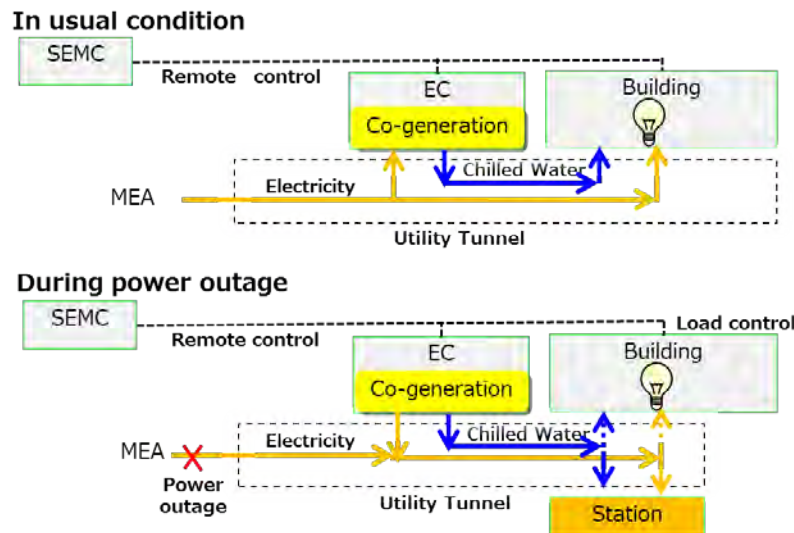
Source: JICA Study Team.

Figure4.92 Comparison on Life Cycle Cost ②

³³ See the calculation conditions for comparison in “5.5.3 Consideration on Smart Energy Business Profitability.”

2) Reliable Supply

As EC or energy supply system achieves stable energy supply, it uses cogeneration at power outage to continue energy supply for key facilities or equipment. The following figures show power supply flows under normal circumstances and at time of emergency.

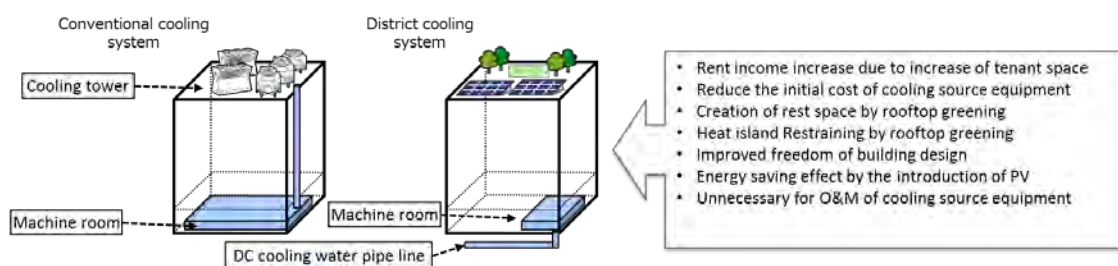


Source: JICA Study Team.

Figure4.93 Power Supply Flow at Emergency through Cogeneration (as shown earlier)

3) Use of Effective Space and Labor-Saving for Operation Management

- The smart energy network operates or handles heat source equipment through SEMC's intensive management and saves maintenance and other work for concentration on the core business.
- As each building does not need to secure the installation space for heat source equipment, building owners can lease the space to tenants and use it for warehouse or parking lot.
- As cooling towers are not needed, more flexible building design is possible with relaxation space production like rooftop greenery and the use of solar power generation.



Source: JICA Study Team.

Figure4.94 Effective Use of Space

4.4.7 Legal System/Regulation related to Development of Smart Energy Network

(1) Legal Framework and Regulation related to Energy Conservation

1) The Energy Conservation Promotion Act

Thailand enacted the Energy Conservation Promotion Act B.E.2535, in 1992, which was enforced in 1998 and revised in 2007. The act requires the owner of Designated Building or Designated Factory, 1) at 1,000 kW or larger as contracted power demand, 2) at 1,175 kVA or larger as total volume for installed reformers, or 3) at 20 million MJ or larger as annual power and vapor consumption, to implement the following:

- Appoint Person Responsible for Energy (PRE)
- Report energy consumption volume and energy saving activities
- Submit energy saving goal and plan

2) Building Energy Code

The Building Energy Code, taken effect in 2009, stipulates, for newly built or renovated buildings with the total floor area at 2,000 m² or larger, the following six items: 1) outer surface of building, 2) lighting equipment, 3) air conditioning equipment, 4) hot water equipment, 5) renewable energy use and 6) building energy performance.

The building with the site area of 10,000 m² or larger need to comply with Building Energy Code (BEC) newly enacted in mid-2018. The code applies to nine kinds of newly built large-scale construction structures, including hotel, office, hospital, department store, theater, gasoline station, hall for conference, campus building and condominium. The factors for new building subject to the code include 1) building materials, 2) air conditioning equipment, 3) lighting, 4) hot water, 5) renewable energy and 6) building structure.

In addition, the code aims to reduce power consumption by approximately 10% or 13.7 billion kWh for the next two decades, which is equivalent to 48 billion baht of power costs. The code is enforced in a stepwise fashion with the following three procedures. With the code enforcement, the Department of Alternative Energy Development and Efficiency (DEDE) facilities efforts described in the following table.

- The code applies to newly built structures with the site area of 10,000 m² from 2018 onwards.
- The code applies to newly built structures with the site area of 5,000 m² to 10,000 m² from 2019 onwards.
- The code applies to newly built structures with the site area of 2,000 m² to 5,000 m² from 2022 onwards.

Table4.36 Building Energy Code

Effort	Outline
Facilitate Code Execution	• Secure BEC execution. • Nurture BEC auditors. • Tighten BEC. (Stepwise regulation expansion)
Support Energy-Saving Construction	• Establish certification system for energy-saving construction. (LEED, TREES and other green certifications) • Provide financial support like government subsidy or low-interest rate personal loan, etc.

Zero Energy Building	• Validate green building design, economic value and climate change in Thailand. • Work out zero energy building plan. • Goal: Newly built public and private structure with the site area of 2,000 m² or larger.
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Source: JICA Study Team.

3) New Energy Efficiency Development Plan

On January 23, 2019 the National Energy Policy Council in Thailand approved revised Power Development Plan 2018 (PDP 2018), as a revision for PDP 2015, to secure future power sources. As PDP 2018 stipulates the promotion of renewable energy or cogeneration for 20 years from 2018 to 2037, larger investments are expected on renewable energy or cogeneration.

In PDP 2018, in comparison with PDP 2015, power generation volume is raised by approximately 10% and the degree of dependence on coal power is slashed by about 10%. Meanwhile, the dependence level on natural gas remains. In order to encourage private operators to enter the power generation market for efficiency, PDP 2018 describes a policy to reduce EGAT's current power generation rate to mid-20%.

(2) Legal System/Regulation on Cogeneration Business

As there is no legal system/regulation on cogeneration business itself in Thailand, the legal system/regulation chiefly on power supply or gas cogeneration development is organized. Meanwhile, under current Legal System/Regulation, cogeneration system can be constructed only in industrial area (called purple zone). Therefore, deregulation (Special zone certification, etc.) is required for installing cogeneration system into the Bang Sue Area.

1) Permit for Power Supply Business

In Thailand, if power generation, power transmission or distribution, or power retail business and power operation exceeds 1,000 kVA, permit or approval, stipulated in Energy Industrial Act, B.E.2550 (2007), is needed.

2) License on Power Generation

The power generation operator, running a power plant at 1,000 kVA or larger, has to gain Electricity Generation License, irrespective of Industrial Power Supplier (IPS), Very Small Power Producer (VSPP) or In-Plant Utility (IPU).

3) Power Purchase Agreement

Although it was possible to sell generated power to power transmission and distribution companies like EMA or specific suppliers' customers, sales of excess power produced by cogeneration is currently suspended.

4) Factory Operation License

As the power plant is classified as “type-3 factory,” ERC-issued Factory Operation License needs to be gained.

5) Building Construction Permit

Before the start of construction, Building Construction Permit needs to be gained. After the end of construction, the operator needs to gain Building Permit.

6) Energy Production Permit (Por Kor 2)

The power plant with 200 kVA or larger volume needs to gain Regulated Energy Production Permit.

If natural gas is used for power generation, as the business is classified as “type3 regulated business” under the Fuel Control Act, the operator also needs to gain a license under the act.

And also, if Small Power Producer (SPP) operates renewable energy power generation, it needs to submit company registration documents, wiring or device design drawings, necessary warranties and related certificates, requests for power sales to EGAT and application documents in the license application process.

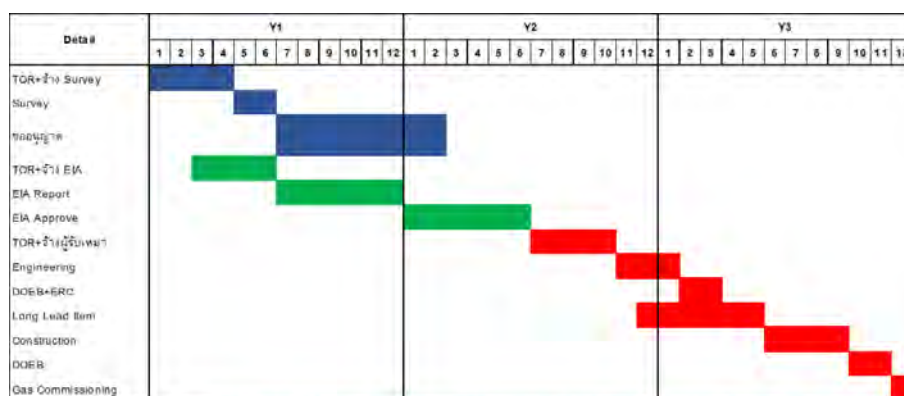
7) Environmental Impact Assessment

After the Enhancement and Conservation of National Environment Quality Act (NEQA) was enacted in 1992, the Notification of Ministry of Natural Resources and Environment under NEQA stipulates project classification and scale needed for environmental impact assessment (EIA), and regulations or procedures (screening, EIA report production, screening process/time, environmental preservation measures, monitoring, etc.).

Under Constitution Article 67 for 2017, if projects are likely to have a serious impact on environmental quality, natural resources or health in the community, Environment and Health Impact Assessment (EHIA) is needed.

Based on the above, in the case of a power station with the output of 10 MW or larger, EIA is needed. In the case of a power station with coal as fuel and the output of 100 MW or larger, EHIA is needed. This regulation is also applicable to cogeneration system.

In the case of gas-fired power generation at less than 10 MW, Environmental and Safe Assessment (ESA), based on Factory Act, or Initial Environmental Examination (IEE), in line with local rules, is required. Furthermore, installing or prolonging gas pipeline also subject to environmental impact assessment. The rough schedule for the gas pipeline connection and installation is shown below.



**Plan will be started when PTT receive the SRT conclusion about Future Project

Source: Material supplied by PTT.

Figure4.95 Pathumthani-Phayathai Gas Pipeline (Reprint)

8) Air Quality Standards

Thai gas emission-related standards need to be met before the development of cogeneration. Regulations for air pollution prevention in Thailand stipulate general or comprehensive standards on environmental air and standard concentration on contained materials by generated source, including fixed emission source like factory or mobile source like vehicle or two-wheel vehicle. As cogeneration is classified as fixed emission source, the following emission standards need to be met.

Table4.37 Emission Gas Standards from Fixed Source in Thailand

No	Harmful Material	Unit	Standard Value
1	Total suspended particulates	mg/Nm ³	320
2	Antimony	mg/Nm ³	16
3	Arsenic	mg/Nm ³	16
4	Copper	mg/Nm ³	24
5	Lead	mg/Nm ³	24
6	Mercury	mg/Nm ³	2.4
7	Chlorine	mg/Nm ³	24
8	Hydrogen chloride	mg/Nm ³	160
9	Hydrogen sulfide	ppm	80
10	Carbon monoxide	ppm	690
11	Carbon dioxide	ppm	60
12	Nitrogen oxide	ppm	200

Source: JICA Study Team.

9) Permit/Approval toward Development of Smart Energy Network

Table4.38 shows permits and approvals on the development of smart energy network.

Table4.38 Permit/Approval Overview

Rule/Regulation	Administration	Remarks
Factory license	ERC	Product: Power, heat
Investment promotion	BOI	Tax benefit

Rule/Regulation	Administration	Remarks
Building construction permit	ERC (Power Plant) & BMA	Building
Building use permit	ERC (Power Plant) & BMA	Building
Gas use permit	ERC (Power Plant) & DOEB	Gas use facility
ERC Package	ERC	Cogeneration
ERC POK KOR 2	ERC	Cogeneration
Grid connection	MEA	Cogeneration
Power purchase contract	EGAT/MEA	District power source supply system
EIA/ ESA	ONEP	EIA: Cogeneration $\geq 10\text{MW}$ ESA: Cogeneration $<10\text{MW}$ Installation and extension of gas pipeline

Source: JICA Study Team.

(3) Certification Standards on Smart City in Thailand

If operators meet smart city requirements stipulated by Thai Board of Investment (BOI), they are given to tax privileges or other benefits. Therefore, this study aims to satisfy certification standards in the energy sector and achieve a smart city network suitable for a new gateway for Bangkok. The following describes comparison between smart energy certification standards and response status. As specific standard values are not set in the screening process for the certification standards, screening is done individually, depending on application.

Table4.39 Smart Energy Certification Standards and Response Status

No	Item	Consideration Standards	Response Status
1	Specific Energy Consumption (Mandatory)	All buildings and enterprises within the smart city have to meet the energy consumption average reference criteria for each type of buildings and enterprises.	- Smart energy network is expected to reduce CO₂ emission by 28%, compared with the traditional air conditioning system. - The Thai government sets an international goal to slash emission by 25% (compared with 2005).
2	Energy Generation	Renewable energy production (mandatory)	Install solar power generation on the roofs of all facilities.
		Onsite power generation	Generate onsite power generation through cogeneration.
		Energy storage	- Introduce heat storage tanks to each EC. - Store power in PRT's reserve cells to use at either peak cutting or supply and demand adjustment.
3	Energy Distribution	District cooling or district heating system	Build district cooling system in the area with high energy demand density.
		Promoting the usage of environmental friendly vehicles (Eco-vehicle)	Operate PRT and introduce EV-sharing service.
4	Greenhouse Gas Reduction	Greenhouse gas reduction target throughout the project period. Greenhouse gas reduction target in the first year for the project	Reduce CO ₂ emission by 28%, compared with the traditional system. (Phase 1: 7%, Phase 2: 18% and Phase 3: 28%)

No	Item	Consideration Standards	Response Status
5	SMART Grid System	Area energy management system (AEMS)	Aim to be high efficiency by introducing AEMS to collaborate with PRT's smart service or environmental monitoring data.
		SMART Meters	Introduce smart meters to all facilities in order to visualize energy demand and realization of effective charge collection.
		Micro-grid system	Build microgrids in all areas to improve energy security.
		Smart Home / Smart Building system	• Introduce BEMS to facilities with a certain degree of scale or larger. • Introduce HEMS to all residential facilities.
6	Other Innovative Proposal for Smart Energy (SMART Energy Innovation)	Presenting the innovations that can support the development of smart city in Smart Energy field.	Integrate energy management through SEMC and create innovation through the open data platform.

Source: JICA Study Team.

4.4.8 Consideration and Challenge towards Business Execution

(1) Consideration in Business Execution

1) Conduit Pipe Maintenance for Development Business Site

If cold water conduit pipes are installed in the commercial land to lease to operators like developer, as facility maintenance is likely to be difficult (at building rehabilitation, removal, etc.) due to a change in operators and others, risk factors in the redevelopment of cold water conduit pipe are higher than those for public space. Therefore, they need to be reduced by using public space like utility conduit to the extent possible to be developed in the land for road.

2) Scalable Facility Development

In order to expand the energy network in a stepwise fashion in accordance with each development work, facilities need to be developed with the future demand scale in mind. As for facilities that are difficult to expand facilities with cold water conduit pipes, development work needs to be facilitated, based on facility plans devised in line with the future demand size to the extent possible.

In addition, in order to secure plant space in the zone in the mid-stage in accordance with the stepwise development, expandable plant space needs to be secured beforehand, considering the maximum demand. Therefore, plant space needs to be considered together with public preferential treatment like excluding plant space from the calculation of floor space ratio for building.

3) Peak Load Expansion Brought by Users with Similar Industry Sectors

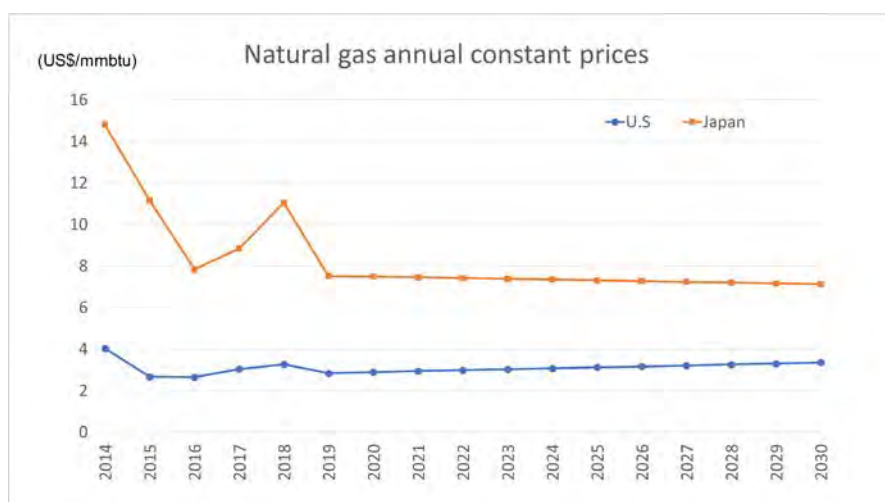
In the case of users with similar business sectors like commercial or business facility, the maximum load is especially likely to be large at peak hour. As energy suppliers need to secure facilities to meet peak load for respective users, the initial cost on facility introduction is risen. It is therefore effective to attract users like hotel or hospital whose demand patterns are different.

4) Encouragement to Use Smart Energy Network

In order to encourage to use smart energy network, awareness/understanding is expanded on advantage brought by use of energy network or on energy conservation in the Bang Sue area, and incentives are given to zone developers or users except for energy cost reduction. To this end, government policies are encouraged including preference policies or privilege expansion, based on land price growth evaluation through added values as smart city, revenue increase and social benefits.

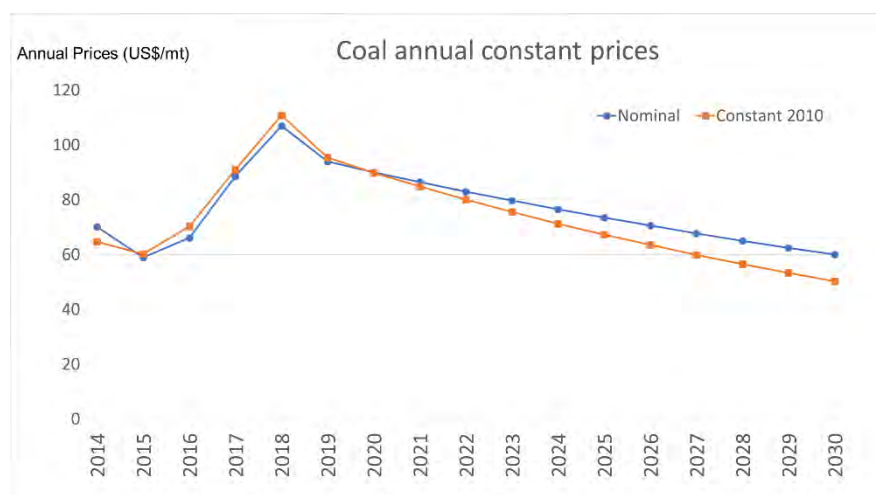
5) Unit Price Fluctuations for Gas and Power

As fluctuation risks for primary energy sources like gas and power are caused by fuel adjustment prices, the cost structure needs to be considered so that these unit price fluctuations can reflect to direct heat costs. In general, fuel adjustment prices are added to commodity charges.



Source: World Bank Commodity Markets Outlook April 2019

Figure4.96 Natural Gas Price Trend and Future Forecast



Source: World Bank Commodity Markets Outlook April 2019

Figure4.97 Coal Price Trend and Future Forecast

6) Business Risk Reduction

As it is common to take a long period to develop a wider energy network in the Bang Sue area, one of large business risk factors for energy suppliers is delay in the development of demand facilities or planning change.

In order to avoid development delay attributable to users, at the time of concluding supply and demand contracts, actions can be considered including settlement with capped late payment charge.

Assuming that actual usage volume falls below demand forecast due to planning change, it is important to hedge risks between energy suppliers and users, including basic charge setup on the basis of the demand size in the initial plan.

Table4.40 Energy Cost Setup (Example)

Charge	Breakdown
Basic charge	Fixed cost (Depreciation/ Interest/ Labor cost/ Maintenance cost/ Insurance premium) + Profit
Usage charge	Cold water usage volume x unit price + Ft (Fuel adjustment)

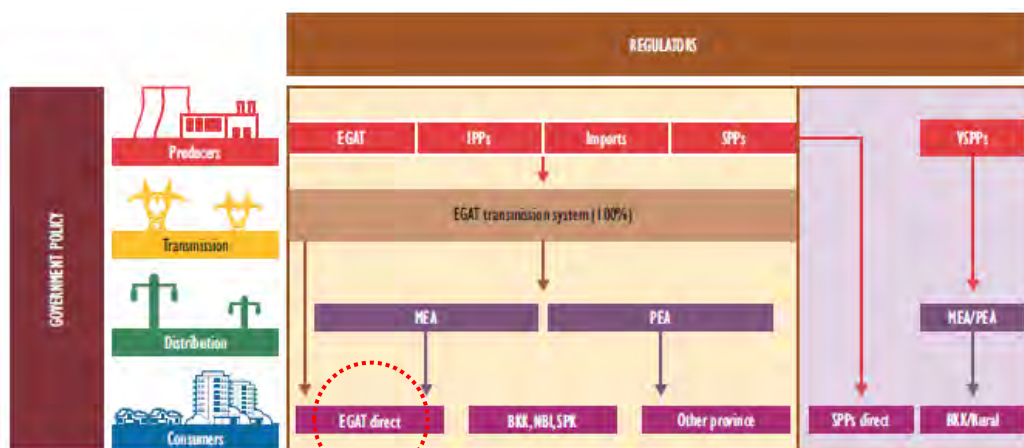
Source: JICA Study Team.

7) Regional Power Network Development in Preparation for Disasters

As the microgrid installed for each zone needs to be separate from the existing power transmission and distribution network, the power system management needs to be established, in an effort to achieve independent energy supply at time of disasters.

8) Wholesale Procurement Price for Power

In the Bang Sue area, power is distributed collectively to respective zones and energy suppliers established in the area make retail sales to respective users. At that time, prior negotiations are needed on power wholesale prices to be procured by EGAT or the MEA. Wholesale procurement prices need to be set, considering running costs generated by operation or equipment renewal for microgrid or secondary substation together with business profits in Bang Sue.



Notes: BKK = Bangkok; NBI = Nonthaburi; SPK = Samut Prakan; these three provinces make up the service area of MEA.

Source: Added partially by JICA Study Team, based on Thailand Questionnaire conducted by IEA in 2015.

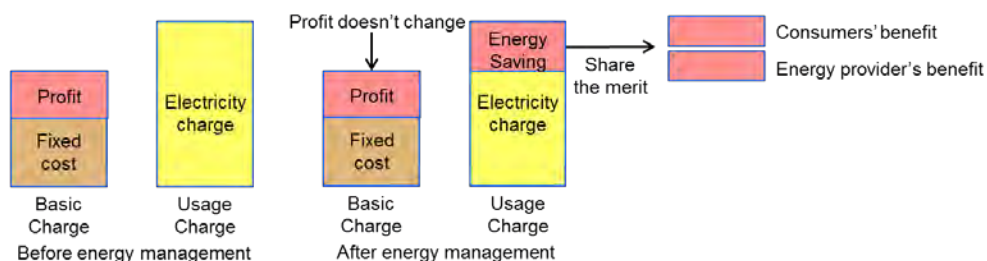
Figure4.98 Power Supply System in Thailand

9) Revenue Sharing for Energy Conservation

If EMS to be introduced to business facilities is used to reduce energy costs, energy suppliers can properly share profits with developers or building users to enjoy incentives mutually as an effective system³⁴.

The following figure organizes a way to consider profit sharing, when energy costs for users are slashed through energy management or energy-saving services delivered by energy suppliers.

³⁴ Energy suppliers are expected to deliver energy services for energy conservation.



Source: JICA Study Team.

Figure4.99 Revenue Sharing Concept through Energy Conservation

10) Requirements on smart energy clarified in the bid document for zone developers

The issues to be described in bid requirements for each zone are as follows:

- Developers shall confirm requirements on utility development and management given by the SSC and cooperate with the SSC.
- Developers shall clearly describe, in the bid document, connection obligations to the smart energy network, including microgrid and district heating network.
- Developers shall supply Smart Energy Company (SSC) with energy demand volume and energy investment plans in order to secure the proper joint design performance on energy management.
- Developers shall implement the HEMS and the BEMS, based on data collection requirements for the AEMS managed by the SSC, in an effort to make energy management effective and sophisticated in the Bang Sue area.
- In order for developers to consider investments on renewable energy, they shall discuss investment schemes beforehand with the SSC, including additional installation of storage batteries or sales to smart energy network.
- Developers or private zone operators shall consider investments in EV battery charger, after consultations with the SSC.

11) Management shift of heat source equipment for Bang Sue Grand Station

It is desirable to shift, to the SSC, operation and management for heat source equipment and emergency power generators for Bang Sue Grand Station in order to connect Bang Sue Grand Station with the smart energy network and make the integrated management operation effective.

(2) Challenge on Business Execution

1) Restriction for Use District in Introduction of Cogeneration

The cogeneration system cannot be installed in the commercial district under the current regulation. Therefore, efforts are needed to encourage the government to ease restrictions including special district system or use district.

2) Deregulation on Power Sharing or Transaction for Power Supply and Demand Balancing

Flexible deregulation is needed on power sharing or transaction for power supply and demand balancing capability in an effort to facilitate effective use of smart energy network integrated with town development in the area. Although some demonstration cases have been given in Thailand, flexible deregulation, like special district certification to encourage advanced efforts for smart city, is needed due to no specific business market no legal system.