FY2014 Consigned Survey of the Introduction of Technologies to Reduce Carbon Dioxide Generated by JCM Large-scale Energy to Achieve a Low-Carbon Society in Asia

Feasible Study of the large scale CO2 reduction by JCM program for DCS plant and co-generation system in Thai International Airport (Suvarnabhumi International Airport)

March 2015

Surveying Organization: Institute for Global Environmental Strategies (IGES)

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■Abbreviation

ACM	Approved Consolidated Methodology
AM	Approved Methodology
BaU(BAU)	Business-as-Usual
BOCM	Bilateral Offset Credit Mechanism
C/P	Counter Part
CDM	Clean Development Mechanism
DOEs	Designated Operational Entities
GHG	Green House Gas
IPCC	Intergovernmental Panel on Climate Change
JCM	Joint Crediting Mechanism
JICA	Japan International Cooperation Agency
MRV	Measurement, Reporting, Verification
NAMAs	Nationally Appropriate Mitigation Actions
NAPA	National Adaptation Programmes of Action
NGO	Non-Governmental Organizations
TPEs	
UNFCCC	UN Framework Convention on Climate Change
PDD	Project Design Document
PPP	Public Private Partnership
QA/QC	Quality Assurance/Quality Control
REDD+	Reducing Emissions from Deforestation and Forest Degradation PLUS
TOE	Ton of Oil Equivalent
CHP	Combined Heat and Power
DEDE	Department of Alternative Energy Development and Efficiency
DEDP	Department of Energy Development and Promotion
ECP	Energy Conservation Plan
EGAT	Electric Generating Authority of Thailand
EGCO	Electricity Generating Company
EPPO	Energy Policy Planning Office
ESI	Electricity supply industry
GEF	Global Environment Fund
IPP	Independent Power Producers
LNG	Liquid Natural Gas
LPG	Liquid Petroleum Gas
MEA	Metropolitan Electric Authority
NEPO	National Energy Policy Office, Now EPPO.
NERC	National Energy Regulatory Commission
NPC	National Policy Committee
PCAF	Power Consumer Assistant Fund
PEA	Provincial Electric Authority
PTT	Plc Petroleum Authority of Thailand Public Company
RATCH	Ratchaburi Electricity Generating Holding
SPP	Small Power Producer
TOD	Time of Day
TOU	Time of Use
VSPP	Very Small Power Producer
VAT	Value Added Tax
PTTEP	PTT EXPLORATION AND PRODUCTION PUBLIC COMPANY LIMITED
CSP	Combined Steam and Power

Final Report (Summary) on Contract Research for Introducing Technology of Reducing Carbon Dioxide Emitted by JCM Large-Scale Energy Generation to Realize Low Carbon Society in Asia in FY 2014

Feasible Study of the large scale CO2 reduction by JCM program for DCS plant and co-generation system in Thai International Airport (Suvarnabhumi International Airport)

(Investigator: Institute for Global Environmental Strategies)

Partners		Mitsubishi Heavy Industries, Ltd. Mitsubishi Heavy Industries (Thailand) Ltd.
Country or area		Thailand
Technical field		Energy saving
Outline of the project		The purpose of this feasibility study is to reduce carbon dioxide emitted from existing SPP gas-turbine combined-cycle generators in Thailand by introducing an air cooling system for gas turbines to increase the power output and to supply to the power grid electricity having a low CO_2 emission factor.
JCM methodologies	Qualification requirements	Requirement 1: The generator in question shall be a gas-turbine combined-cycle type operated by an SPP or IPP in Thailand. Requirement 2: The generator in question shall be equipped with an air cooling system. Requirement 3: The generator in question shall sell additional power generated by the air cooling system to the surrounding consumers.
	Default settings	The following shows settings given by default. a) Emission factor of grid power $FE_{EL\ GRID}$ (tCO_2/MWh): See the formal information shown by TGO. b) Emission factor of fuel (natural gas) FE_{FUEL} (tCO_2/Nm^3): See the formal information shown by TGO.
	Estimation of the baseline emission	The following shows the baseline emission estimated from the power output and emission factor of the generator in question. $BE_y = EG_{B\,y} \times FE_{EL\ COM\ B}$ BE_y: Baseline emission (tCO_2/yr) $EG_{B\,y}$: Power output of the generator in question (MWh/yr) $FE_{EL\ COM\ B}$: Emission factor of the generator in question (tCO_2/MWh)
	Estimation of the project emission	The following shows the project emissions given by subtracting a reduction in emissions corresponding to additional power generated by the project from emissions corresponding to fuel consumed by the project for power generation. $PE_y = PE_{FUEL\ COM\ y} - PE_{EL,GRID\ y}$ PE_y: Project emissions (tCO_2/yr)

		$PE_{FUEL\ COM\ y}$: Emission corresponding to project fuel consumption (tCO_2/yr) $PE_{EL,GRID}$: Grid emission corresponding to additional power (tCO_2/yr)
	Monitoring method	Key parameters to be monitored include the power output, fuel consumption, and intake air temperature of the generator. The values are derived from generator operation records and additional measurements.
GHG emissions and reduction		$ER_y = (BE_y - PE_y) \times ETA_{OPE} \times ETA_{LOAD}$ BE_y: Baseline emission (tCO_2/yr) PE_y: Project emission (tCO_2/yr) ER_y: Reduction in emission (tCO_2/yr) ETA_{OPE}: Operating rate of the generator (–) ETA_{LOAD}: Load factor of the generator (–) This study showed that estimated GHG emissions reductions by two SPPs were 39,922 ton-CO_2/yr and 27,370 ton-CO_2/yr, respectively. Both are given assuming that the operation and usage rates of the generator are 100 percent, so it is necessary to evaluate the real effectiveness according to the results of checking the actual operation at the site.
Environmental impacts		The purpose of this project is to improve the power output of existing gas-turbine combined-cycle generators. Therefore, running the project does not change the environmental impact. No action is required to run the project because it has no factor of having an effect on the environment.
Project and money plans		Currently, SPPs shall raise 50 percent of the funds by themselves if the project receives JCM subsidies. Accordingly, it takes time and money to attain the goal.
Feasibility of introducing Japanese technologies		Japanese technologies to be introduced in the project include a centrifugal chiller, air cooling system, and system controller.
Contribution to sustainable development in the host country		In this project, Japan provides advanced high-efficiency power generation and cooling system technologies. In addition, it hands down to the host country know-how for increasing the efficiency of the same system, such as application and operation technologies.

Title: Contract Research for Introducing Technology of Reducing Carbon Dioxide Emitted by JCM Large-Scale Energy Generation to Realize Low Carbon Society in Asia in FY 2014

Feasibility Study of Applying Technology of Reducing Carbon Dioxide Emitted from JCM Large-Scale Energy Generation to the Local Cooling and Cogeneration Plants of the Suvarnabhumi Airport in Suwannaphum, Thailand
(Host country: Thailand)

Investigator: Institute for Global Environmental Strategies (IGES)

1. Research Organization

In this research, the investigator shown above works with the following two partners:

- Mitsubishi Heavy Industries, Ltd.: Main contractor in charge of research and study for reducing carbon dioxide emissions and applying energy saving technologies.
- MHI (Thailand) Ltd.: Co-ordination between SPPs in Thailand and Japanese side.

2. Research Overview

2.1. Outline of the Project

The main purpose of this research contracted with the Ministry of the Environment in Japan is to conduct a survey for introducing technologies and plants that are used in power plants and energy-consuming industries as well as that can reduce carbon dioxide emitted by large-scale energy generation. The details of the survey are shown below.

- Research for introducing carbon dioxide reduction technologies to SPP cogeneration plants
  In Thailand, SPPs (small power producers) operate large-scale cogeneration plant business by installing a gas-turbine combined-cycle generator in an industrial park to supply electricity, water, and steam at the site.
  In this research, IGES not only introduces an air cooling system to such cogeneration plants to reduce the carbon dioxide emission and energy cost but also estimates the investment cost to check the effectiveness of the introduced system.

2.2. Current Situation of the Host Country

(1) SPPs including Thai international airports and SPP programs

The Thai government promotes systems for using energy effectively. In 1992, the “Regulations for the purchase of power from small power producers (SPPs) for electricity generated from non-conventional energy, waste, residual fuel, and co-generation” were enforced to reduce the import and consumption of oil by encouraging the SPPs to use exhaust heat during power generation and to regenerate energy for a rise in energy usage efficiency.

Some Thai international airports follow the regulations in order to generate electricity with a gas turbine, to produce steam by using exhaust heat during power generation, to regenerate electricity with a steam turbine, and to produce cold water with the remaining steam and an absorption refrigerator. They sell the resulting electricity to EGAT and other airports, so they are considered to be SPPs.

(2) Thailand participating in the JCM

When IGES produced this report, Thailand had not signed the JCM, but the Japanese government will have a talk with the counterpart about as early signature as possible.

2.3. SPP

In this research project, IGES planned to conduct a survey of Thailand international airports having a cogeneration plant, but changed it to SPP power plants having similar facilities, because of lack of information about the former.

3. Carbon Dioxide Reduction Technologies Applicable to the cogeneration plant of Thai international airports and SPP power plants

3.1. Feasibility Study on SPPs

To introduce technologies and plants for reducing carbon dioxide emitted by large-scale energy generation to power plants and energy-consuming industries, IGES conducted a survey of power plants operated by SPPs and gas-turbine combined-cycle power generation systems operated by IPPs or EGAT (Electricity Generating Authority of Thailand) to check the cold water and steam supply system for an effect on the power generation system in the air cooling system and the SPP power plant that supplies not only electricity but also cold water and steam.
IGES held a hearing with the owners of some SPPs and found that most of them used either of two gas turbines: one was SGT-800 made by Siemens in Germany and the other was LM 6000 provided by General Electric in the US.

3.2. Air Cooling System for Gas Turbines

In a standard gas-turbine generator, as the intake air temperature increases, the density of the air, a working fluid, decreased and the mass flow rate of the air burned is lower, resulting in a reduction in output. Therefore, if the atmospheric temperature is high, the power demand is high but the power supply capacity is low. The air cooling system prevents a reduction in output at high temperatures by decreasing the intake air temperature.

4. Requirements for Applying the Air Cooling System

4.1. Meteorological Conditions of Thailand

Thailand has a tropical monsoon climate, which consists roughly of rainy and dry seasons. Bangkok is sultry because of high temperatures and humidity throughout the year. The annual average temperature and humidity of the City were 29.1 degrees Celsius and 76.2 percent respectively in 2012.

4.2. CO_2 Emissions Recorded by Power Generation Companies

The amount of CO_2 emitted by power generation varies depending on the fuel type and plant-by-plant power generation efficiency. The following shows CO_2 emissions based on the current power generation efficiency and fuel type.

Table 4.1: Plant-by-plant CO_2 emissions

Classification	Efficiency	CO_2 emission kg-CO_2/kWh
Thermal PP with coal	41%	0.864
Thermal PP with oil	41%	0.695
Thermal PP with LNG	41%	0.476
SPP-class gas-turbine combined-cycle generator	52.7%	0.371
IPP-class gas-turbine combined-cycle generator	56.7%	0.344

Sources:
The CO_2 emissions of thermal plants are excerpted from Reference 3.
The reporter finds the efficiency of gas-turbine combined-cycle power generation. The CO_2 emission of the power generation is calculated according to Reference 4: Physical Properties of Natural Gas.

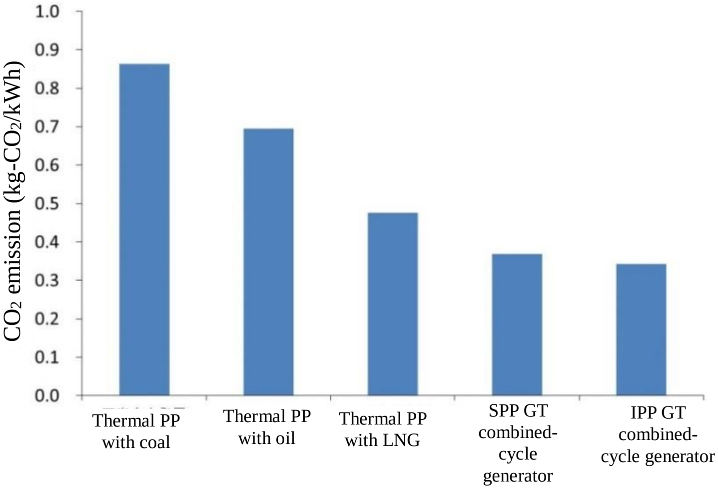


Figure 4.1: Plant-by-plant CO_2 emissions

IGES evaluates the CO_2 reduction effect of the air cooling system to be introduced according to the following two points:

(1) CO_2 reduction effect given by increasing the power output of the gas-turbine combined-cycle generator featuring low emissions to reduce reliance on coal-fired power.
(2) Effect given by improving the heat rate of the gas turbine

4.3. Plant-by-Plant CO_2 Emissions in Thailand

In this FS, IGES made a decision to use CO_2 emissions announced by TGO. This is because TGO, an abbreviation for Thailand Greenhouse Gas Management Organization established in 2007, works as an organ that approves and checks CDM projects.

Accordingly, this FS adopts 0.5994 kg-CO_2/kWh, an OM shown by TGO.

5. Application of the Air Cooling System to Gas-turbine Combined-cycle Generators Operated by SPPs

5.1. Selection of SPP Gas-turbine Combined-cycle Plants

To choose SPP gas-turbine combined-cycle plants to which the air cooling system applies, IGEA met the producers, asked them to pick up gas-turbine combined-cycle generators to which the system is applicable, and worked on the CO_2 reduction and cost effectiveness after the introduction. As a result, the institute selected two typical generators used in Thailand: one was a 40 MW generator operated by Company G and the other was a 40 MW generator operated by Company S.

SPP programs have a limitation—power that can be sold to EGAT is up to 90 MW. Therefore, producers having a gas-turbine combined-cycle generator rated at 110-120 MW gain no merit if the industrial park has a power load of about 40 MW, because they cannot sell additional electricity given by introducing the air cooling system. Accordingly, IGES asked the SPPs to select an industrial park having a sufficiently high load.

6. Study on MRV verification methodology

6.1 MRV methodology

(1) Title of the methodology

"Introduction of a Suction Cooling System to the Gas Turbine Co-generation Plants of IPP and SPP"

(2) Outline of the methodology

1) GHG reduction mechanisms

Addition of a suction cooling system to the existing gas turbine-combined power generation plant will increase the power generation of the plant. Since the carbon dioxide gas emissions per unit of electricity generated by a gas turbine-combined power plant are in general considerably smaller than those arising from grid power generation, substitution of grid power consumption by the power generated by a gas turbine-combined power plant equipped with the suction cooling system will reduce total carbon dioxide emissions.

In addition, installation of the suction cooling system will lower the temperature of the intake air, and hence increase the power generation efficiency of the gas turbine-combined power plant. Thus, the accompanying reduction in fuel consumption will lower the carbon dioxide emissions.

2) Calculation of the baseline emissions

As the baseline emissions, there will be used the carbon dioxide emissions arising from the fuel used to generate electricity at the gas turbine-combined power generation plant "as is."

3) Definition of project-related emissions

The project-related emissions will be the carbon dioxide emitted from the gas turbine-combined power generation plant equipped with the suction cooling system less the amount of carbon dioxide emissions saved on the part of the power grid because of the increased supply to the grid of the electricity generated by the power plant equipped with the cooling suction system. As the increased power supply, there will be used the net increase in the power generation by subtracting from the actual increased power generation resulting from the installation of the suction cooling system the amount of electricity consumed in relation to the project scenario (such as the power consumed to drive the freezer).

(3) Eligibility requirements

This methodology is applicable to projects that satisfy all the following three requirements:

Requirement 1. That the power generation equipment is an SPP or IPP gas turbine-combined cycle power generation unit in Thailand;

Requirement 2. That the gas turbine power generation unit is equipped with a suction cooling system; and

Requirement 3. That the incremental power generated by the addition of the suction cooling system can be sold either to the power grid or to nearby consumers.

(4) Emission sources and GHG types

1) Baseline emissions

The emissions arise from the fuel consumed to generate power in the gas turbine-combined power generation plant, and the GHG concerned is carbon dioxide.

2) Project-related emissions

The project-related emissions represent the amount of emissions arising from the fuel consumed to generate power in the gas turbine-combined cycle power generation plant equipped, as a result of the project activity, with the suction cooling system, less the estimated amount of emissions that would have resulted if a power generation means commonly employed in the country were used to generate the incremental amount of electricity that the project activity has brought about. The GHG is carbon dioxide.

(5) Determination of the baseline emissions and the calculation

The baseline emissions can be computed by the following formula:

$$BE_y = BE_{FUEL,COM\ y} \qquad (6.1.\text{-}1)$$

(6) Determination of the project-related emissions

The project-related emissions can be computed by the following formula:

$$PE_y = PE_{FUEL\ COM\ y} - PE_{EL,GRID\ y} \qquad (6.1.\text{-}2)$$

(7) Computation of the GHG emissions reduction

The GHG emissions reduction can be computed by the following formula:

$$ER_y = (BE_y - PE_y) \times ETA_{OPE} \times ETA_{LOAD} \qquad (6.1.\text{-}3)$$

Parameter	SI unit	Description
BE_y	tCO_2/yr	CO_2 emissions at baseline
PE_y	tCO_2/yr	CO_2 emissions after project
$BE_{FUEL\ COM\ y}$	tCO_2/yr	CO_2 emissions arising from fuel used to generate power at the baseline gas turbine-combined power generation plant
$PE_{FUEL\ COM\ y}$	tCO_2/yr	CO_2 emissions arising from fuel used to generate power at the project gas turbine-combined power generation plant
$PE_{EL,GRID\ y}$	tCO_2/yr	CO_2 emissions arising from the grid if the incremental power generated by the project were supplied by the grid
ER_y	tCO_2/yr	Estimated CO_2 emissions reduction
ETA_{OPE}	—	Operation rate (capacity utilization) of the project unit
ETA_{LOAD}	—	Operational load of the project unit

(8) Data parameters for monitoring

Major data parameters that need be monitored for GHG emissions reduction determination are summarized as follows:

Parameter	SI unit	Description
$FE_{EL\ GRID}$	tCO_2/MWh	Average electricity CO_2 emissions coefficient supplied by the grid ➢ Default value: (0.599 t-CO_2/MWh: Thai GTO report)
$FE_{EL\ COM\ B}$	tCO_2/MWh	Electricity CO_2 emissions coefficient of the baseline gas turbine-combined power generation plant
$FE_{EL\ COM\ P}$	tCO_2/MWh	Electricity CO_2 emissions coefficient of the project gas turbine-combined power generation plant
T	K	Gas turbine suction temperature ➢ temperature reading
EG_{By}	MWh/yr	Annual power generation by the baseline power plant ➢ Computed from the project annual power generation

		and the suction temperature *T*
ETA_{OPE}	—	Project operation rate in year “y” ➢ Power generation plant operation record
ETA_{LOAD}	—	Average operational load of the project plant in year “y” ➢ Power generation plant operation record
$FE_{EL\ COM\ P}$	tCO_2/MWh	Electricity CO_2 coefficient of the project power generation plant ➢ Estimated from the annual power generation and fuel consumption shown in the power generation plant operation record

6.2 Draft survey on the project design document (PDD) preparation

(1) Project name

“Introduction of a Suction Cooling System to the Gas Turbine Co-generation Plants of IPP and SPP”

(2) Outline of the Project and the Applied Technology and/or Measures

The proposed JCM project aims to improve the energy efficiency and reduce energy-derived carbon dioxide emissions by introducing a gas turbine suction pre-cooling system and a high-efficiency centrifugal chiller to co-generation plants in Thailand and the area-wide air conditioning plant for the Thai International Airport.

More specifically, the following two systems will be examined for their effectiveness and feasibility:

1) A suction cooling system which will be installed additionally to the gas turbines of SPP and IPP in Thailand, with the view of increasing the output of the co-generation system and improving the power generation efficiency so that electricity of lower CO_2 generation intensity may be fed into the power grid in order to reduce carbon dioxide emissions.
2) The area-wide air conditioning plant for the Suvarnabhumi International Airport area is chosen because it is representative of many co-generation plants in Thailand. The absorption freezer currently in use will be replaced by a high-efficiency centrifugal chiller, which will generate excess vapor, which in turn will be used to generate more electricity. In this way, electricity of lower CO_2 generation intensity will be fed into the power grid, contributing to reduction of carbon dioxide emissions. (This item was dropped from the scope of the present study because of the unavailability of the equipment information.)

(3) Contribution from industrialized countries

In the proposed project, advanced high-efficiency power generation technology and freezer system technology will be made available. In addition, knowhow relating to the implementation, operation technology, and the like of high-efficiency systems of this kind will be passed on.

(4) Application of approved methodologies

Eligibility standard	Description of the methodology	Project information
Standard 1	The subject power generation unit must be an SPP or IPP gas turbine-combined cycle power plant in Thailand	There exist many SPP-based projects in Thailand through cooperation between Thai and foreign companies. There are many potentially eligible units.
Standard 2	The gas turbine power generation unit must be suitable for addition of the suction cooling system	Many of the SPP operators have gas turbine plants that are suitable for addition of the suction cooling system.
Standard 3	It must be possible to feed the incremental power generated by the addition of the suction cooling system into the power grid or to sell it to power users nearby.	The suction cooling system is an established technology which has been commercially proven in Japan.

(5) Calculation of emissions reduction

The GHG emission source in this project is fuel for power generation and the GHG is carbon dioxide.

The measurement of emissions reduction will be in accordance with "6.1. MRV Methodologies."

7. Concrete financing, work schedule, operational scheme, project implementation scheme, etc.

In this section, we review the concrete financing, work schedule, operational scheme, project implementation scheme, etc. directed toward project implementation.

7.1 Gas turbine suction cooling system implementation process

The SPP gas turbine suction cooling system project in Thailand is envisaged as follows:

(1) Eligibility of the gas turbine suction cooling system against JCM requirements as applied to SPP operators

Table-7.1 Eligibility consideration on SPP gas turbine suction cooling system

Eligibility	Requirement	Description about this project
Requirement 1	• The "Check list" will allow for easy judgment on the JCM eligibility of the contemplated project and the applicability of JCM methodologies to it.	MRV and PPD are explained in Chapter 6 of the FS.
Data (parameters)	• The list of parameters will enable the project participants to know the data required for calculation of the GHG emissions reduction/absorption based on JCM methodologies	Reduction measurement to verify the effect of the installation of the gas turbine suction cooling systems to an SPP power generation unit is possible, if the following is available: • The power generation unit:

	• Default values specific to the country and the sector will be provided in advance.	That all operational data are recorded by a central control system. • The added gas turbine suction cooling system: Monitoring and operational data recording units will be installed. The public organization, TGO (Thailand Greenhouse Gas Management Organization) publicly announces the CO_2 generation intensity of power generation in Thailand every year.
Calculation	• The GHG emissions reduction/ absorption quantity can be calculated automatically by inputting the values corresponding to the parameters to the spread sheet prepared beforehand.	MRV and PPD are explained in Chapter 6 of the FS.

As discussed above, the eligibility of the gas turbine suction cooling system against JCM requirements as applied to SPP operators is believed to be met.

(2) Schedule related to the suction cooling system

Generally a project schedule is determined by the delivery of the equipment. A likely manufacturing schedule of major pieces of equipment is shown below.

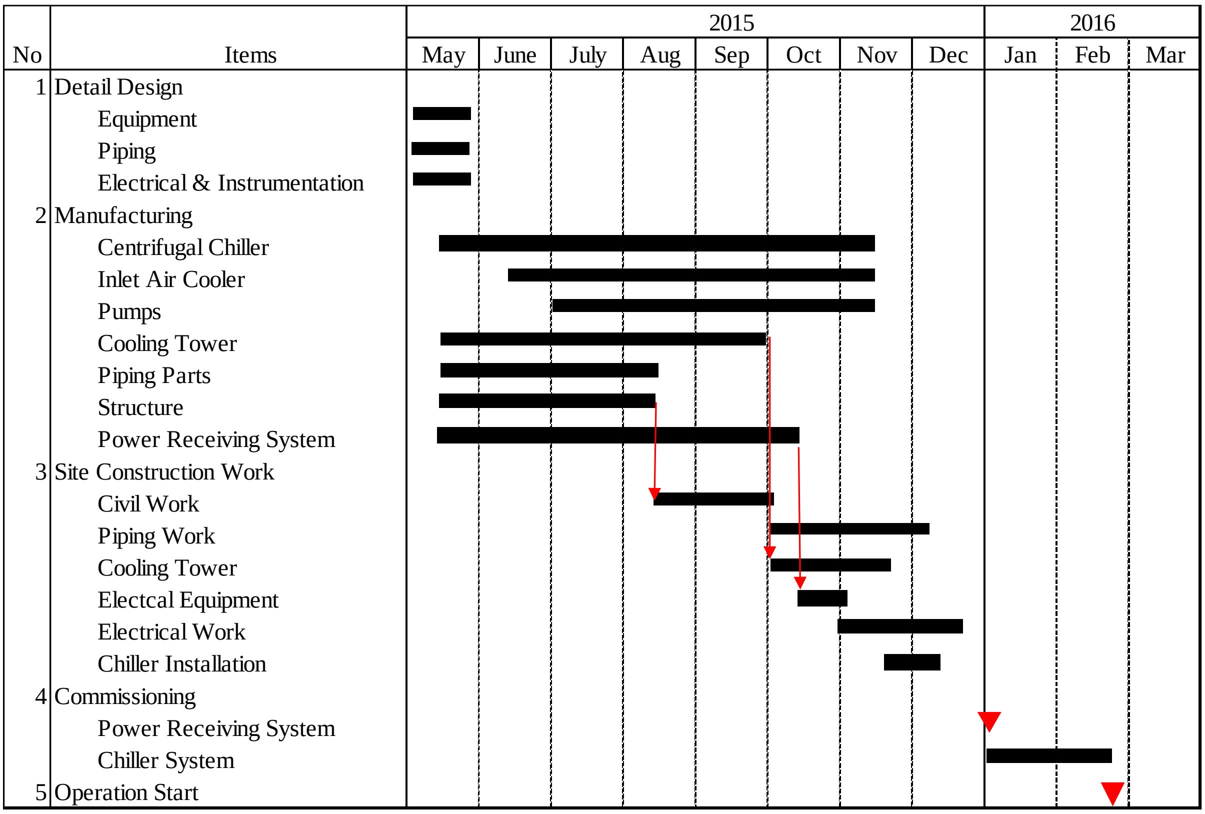
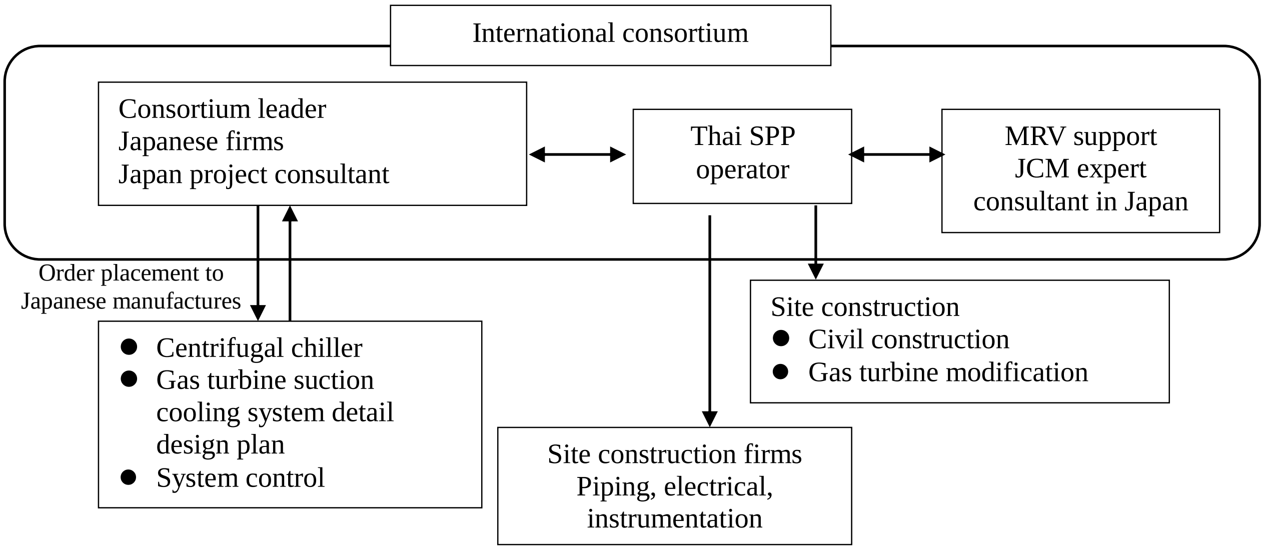


Chart-7.1 SPP gas turbine suction cooling system construction schedule

7.2 Project implementation scheme

Among the pieces of equipment required for the gas turbine suction cooling system, the centrifugal chiller, the suction cooling system, and the system control system cannot be procured from within Thailand or ASEAN. All others can be procured locally.

For the project implementation, the organizational scheme shown below is envisaged.

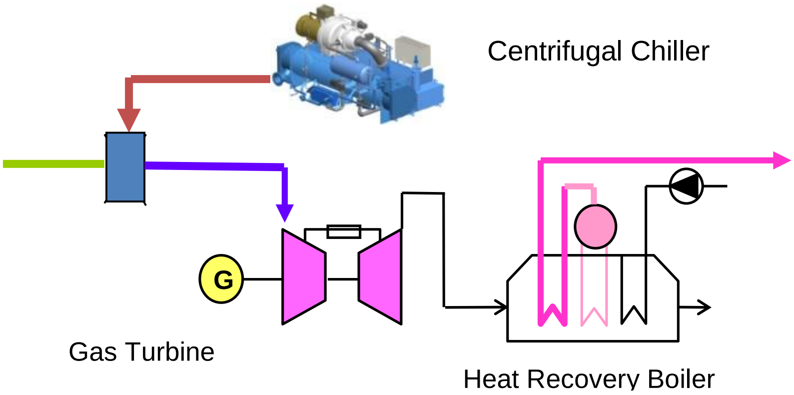


[Needed considerations for the above scheme]

1) Order placement to Japanese makers for the critical pieces of equipment (centrifugal chiller and the control system)
   To ensure system reliability and product quality
2) Constructions
   Order placement to site construction firms

CO$_2$ Reduction By Applying Inlet Air Cooling System
To SPP Gas Turbine Combined Power Plant

1. Effectiveness of Gas Turbine Inlet Air Cooling System
Gas Turbine performance (power output and efficiency) will be improved by cooling the inlet air.



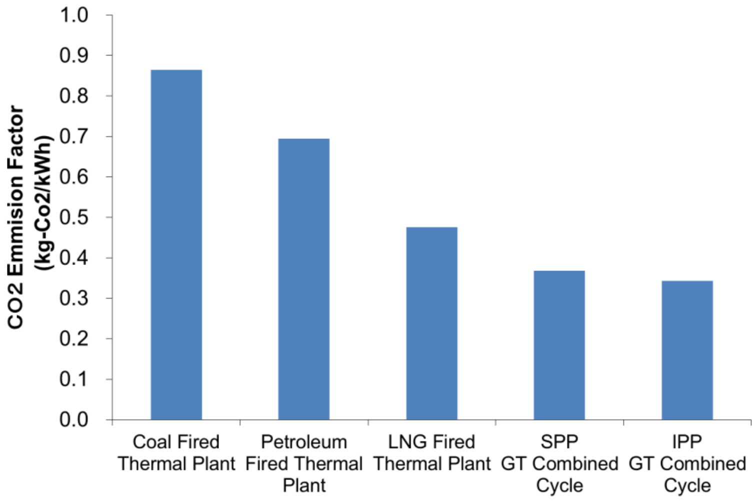
a. Gas Turbine Output by Ambient Temperature

Manufactures	Power Generation At 35℃	Power Generation At 15℃	Output
G Company Gas Turbine (USA)	36.6MW	42MW	5.4MW
S Company Gas Turbine (Germany)	39MW	47MW	8MW

b. Gas Turbine Efficiency Improvement by Inlet Air Cooling
3.7% - 4% Heat Rate Improvement

2. CO$_2$ Reduction by Inlet Air Cooling System application to Gas Turbine
CO$_2$ emission rate of power plant type is listed below. CO$_2$ reduction will be done by increase the power generation by applying

Category	Power generation efficiency	CO$_2$ emissions per unit kg-CO$_2$/kWh
Coal fired power generation	41%	0.864
Oil-fired power generation	41%	0.695
LNG-fired power generation	41%	0.476
SPP class gas turbine combined cycle power generation	52.7%	0.371
IPP class gas turbine combined cycle power generation	56.7%	0.344



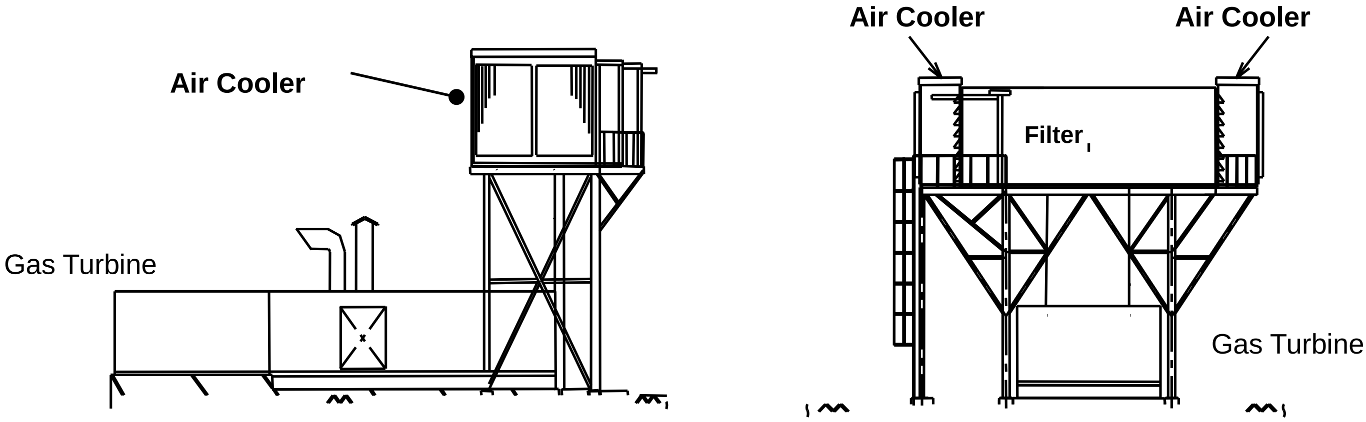
CO2 Emission Factor of Power Plant

The average of CO_2 emission factor of power grid in Thailand is 0.599kg-CO2/kWh and CO_2 emission factor of Gas Turbine Combined Cycle power plant is 0.371kg-CO_2/kWh.
The CO_2 reduction will be achieved by increasing of power generation of SPP Gas Turbine Combined Power Plant using Inlet Air Cooling System.
Yearly CO2 emission reduction amounts are shown below table.

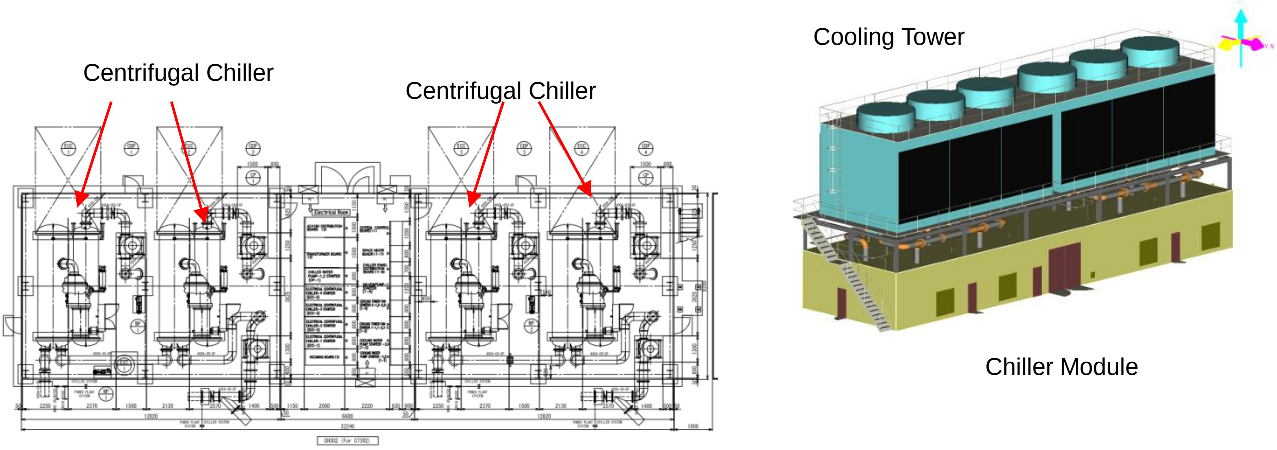
System	CO2 emission reduction
G Company GT x 2 + ST Combined Cycle Power Plant	39,922 ton-CO2/Year
S Company GT x 2 + ST Combined Cycle Power Plant	27,370ton-CO2/Year

Note : Above value is calculated based on the power plant is operated all year.

3. Gas Turbine Inlet Air Cooling System



Air Cooler Installation Image



Gas Turbine Inlet Air Cooling System Module Image

Chapter 1　Background and Outline of the Survey

1.1 Survey background

(1) Survey purpose

At the 36th Intergovernmental Panel on Climate Change (IPCC) held in Stockholm, Sweden, on September 26, 2013, the Summary for Policymakers from Working Group I's Report (the Physical Science Basis) for the IPCC's Fifth Assessment Report was approved and published, and it was announced that there was no room for doubt regarding the warming of climate systems, and that human activities were extremely likely to be the major cause of the warming observed from the middle of the 20th century. Japan is working to share among all countries the goal of at least halving greenhouse gas emissions worldwide by 2050 while aiming for an 80% reduction in greenhouse gas emissions by 2050 as a long-term goal (based on the Basic Environment Plan in the Cabinet decision of April 27, 2012). In order to halve greenhouse gas emissions worldwide by 2050, greenhouse gas emission projects will need to be discovered and formed on a large scale in the countries of the Asia-Pacific region, which are experiencing rapid economic growth, and moves towards the construction of a sustainable, low-carbon society in Asia accelerated. For that reason, the construction of a new mechanism, JCM (Joint Crediting Mechanism) to appropriately assess Japan's contributions to energy-generated CO_2 emissions reduction overseas.

A survey on the introduction of JCM large-scale energy-generated carbon dioxide reduction technologies for a cogeneration plant and refrigeration plant at Thailand's Suvarnabhumi International Airport was undertaken with the title of "FY2014 Consigned Survey of the Introduction of Technologies to Reduce Carbon Dioxide Generated by JCM Large-scale Energy to Achieve a Low-Carbon Society in Asia," aimed at surveying the introduction of technologies and plants which would allow reductions on a large-scale of power-generated carbon dioxide in power plants and energy-hungry industries as a survey to contribute to the commercialization of future joint crediting mechanisms (JCM)

(2) Survey period

December 10, 2014 to Friday March 20, 2015

1.2 Work outline

Main goal of the current project assigned by the Ministry of the Environment: To conduct the following survey with the aim of introducing technologies and plants that would allow the reduction of energy-generated carbon dioxide on a large scale and would be used by power plants and energy-hungry industries.

(1) Survey of the introduction of carbon dioxide-reduction technologies for SPP cogeneration plants

Gas turbine combined-cycles are installed in industrial estates in Thailand as cogeneration plants, and SPPs (Small Power Producers) that supply power, water, and heat, and to industrial estates are showing large-scale business growth. The introduction of an inlet cooling system in cogeneration plants used by existing SPPs and the amount of carbon dioxide removed, the energy cost reductions, and the investment costs will be studied.

Chapter 2 Systems Related to Energy Supply in Thailand

2.1 SPPs, including international airports in Thailand

(1) About the SPP program

The government of Thailand established a program for small power producers(SPPs) called "Regulations for the purchase of power from small power producers(SPPs) (For Electricity Generated from Non-Conventional Energy, Waste, Residual Fuel and Co-generation)" in 1992 with the aim of working to reduce oil imports and increasing energy efficiency through the use of renewable energy or waste heat from power generation, and has been expanding this system to ensure the effective use of energy.

This system grants approval as SPP businesses to businesses that meet specific criteria and have applied to EGAT for this project. Prices and other power sales conditions are presented by EGAT and applied equally to all approved businesses, so this is different to competitive bidding. When an SPP business is permitted to join this program, EGAT guarantees to buy up to 90 MW of electricity, and the remainder, as well as the heat (steam, cooling water) can be sold independently to client companies in the industrial estates. The results of the survey of companies selling generated power using this system are shown in Chapter 3.

(2) Cogeneration systems and district cooling plants at Suvarnabhumi International Airport

The District Cooling System and Power Plant Company (DCAP) was founded by the Electric Generating Authority of Thailand (EGAT), the Petroleum Authority of Thailand (PTT), and the Metropolitan Electric Authority (MEA), and has been supplying utilities such as cooling water, power, and steam to Suvarnabhumi International Airport, in the capital of Bangkok, and nearby facilities since 2006.

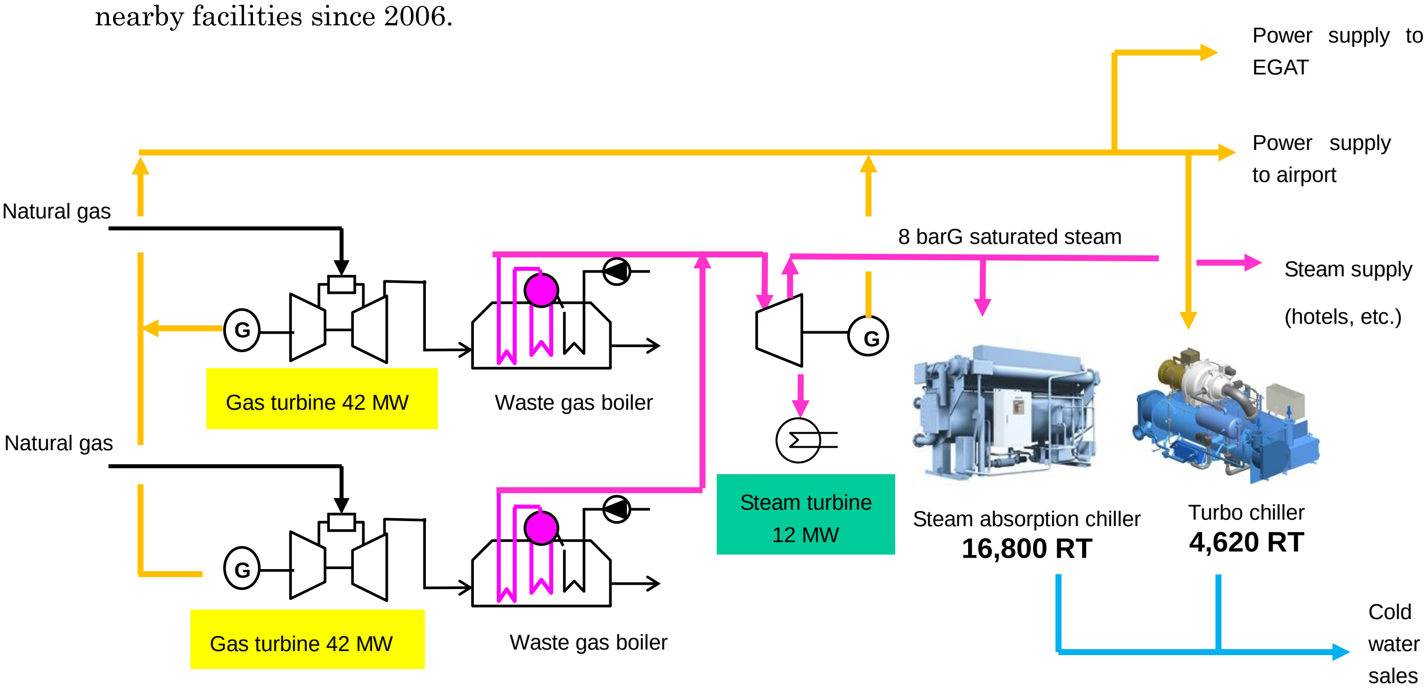


Fig. 2.1 DCAP cogeneration plant + district cooling plant

DCAP generates power from gas turbines using this system, creating steam by using their hot waste heat, which generates more electricity from steam turbines, and also generates cold water from the excess steam using an inlet refrigeration system. This power is sold to EGAT and Suvarnabhumi International Airport (BKK), and the company is classified as an SPP. The cogeneration system at BKK has also registered in the SPP program and signed a contract to sell 50 MW of power to EGAT (a five-year contract that as of 2015 is still current). The contract category is "SPP Non-Firm contract cogeneration system that was started commercial with EGAT."

(3) Small power producers

Overseas companies using the SPP program jointly with Thai businesses include ones from Japan, German, and France. The power generation systems using this system usually assume sales to EGAT of 90 MW and to industrial estates of about 30 MW for a total planned capacity of around 110 MW.

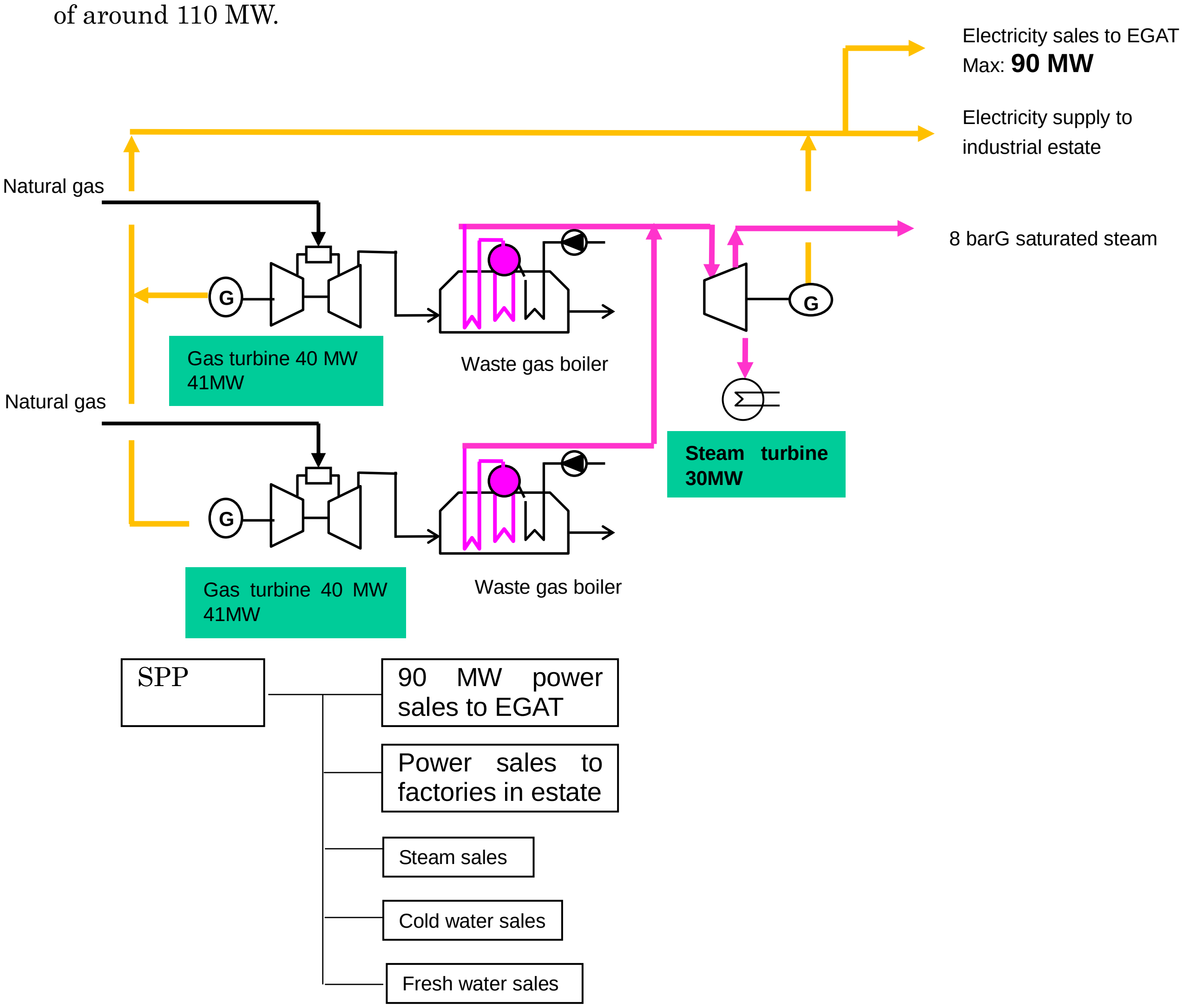


Fig. 2.2 Illustration of SPP energy sales

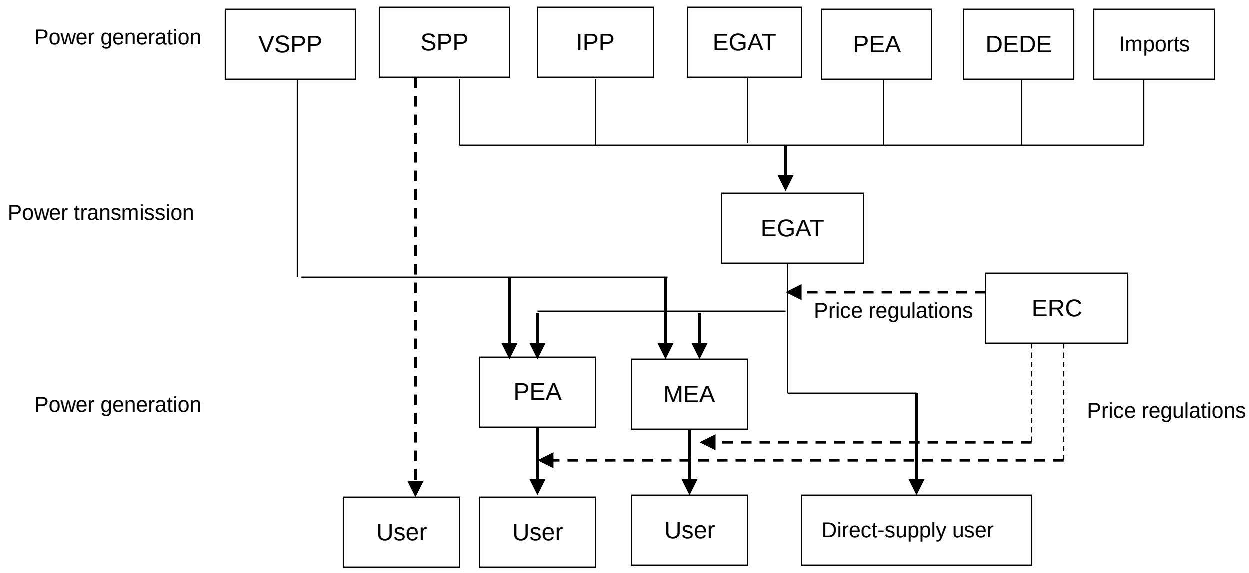
SPPs are expanding their businesses in steam, cold water, and pure water sales in addition to power for energy users in factories. The power sale unit cost for energy users in factories is determined independently (through negotiations with the factory owner).

The factory owner can choose to buy either from EGAT or from the SPP.

2.2 Power supply system

The power supply system in Thailand is as follows.

Organizational chart of power businesses in Thailand



Source: The Future of Thai Power Generation and Commercial Opportunities for Japanese Companies 1)

Fig 2.3 Power supply system in Thailand

(1) Electric Generating Authority of Thailand (EGAT)

EGAT is a state-owned power generation and transmission company (under the jurisdiction of the Ministry of Energy) that was established by the merger in May 1969 of three state enterprises, namely the Yanhee Electricity Authority (YEA), the Lignite Authority (LA), and the North-East Electricity Authority (NEEA). It enjoyed a monopoly on power generation and transmission in Thailand for many years after that, but with the liberalization of electricity businesses (discussed later), in 1992 independent power producers (IPPs) and small power producers (SPPs) entered the field of power generation, so EGAT has played the role of the off-taker (power purchaser) from that time. As of the end of 2011, EGAT owned and operated 51.3% (14,998 MW) of the power generation capacity of power companies overall (not including home-generated). In addition, it buys electricity from IPPs, SPPs, and neighboring countries, supplying this wholesale to the distribution companies (MEA and PEA), as well as directly supplying it to major energy users. Moreover, it owns the power transmission equipment and supply equipment, and operates the main power grid.

(2) Metropolitan Electricity Authority (MEA)

MEA was founded in 1958, before EGAT, from the Bangkok Power Company and the government Bureau of Electricity Generation, and is under the jurisdiction of the Ministry of Interior. As of 2012, it supplies power to the capital, Bangkok, and two neighboring provinces.

(3) Provincial Electricity Authority (PEA)

PEA was founded in 1960 with the aim of promoting electrification in rural areas, and is under the jurisdiction of the Ministry of Interior. It provides power to those regions not covered by the MEA (73 provinces) in four separate groups, and its operational areas cover 99% of the area of Thailand.

(4) Independent power producers (IPP)

In Thailand, it has been possible for the private sector to invest in power generation starting in 1992. After Electricity Generating Public Co., Ltd (EGCO) was established by being separated and made independent from EGAT, IPP recruitment (initial) started in 1994. Recruitment was divided into Phase I (operations starting from 1996 to 2000, three sites with a total output of 1,75o MW) and Phase II (operations starting from 2001, four sites with a total output of 計4,927.5 MW), and seven projects were selected. Next, the second round of recruitment was carried out in December 2007, for operations starting between 2012 and 2014, with an extra 4 projects, for a total of 4,400 MW, selected. Then, on December 4, 2012, recruitment started for the third batch, for operations starting from 2021 to 2026, and it has been clarified that in July 2013 5,000 MW worth of enterprises were in the final list. IPPs are broadly divided into those split off from EGAT such as EGCO and Ratchaburi Electricity Generating Holding (RATCH), and others.

(5) Small power producers (SPP)

SPPs are power producing companies that sell between 10 and 90 MW of power to EGAT. The system was introduced in 1992 in order to increase energy use efficiency and also help reduce the importation and use of foreign oil by using cogeneration systems that use existing fuels such as natural gas and coal, as well as renewable energy such as rubbish, biomass, photovoltaics, and solar heat. As of March 2012, the total amount of power sold from SPPs to EGAT was 2,554 MW. Note that Chubu Electric Power, Kansai Electric Power, and other Japanese companies are also involved in power generation.

(6) Very small power producers (VSPP)

VSPPs are extremely small-scale power producers that sell less than 10 MW of power to MEA or PEA. They encourage the development of renewable energy. As of March 2012, the total amount of power sold from VSPPs was 682 MW.

(7) Energy Regulatory Commission (ERC)

The highest decision-making authority for energy policy overall, under the direct jurisdiction of Office of the Prime Minister.

2.3 Participation of Japanese and overseas businesses in the SPP program

SPPs that have been approved by the Thai government are given guarantees that EGAT will buy their electricity for the long term, between 20 and 25 years. Most SPPs use natural gas as a fuel, but any increases in the cost of natural gas are reflected in the purchase price. Therefore they are a low-risk, profit-guaranteed business, so companies from outside Thailand are also investing in this business.

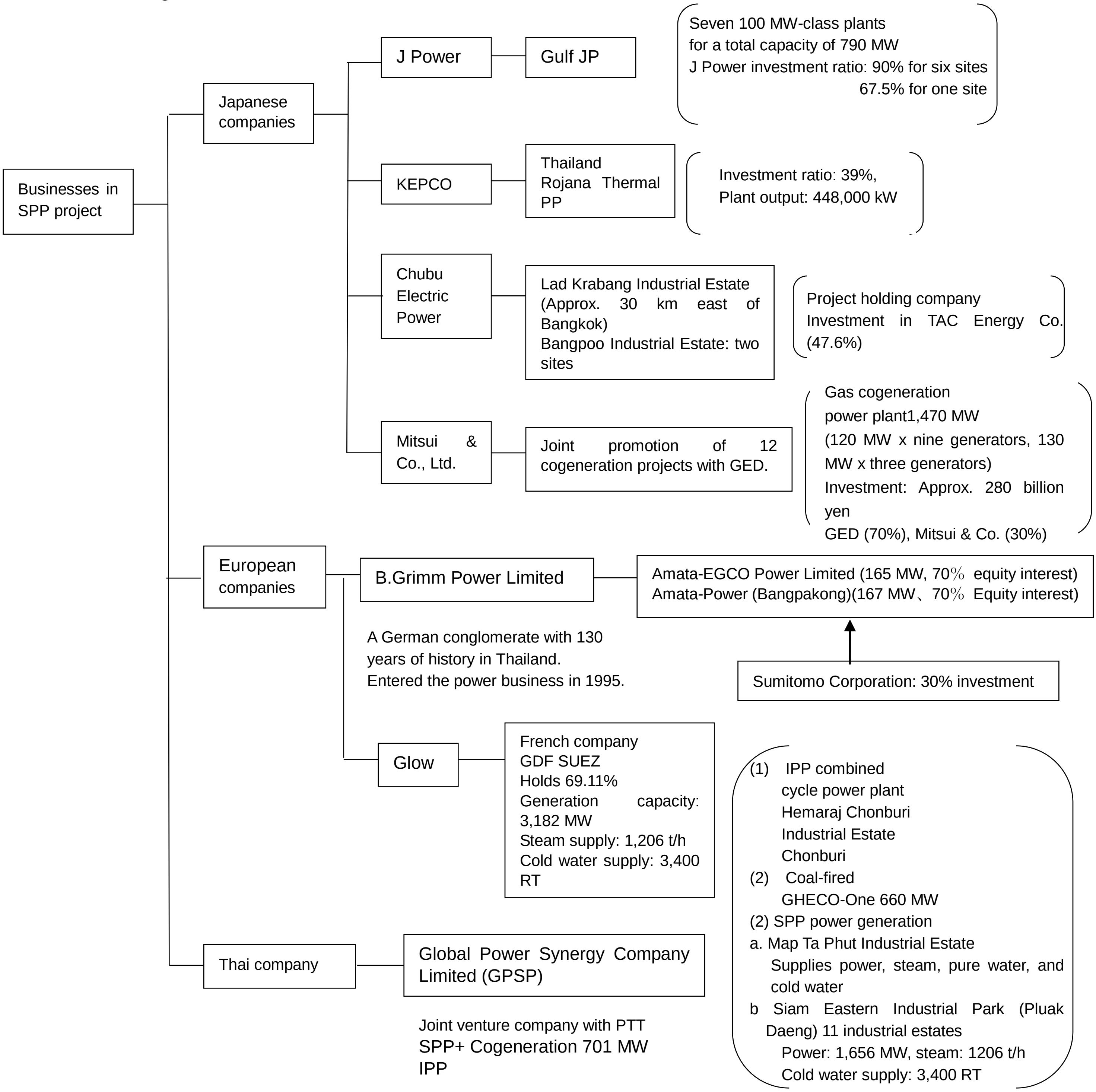


Fig. 2.4 Power supply system in Thailand

Japanese and European companies are investing, but businesses that are a merger with Thai companies are being promoted.

2.4 Industrial estates where SPPs supply power

The Industrial Estate Authority of Thailand (IEAT) develops and operates industrial estates for the purpose of developing industry through the development and operation of industrial estates throughout Thailand. In addition to industrial-use land, IEAT-operated industrial estates also have infrastructure such as roads, sewers, waste processing facilities, flood protection systems, and utilities such as electricity, water, and phones.

The IEAT owns 47 industrial estates throughout 15 provinces in Thailand. It directly runs 11 of these, while the remaining 36 are operating through joint ventures with the private sector. Japan holds a 41.4% share of the investment accepted from overseas starting in 2009, the largest single share.

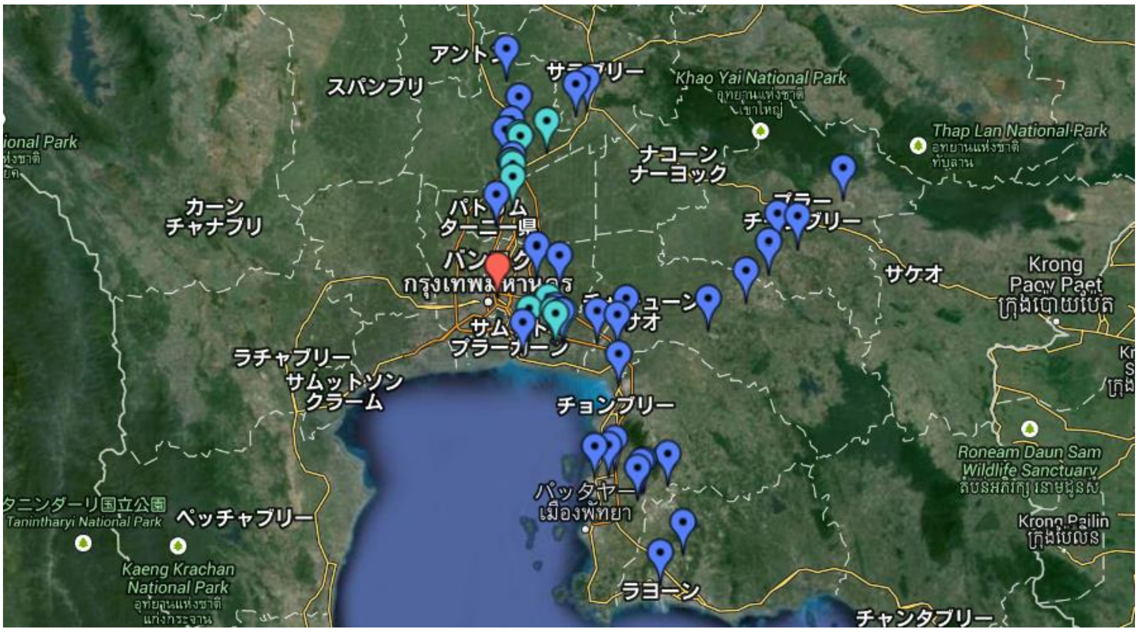


Fig.2.5 Location of industrial estates near Bangkok

2.5 Power generation ratio and direction of Thai power generation

The estimated population of Thailand as of 2007 was 64 million, and the primary energy supply volume for 2006 was approx. 100 million tons of oil equivalent (TOE), giving the country an energy self-sufficiency rate of 52%. The total energy supplied in 2006 was 139 billion kWh, of which 48.9% was generated and supplied by EGAT.

In addition, 70% of the fuel for current thermal power generation in Thailand is natural gas, and 20% is coal. On March 14, 2013, EGAT announced that as around 70% of the 32,000,000 kW of power generation gas thermal power it held was gas-fired, and so there was the risk of power shortages if the gas supply from Myanmar was stopped, it would review its current Power Development Plan (PDP: 2013-2013: Develop 39,000,000 kW by 2030) and increase the ratio of coal-fired power plants in the future. Development in the current PDP is focused on combined cycle power plants, and development of coal-fired plants remains at 8,000,000 kW. The new PDP, which is scheduled for announcement in October, is expected to include the development of coal-fired plants to at least 20,000,000 kW. The increase is expected to be based around coal-fired power generation.

Cases of planning delays due to the opposition of local residents and studies on the construction of IPPs with a view towards improving the power situation have also been reported. The speed of development of combined cycle power facilities using gas turbines is slowing, and with the increase in the ratio of coal-fired power plants, it is thought that the CO_2 emissions per unit for power in Thailand will worsen. As the construction of power plants shifts from gas-fired to coal-fired, the introduction of technologies to improve the efficiency and boost the output of the existing high-efficiency gas turbine combined cycle power plants is important.

2.6 Gas supply for power generation

70% of power generation relies on natural gas, which is imported from Myanmar and supplied from gas fields being co-developed with Malaysia. Gas supply for natural gas-fired power plants in Thailand relies on gas supplied from Myanmar as well. With 2013 as a base, the amount of natural gas produced in Myanmar was 13.1 billion m^3, of which 70% was supplied to Thailand.

(1) Natural gas supply within Thailand

Thai pipelines are divided into two, with the marine trunk line transporting gas overland from the gas fields in the Gulf of Thailand and the Myanmar pipeline importing gas from Myanmar. The completion at the end of 2000 of the pipeline between Wangnoi and the Ratchaburi power plant where Myanmar gas is used to generate power has allowed the development of an east-west pipeline network centered in Bangkok. This has also allowed natural gas from the Gulf of Thailand to be supplied to the Ratchaburi power plant, as well as transportation the other way.

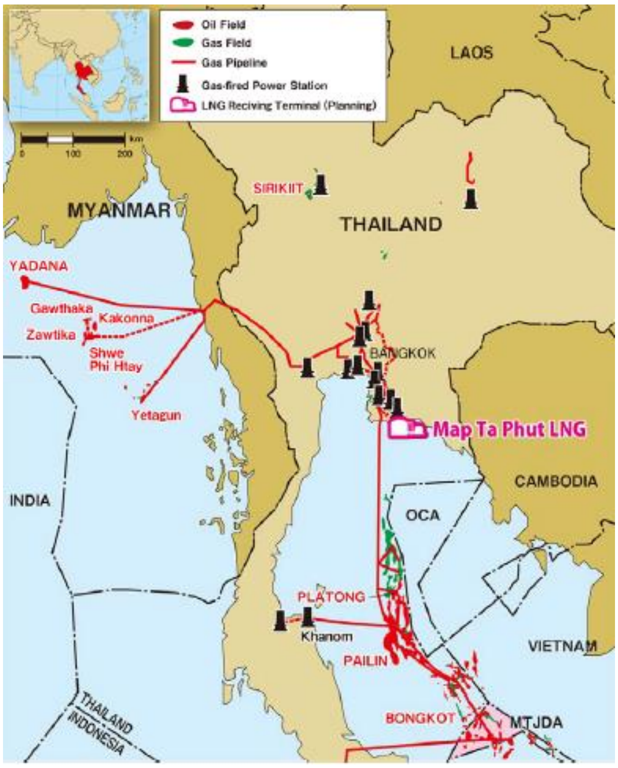
(2) Gas supply from Myanmar

1) Yetagun gas field

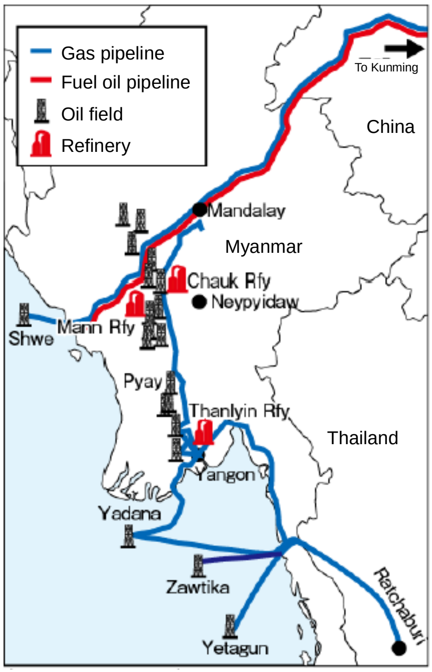
Discovered in 1992 by ChevronTexaco, production started in 2000. A contract to supply gas for 30 years was signed, and gas is exported to Thailand along a 230 km underwater and a 42 km overland pipeline.

2) Zawtika gas field

A contract to sell 240,000,000 cf of natural gas per day was signed with Thailand in July 2010, and supply started in August 2914 using a 270 km underwater and 30 km overland pipeline. PTT Exploration and Production Public Company Limited (PTTEP) owns 80% of the interests, with MOGE owning 20%. This the largest foreign gas field development for PTTEP.



Natural gas pipelines within Thailand
Source: Wide-area ASEAN Natural Gas Pipeline Network Concepts[4)]



(From “East & West Report”)

Natural gas pipelines from Myanmar
Source: JPEC Report[5)]

2.7 Considerations regarding the direction of natural gas usage in Thailand

The Power Development Plan (PDP: 2013-2030: Develop 39,000,000 kW by 2030) announced in December 2014 contained revisions for increasing the amount of coal-fired power plants, which is expected to increase the CO_2 emissions per unit for power in Thailand.

(1) Natural gas export production trends in Thailand and changes to coal-fired power production

Thailand’s energy supply is mainly reliant on domestic natural gas. However, gas production and imports of gas from neighboring countries will peak in the latter half of the 2010s and then gradually decrease, with LNG imports planned, which will happen in 2011 and 2012 respectively.

(2) Issues for the stable supply of natural gas

In both April and December, 2013, gas supply from Myanmar was stopped for a week, and in June 2014, supply from the joint fields in the Gulf of Thailand was stopped, forcing a 10% cut in power consumption among factories in southern Thailand. Development of gas fields in the Gulf of Thailand has also seen no new concessions for the last seven or so years. The costs of natural gas in Thailand are kept lower than the prevailing cost-based market rate through subsidies.

2.8 Current issues regarding SPPs in Thailand

The SPP project contracts that started from the program created in 1992 will start to expire from 2017. SPPs normally sign contracts with government organizations to supply electricity for 25 years, and supply electricity as well as heat and steam to commercial factories in industrial estates from power plants built in these estates. Power plants in 25 older industrial estates, including Amata Nakorn in Chonburi province and Map Ta Phut and Laem Chabang in Rayong province will see their contracts expire in 2017 as part of the first wave. These 25 power plants produce a total of 2,908 MW, of which the contracted supply amount is 1,800 MW. After the contracts between the SPPs and the government expires, power supply will be assured through re-bidding for concessions or the signing of new contracts or replacement contacts with existing businesses, but the recent political upheavals have meant that the government has not determined its policy. There are 28 businesses in Thailand that will see their contracts expire in the next decade. In addition to 25 SPPs, this number also includes three IPPs (contracted to supply 2,250 MW of power) whose contracts will expire.

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Chapter 3 Applicable Carbon Dioxide Reduction Technologies for SPPs and Cogeneration Systems at Suvarnabhumi International Airport

This section will explain the technologies that can be applied to SPP power generation systems (including the cogeneration system at Suvarnabhumi International Airport).

3.1 SPP businesses targeted for the field survey

A study was made of the effects on combined cycle power generation for cold water and steam supply systems in SPP power plants that provide power, steam, and cold water as well as inlet cooling systems for gas turbine combined cycle power generation systems run by IPP and EGAT, and power plants operated under the SPP program, with the aim of creating a survey that aims for the introduction of technologies, plants, etc. which can allow the reduction of energy-based carbon dioxide on a large scale and be used in power plants and major energy-consuming industries.

(1) Survey of power plants in the SPP program

The SPP power plant owners below were requested to cooperate with the survey through interviews.

First Survey January 7 – 9, 2015

SPP owner interview and field survey cooperation requests

a. SPP company with investment from Japan (G Co.)
b. SPP company with investment from Europe (G. Co.)
c. SPP company with investment from Europe (B. Co.)
d. Domestic Thai SPP company (G. Co.)

Second survey January 26 – 28, 2015

SPP owner interview and field survey cooperation requests

a. Domestic Thai SPP company (G. Co.)
b. Domestic Thai SPP company (D. Co.)

An outline of these clients is shown in "2.3 Participation of Japanese and overseas businesses in the SPP program." Interviews were conducted with each SPP owner, and the data for the power generation capacity and gas turbine manufacturer model for each industrial estate are shown in Table 3.1.

As shown in Table 3.1, gas turbines used in SPP companies are divided into two types: the German Siemens SGT-800 gas turbine and the US General Electric LM6000.

In addition, Table 3.2 shows the lists of businesses that are registered as SPPs.

Table 3.2 classifies SPPs into "Firm Contract" and Non-Firm Contract."

［Firm Contract］

The companies have contracts that do guarantee the operation schedule of power plants and the supplied power output with EGAT. Therefore the power plant outputs and operation are bound by the EGAT contract. The contract period is long, 25 years.

Non-Firm Contract

The companies have contracts that do not guarantee the operation schedule of power plants and the supplied power output with EGAT. These contracts do not bind power sales to EGAT in particular. The contracts are for five years, and can be extended as needed. The Suvarnabhumi International Airport (BKK) district cooling plant's cogeneration equipment also use non-firm contracts

Table 3.1 List of SPP combined power plants

Major Investors	Company Name/Location	Gas Turbine		Capacity (MW)	EGAT sales	Steam Supply
Gulf JP	Saraburi A Cogeneration Co,.Ltd	Siemens	SGT-800	106.2		
	Saraburi B Cogeneration Co,.Ltd	Siemens	SGT-800	106.2		
	Industrial Cogen Co,. Ltd	Siemens	SGT-800	113.3		
	Combine Heat & Power Co., Ltd	Siemens	SGT-800	109.1		
	Chachoensao Cogeneration Co,Ltd	Siemens	SGT-800	107.8		
	Phatum Cogeneration Co,.Ltd	Siemens	SGT-800	118.9		
	R1L Cogenration Co,.Ltd	Siemens	SGT-800	124.1		
	Gulf Cogeneration Co,. Ltd	General Electric	GE(MS6001B)	111	90	
	Sumut Prakan Cogeneration Co, Ltd	General Electric	GE(MS6001B)	128	90	
	Nong Khae Cogeneration Co, Ltd	General Electric	GE(MS6001B)	131	90	
G Grim	Amata Steam Supply Co,.Ltd	Siemens	SGT-800	165.8		
	Amata Power Co,.Ltd	Siemens	SGT-800	108.7		
	Amata Power Co,.Ltd	Siemens	SGT-800	165.8		
	Amata B Grim Power 1 Limited	Siemens	V 64.3	168	90	
	Amata B Grim Power 2 Limited	Alstom	PG 6561B	108	90	
Glow Energy	Glow SPP1 Co,Ltd (1)	Alstom	GT8C	67.7	55	
	Glow SPP1 Co,Ltd (2)	Alstom	GT8C	68.3	55	
	Glow SPP2 Co,Ltd (1)	General Electric	GE(MS6001B)	70	60	
	Glow SPP2 Co,Ltd (2)	General Electric	GE(MS6001B)	120	90	
	Thai National Power Co,.Ltd	IHI	LM6000F	101.2		
Rojana Power	Rojana Power Co,Ltd	IHI	LM6000PD	106		
	Rojana Power Co,Ltd	IHI	LM6000PD	122	90	
Sahacogen Power Plants	Sahacogen (Chonburi) Public Company Limited.	IHI	LM6000PC x 3	170		50 t/h
PTT Global Power Synergy Company Limited (GPSC)	Banpa-in Ayutthaya			119		20t/h
	Bangkadee Pathumthani			117		15t/h
	Nawanakorn Pathumthani			127		15t/h
	CUP-1 (At Map Ta Phut, Rayong)					
	CUP-2 (At Map Ta Phut, Rayong)					
	CUP-3 (At Hemaraj IE, Rayong)					
ROJANA POWER COMPANY LTD	Rojana Industrial Park at Ayyuthaya	General Electric	LM 6000 PCx 6	344 MWe		
EGCO Cogeneration Co., Ltd	Rayong, Thailand	General Electric	LM 6000 PCx 2	120		10t/h
DCAP	Suwannabumi International Air Port	IHI	LM 6000 PCx 2	55	50	

Table 3.2.1 List of SPPs (SPP Firm Contract)

No.	Company	Location	Power Plant Type	Type of fuel	Installed Capacity (MW)	Contract amount of electric power (MW)	Term of agreement	SCOD	COD
				SPP Firm contract cogeneration system that were started commercial with EGAT					
1	Glow Energy Public Company Limited. (Phase 1)	Mueang, Rayong	Co-Generation Power Plant	Natural Gas	150.000	90.000	21	1-Apr-1996	1-Apr-1996
2	Glow Energy Public Company Limited. (Phase 2)	Mueang, Rayong	Co-Generation Power Plant	Natural Gas	150.000	90.000	21	1-Oct-1996	1-Oct-1996
3	PTT Petrochemical Public Company Limited	Mueang, Rayong	Thermal Power Plant	Coal	55.000	9.500	21	1-Feb-1997	1-Feb-1997
4	PTT Global Chemical Public Company Limited	Mueang, Rayong	Co-Generation Power Plant	Natural Gas, Off Gas	171.100	32.000	21	1-Apr-1997	1-Apr-1997
5	Glow SPP 1 Co.,Ltd. (Phase 1)	Mueang, Rayong	Co-Generation Power Plant	Natural Gas	67.680	55.000	23	15-Jan-1998	3-Feb-1998
6	Thaioil Power Co.,Ltd.	Sriracha, Chonburi	Co-Generation Power Plant	Natural Gas	138.880	41.000	25	1-Mar-1998	1-Apr-1998
7	Defence Energy Department	Phang, Chiangmai	Biodiesel	Fuel Oil	10.400	4.500	21	1-May-1998	26-Jun-1998
8	Gulf Cogeneration Co.,Ltd.	Mueang, Saraburi	Co-Generation Power Plant	Natural Gas	111.000	90.000	21	14-Aug-1998	3-Sep-1998
9	Amata B.Grimm Power 1 Co.,Ltd.	Mueang, Chonburi	Co-Generation Power Plant	Natural Gas	168.000	90.000	21	30-Sep-1998	17-Sep-1998
10	Glow SPP 1 Co.,Ltd. (Phase 2)	Mueang, Rayong	Co-Generation Power Plant	Natural Gas	66.345	55.000	23	15-Aug-1998	18-Sep-1998
11	Bangkok Cogeneration Co.,Ltd.	Mueang, Rayong	Co-Generation Power Plant	Natural Gas	115.300	90.000	21	25-Dec-1998	4-Feb-1999
12	National Power Supply Public Company Limited (Phase 1)	Srimahapote, Prachinburi	Thermal Power Plant	Coal, Scraps of wood	164.000	90.000	25	15-Mar-1999	12-Mar-1999
13	Glow SPP 2 Co.,Ltd. (Phase 1)	Mueang, Rayong	Gas Turbine Power Plant	Natural Gas	70.000	60.000	25	1-Apr-1999	29-Mar-1999
14	Sahacogen (Chonburi) Publib Company Limited	Sriracha, Chonburi	Co-Generation Power Plant	Natural Gas	139.000	90.000	25	31-Mar-1999	19-Apr-1999
15	Glow SPP 2 Co.,Ltd. (Phase 2)	Mueang, Rayong	Gas Turbine Power Plant	Natural Gas	70.000	60.000	25	1-May-1999	26-Apr-1999
16	Rojana Power Co.,Ltd. (Phase 1)	U-Thai, Ayutthaya	Co-Generation Power Plant	Natural Gas	131.500	90.000	25	31-Mar-1999	26-May-1999
17	National Power Supply Public Company Limited (Phase 2)	Srimahapote, Prachinburi	Thermal Power Plant	Coal, Scraps of wood	164.000	90.000	25	1-Jul-1999	12-Jul-1999
18	Samutprakarn cogeneration co. ltd	Mueang, Samutprakarn	Co-Generation Power Plant	Coal	128.000	90.000	21	1-Jul-1999	23-Aug-1999
19	Glow SPP 3 Co.,Ltd. (Phase 1)	Srimahapote, Prachinburi	Thermal Power Plant	Coal	160.000	90.000	25	1-Jun-1999	1-Sep-1999
20	Glow SPP 3 Co.,Ltd. (Phase 2)	Srimahapote, Prachinburi	Thermal Power Plant	Natural Gas	160.000	90.000	25	15-Aug-1999	20-Mar-2000
21	Glow SPP 11 Co.,Ltd. (Phase 1)	Pluagdeang, Rayong	Co-Generation Power Plant	Natural Gas	120.000	90.000	25	30-Sep-2000	4-Oct-2000
22	Nong khae cogeneration co. ltd	Nongkhae, Saraburi	Co-Generation Power Plant	Natural Gas	131.000	90.000	21	1-Oct-2000	12-Oct-2000
23	Sime darby power co. ltd	Sriracha, Chonburi	Co-Generation Power Plant	Natural Gas	105.000	60.000	21	15-Jul-2001	16-Jul-2001
24	Amata B.Grimm Power 2 Co.,Ltd.	Mueang, Chonburi	Co-Generation Power Plant	Natural Gas	108.000	90.000	21	30-Sep-2001	28-Sep-2001
25	Egco cogeneration co. ltd	Bankai, Rayong	Co-Generation Power Plant	Natural Gas	120.000	60.000	21	1-Jan-2003	28-Jan-2003
26	Siam Power Generation Public Company Limited. (Phase 1)	Bankai, Rayong	Co-Generation Power Plant	Natural Gas	168.430	90.000	21	30-Oct-2010	29-Dec-2010
27	Glow Energy Public Company Limited. (Phase 3)	MapTaPut Industrial Estate	Co-Generation Power Plant	Natural Gas	77.000	74.000	25	1-Jun-2012	1-Jun-2012
28	Amata B.Grimm Power 3 Co.,Ltd.	Amatanakorn Industrial Estate	Co-Generation Power Plant	Natural Gas	165.820	90.000	25	1-Sep-2012	1-Oct-2012
29	Glow SPP 11 Co.,Ltd. (Phase 2)	Pluagdeang, Rayong	Co-Generation Power Plant	Natural Gas	101.180	90.000	25	1-Dec-2012	12-Dec-2012
30	Gulf JP KP1 Co., Ltd.	Nongkhae, Saraburi	Co-Generation Power Plant	Natural Gas	106.200	90.000	25	5-Jan-2013	5-Jan-2013
31	Gulf JP KP2 Co., Ltd.	Nongkhae, Saraburi	Co-Generation Power Plant	Natural Gas	113.300	90.000	25	1-Feb-2013	1-Feb-2013
32	Gulf JP TCL Co., Ltd.	Mueang, Saraburi	Co-Generation Power Plant	Natural Gas	106.200	90.000	25	1-Mar-2013	1-Mar-2013
33	Gulf JP NNK Co., Ltd.	Mueang, Chachengsao	Co-Generation Power Plant	Natural Gas	107.790	90.000	25	1-Apr-2013	1-Apr-2013
34	Gulf JP NLL Co., Ltd.	Bankai, Rayong	Co-Generation Power Plant	Natural Gas	124.130	90.000	25	1-May-2013	1-May-2013
35	Amata B.Grimm Power (Rayong) 2 Co.,Ltd.	Pluagdeang, Rayong	Co-Generation Power Plant	Natural Gas	108.740	90.000	25	1-Jun-2013	21-Jun-2013
36	Bangpa-in Cogeneration Co.,Ltd.	Bangpa-in Industrial Estate	Co-Generation Power Plant	Natural Gas	106.250	90.000	25	1-Jun-2013	28-Jun-2013
37	Gulf JP CRN Co., Ltd.	Samkhok, Patumthani	Co-Generation Power Plant	Natural Gas	118.890	90.000	25	1-Jul-2013	1-Jul-2013
38	Gulf JP NK2 Co., Ltd.	Nongkhae, Saraburi	Co-Generation Power Plant	Natural Gas	109.100	90.000	25	1-Oct-2013	1-Oct-2013
39	Rojana Power Co.,Ltd. (Phase 2)	U-Thai, Ayutthaya	Co-Generation Power Plant	Natural Gas	131.460	90.000	25	1-Jul-2013	18-Oct-2013
40	Navanakorn Electric Co.,Ltd.	Klongluang, Patumthani	Co-Generation Power Plant	Natural Gas	118.500	90.000	25	2-Apr-2013	31-Oct-2013
41	Amata B.Grimm Power (Rayong) 1 Co.,Ltd.	Pluagdeang, Rayong	Co-Generation Power Plant	Natural Gas	165.820	90.000	25	1-Nov-2013	1-Nov-2013
				Total Capacity	4,903.015	3,211.000	MW		

Table 3.2.2 List of SPPs (SPP Firm Contract) (using renewable energy)

No.	Company	Location	Power Plant Type	Type of fuel	Installed Capacity (MW)	Contract amount of electric power (MW)	Term of agreement	SCOD	COD
42	National Power Plant 3 Co.,Ltd.	Panomsarakham, Chachengsao	Thermal Power Plant	Husk, Scraps of wood	47.400	41.000	25	1-Apr-1999	21-Apr-1999
43	National Power Plant 2 Co.,Ltd.	Bangpakong, Chachengsao	Thermal Power Plant	Husk, Scraps of wood	10.400	8.000	21	1-Apr-1999	7-May-1999
44	Bio-Mass Power Co.,Ltd.	Watsing, Chainat	Thermal Power Plant	Bagasses	6.000	5.000	25	31-Jan-2001	9-Sep-2001
45	Roi-et green co.,ltd.	Mueang, Roi-et	Thermal Power Plant	Bagasses	9.900	8.800	21	1-Apr-2003	29-May-2003
46	National Power Plant 5 Co.,Ltd.	Srimahapote, Prachinburi	Thermal Power Plant	Scraps of wood & Black Liquor	87.200	50.000	25	31-Oct-2003	5-Nov-2003
47	National Power Plant 11 Co.,Ltd.	Srimahapote, Prachinburi	Thermal Power Plant	Black Liquor	32.900	25.000	25	28-Nov-2003	2-Dec-2003
48	Can chang bio-energy co.,ltd.	Danchang, Suphanburi	Thermal Power Plant	Bark, Husk, Bagasse	48.000	25.000	21	16-May-2004	15-Jul-2004
	The company requested to increase production					2.000		1-Jul-2005	
49	Mitr phol bio power co.,ltd. (Mitr Phol Sugar Group)	Phukhiao, Chiayaphum	Thermal Power Plant	Bark, Husk, Bagasse	56.900	29.000	21	16-Jul-2004	6-Sep-2005
50	A.T. biopower co.,ltd.	Bangmunnak, PhiChit	Thermal Power Plant	Husk	22.500	20.000	25	24-Dec-2005	21-Dec-2005
51	SATUK BIOMASS CO., LTD	Satuek, Buriram	Thermal Power Plant	Husk and Other Biomass	7.500	6.500	21	15-Dec-2005	24-Jan-2006
52	Gulf yala green co.,ltd.	Mueang, Yala	Thermal Power Plant	Rubber wood chips	23.000	20.200	25	1-Oct-2006	28-Nov-2006
53	Khon Kaen Sugar Power Plant Co.,Ltd. (Phase 1)	Nampong, Khonkhan	Thermal Power Plant	Bagasses and Other Biomass	30.000	20.000	21	31-Oct-2006	26-Dec-2006
54	Mungcharoen green power co. ltd	Mueang, Surin	Thermal Power Plant	Husk	9.900	8.000	21	15-Dec-2006	23-Jan-2007
55	Surat thani green energy co. ltd	Punpin, Suratthani	Thermal Power Plant	Palm	9.900	8.800	25	1-Jul-2007	13-Sep-2007
56	Dan chang bio-energy co. ltd (Phase 2)	Danchang, Suphanburi	Thermal Power Plant	Bagasse	11.400	10.000	25	15-Sep-2009	13-Nov-2009
	The company requested to increase production					0.800		1-Sep-2012	1-Sep-2012
57	Mitr phol biopower co. ltd (Phase 2)	Phukhiao, Chiayaphum	Thermal Power Plant	Bagasse	11.400	10.000	25	15-Sep-2009	13-Nov-2009
58	Mungcharoen biomass co. ltd	Mueang, Surin	Thermal Power Plant	Bagasse and Scraps of wood	17.000	15.500	25	1-Jul-2012	5-Sep-2012
				Total Capacity	441.300	313.600	MW		

Table 3.2.3 List of SPPs (SPP Firm Contract) (contracted but have not started operation)

No.	Company	Location	Power Plant Type	Type of fuel	Installed Capacity (MW)	Contract amount of electric power (MW)	Term of agreement	SCOD	COD
SPP Firm contract cogeneration system according to the conclusion of the National Energy Policy Council 2007 that were sign the contract but still not start commercial with EGAT.									
59	B.grimm bip power co. ltd	Mueang, Patumthani	Co-Generation Power Plant	Natural Gas	112.000	90.000	25	1-Mar-2015	
60	Siam Power Generation Public Company Limited (Phase 2)	Bankai, Rayong	Co-Generation Power Plant	Natural Gas	166.530	90.000	25	1-Jun-2016	
				Total Capacity	278.530	180.000	MW		
SPP Firm contract cogeneration system according to the conclusion of the National Energy Policy Council 2010 that were sign the commercial contract after EIA but still not start commenrcial with EGAT.									
61	Ratchaburi world cogeneration co. ltd	Ratchaburi Industrial Estate	Co-Generation Power Plant	Natural Gas	115.280	90.000	25	1-Nov-2014	
62	Advance agro asia co. ltd	Panomsarakham, Chachengsao	Co-Generation Power Plant	Natural Gas	105.430	90.000	25	1-Mar-2015	
63	PPTC Co.,Ltd.	Latkrabang Industrial Estate	Co-Generation Power Plant	Natural Gas	113.900	90.000	25	1-Dec-2015	
64	Siam pure rice co. ltd	Chaiyo, Angthong	Co-Generation Power Plant	Natural Gas	105.506	90.000	25	1-Jun-2018	
				Total Capacity	440.116	360.000	MW		
SPP Firm contract cogeneration system according to the conclusion of the National Energy Policy Council 2010 that were sign the commercial contract before EIA and the contract has been effective but still not start commenrcial with EGAT.									
65	Ratchaburi world cogeneration co. ltd (Phase 2)	Ratchaburi Industrial Estate	Co-Generation Power Plant	Natural Gas	115.280	90.000	25	1-Mar-2015	
66	Bangkadi Clean Energy Ltd	Bangkadi Industrial Park	Co-Generation Power Plant	Natural Gas	113.290	90.000	25	1-Jul-2015	
67	SSUT Co.,Ltd.	Bangpu Industrial Estate	Co-Generation Power Plant	Natural Gas	108.300	90.000	25	1-Apr-2016	
68	Bowin Clean Energy Co., Ltd	Hemmarat Industrial Estate Chonburi	Co-Generation Power Plant	Natural Gas	113.902	90.000	25	1-Nov-2016	
69	IRPC Clean power co. ltd (Phase 1)	Mueang, Rayong	Co-Generation Power Plant	Natural Gas	115.217	90.000	25	1-Jun-2017	
70	IRPC Clean power co. ltd (Phase 2)	Mueang, Rayong	Co-Generation Power Plant	Natural Gas	115.217	90.000	25	1-Jun-2017	
				Total Capacity	681.206	540.000	MW		

No.	Company	Location	Power Plant Type	Type of fuel	Installed Capacity (MW)	Contract amount of electric power (MW)	Term of agreement	SCOD	COD
SPP Firm contract cogeneration system according to the conclusion of the National Energy Policy Council 2010 that were sign the commercial contract before EIA and the contract has not been effective and still not start commenrcial with EGAT.									
71	Amata B.Grimm Power 4 Co.,Ltd.	Amatanakorn Industrial Estate	Co-Generation Power Plant	Natural Gas	113.902	90.000	25	1-Nov-2015	
72	Thai Oil Public Company Limited (Phase 1)	Sriracha, Chonburi	Co-Generation Power Plant	Natural Gas	121.730	90.000	25	1-Apr-2016	
73	Amata B.Grimm Power 5 Co.,Ltd.	Amatanakorn Industrial Estate	Co-Generation Power Plant	Natural Gas	113.902	90.000	25	1-Jun-2016	
74	Nava Nakorn Electricity Generating Co., Ltd.	Klongluank, Patumthani	Co-Generation Power Plant	Natural Gas	129.320	90.000	25	1-Jun-2016	
75	Thai Oil Public Company Limited (Phase 2)	Sriracha, Chonburi	Co-Generation Power Plant	Natural Gas	109.740	90.000	25	1-Jun-2016	
76	SSUT Co.,Ltd (Phase 2)	Bangpu Industrial Estate	Co-Generation Power Plant	Natural Gas	108.300	90.000	25	1-Jun-2016	
77	Nava Nakorn Electricity Generating Co., Ltd. (Phase 2)	Banpong, Ratchaburi	Co-Generation Power Plant	Natural Gas	124.640	90.000	25	1-Feb-2017	
78	Nava Nakorn Electricity Generating Co., Ltd. (Phase 3)	Banpong, Ratchaburi	Co-Generation Power Plant	Natural Gas	124.640	90.000	25	1-Feb-2017	
79	Rainbow Power Co.,Ltd.	Eastern Seaboard Industrial Estate, Rayong	Co-Generation Power Plant	Natural Gas	124.957	90.000	25	1-May-2017	
80	Amata B.Grimm Power (Rayong) 3 Co.,Ltd.	Amatacity Industrial Estate	Co-Generation Power Plant	Natural Gas	113.902	90.000	25	1-Jun-2017	
81	Bangpa-in cogeneration co. ltd (Phase 3)	Bangpa-in Industrial Estate	Co-Generation Power Plant	Natural Gas	120.500	90.000	25	1-Jun-2017	
82	Rojana Power Co.,Ltd. (Phase 3)	Rojana Industrial Park	Co-Generation Power Plant	Natural Gas	112.010	90.000	25	1-Jun-2017	
83	The Electricity Generating Public Company Limited (Phase 1)	Klongluang, Patumthani	Co-Generation Power Plant	Natural Gas	125.490	90.000	25	1-Jun-2017	
84	Electric and Steam Co.,Ltd.	Eastern Seaboard Industrial Estate, Rayong	Co-Generation Power Plant	Natural Gas	123.499	90.000	25	1-Jul-2017	
85	Eastern Seaboard Power Co.,Ltd.	Eastern Seaboard Industrial Estate, Rayong	Co-Generation Power Plant	Natural Gas	123.499	90.000	25	1-Sep-2017	
86	Rayong Electricity Generating Co., Ltd.	Hemmarat Eastern Seaboard Industrial Estate, Rayong	Co-Generation Power Plant	Natural Gas	123.499	90.000	25	1-Nov-2017	
87	2010 Cogeneration Co.,Ltd.	Hemmarat Eastern Seaboard Industrial Estate, Rayong	Co-Generation Power Plant	Natural Gas	123.499	90.000	25	1-Jan-2018	
88	Kabin Cogen Co., Ltd	Kabinburi, Prachinburi	Co-Generation Power Plant	Natural Gas	119.643	90.000	25	1-Mar-2018	
89	Amata B.Grim Power (Rayong) 4 Co.,Ltd.	Amatacity Industrial Estate	Co-Generation Power Plant	Natural Gas	113.902	90.000	25	1-Jun-2018	
90	HITECH COGENERATION CO., LTD	Hi-tech Industrial Estate	Co-Generation Power Plant	Natural Gas	124.684	90.000	25	1-Sep-2018	
91	Amata B.Grim Power (Rayong) 5 Co.,Ltd.	Amatacity Industrial Estate	Co-Generation Power Plant	Natural Gas	113.902	90.000	25	1-Oct-2018	
92	Victory Energy Co.,Ltd.	Hi-tech Industrial Estate	Co-Generation Power Plant	Natural Gas	124.957	90.000	25	1-Nov-2018	
93	Palang ngan promburi Co.,Ltd. (บริษัท พลังงานพรหมบุรี จำกัด)	Hemmarat Industrial Zones, Rayong	Co-Generation Power Plant	Natural Gas	122.350	90.000	25	1-Jan-2019	
94	Thai energy generator Co.,Ltd.	Nongkhae, Saraburi	Co-Generation Power Plant	Natural Gas	119.643	90.000	25	1-Mar-2019	
95	Suranaree Energy Generating Co., Ltd	Suranari Industrial Zones, Nakornratchasima	Co-Generation Power Plant	Natural Gas	123.499	90.000	25	1-May-2019	
96	B.Grim Power (Ratchaburi) 1 Co.,Ltd.	V.R.M Industrial Estate, Ratchaburi	Co-Generation Power Plant	Natural Gas	113.902	90.000	25	1-Jun-2019	
97	Ratchaburi cogeneration co. ltd	Bangpong, Ratchaburi	Co-Generation Power Plant	Natural Gas	111.759	90.000	25	1-Jun-2019	
98	Blue sky cogen co ltd	Suranari Industrial Zones, Nakornratchasima	Co-Generation Power Plant	Natural Gas	124.957	90.000	25	1-Jul-2019	
99	B.Grim Power (Ratchaburi) 2 Co.,Ltd.	V.R.M Industrial Estate, Ratchaburi	Co-Generation Power Plant	Natural Gas	113.902	90.000	25	1-Oct-2019	
				Total Capacity	3,464.129	2,610.000	MW		
SPP Firm contract renewable that is pending the signing of the contract.									
100	The Electricity Generating Kornburi Co.,Ltd. (KBS Group)	Kornburi, Nakornratchasima	Thermal Power Plant	Bagasse	35.000	22.000	25	15-Dec-2013	
				Total Capacity	35.000	22.000	MW		
				Grand Total Capacity	10,243.296	7,236.600	MW		

SCOD : Scheduled Commercial Operation Date
COD : Commercial Operation Date
EIA : Environmental Impact Assessment

Table 3.2.4 List of SPPs (SPP Non-Firm Contract)

DCAP

No.	Company	Location	Power Plant Type	Type of fuel	Installed Capacity (MW)	Contract amount of electric power (MW)	Term of agreement	SCOD	COD
	SPP Non-Firm contract cogeneration system that were started commercial with EGAT								
1	IRPC Public Company Limited (Phase 1)	Mueang, Rayong	Thermal Power Plant	Natural Gas, Coal, Oil	108.000	45.000	5 Years and Continuing	–	28-May-1994
2	Panjapol Puls Industries Public Company Limited	Bangsai, Ayutthaya	Thermal Power Plant	Coal	40.000	8.000	5 Years and Continuing	–	16-Nov-1995
3	DCAP	Bangphli, Samutprakarn	Gas Turbine Power Plant	Natural Gas	55.000	50.000	5 Years and Continuing	–	15-Mar-2006
	The company requested to increase produciton				40.000	15.000			28-Jan-2013
4	Global Power Synergy Publib Company limited (Phase1)	Mueang, Rayong	Thermal Power Plant	Natural Gas	300.000	60.000	5 Years and Continuing	–	24-Jan-2009
5	Global Power Synergy Publib Company limited (Phase2)	Mueang, Rayong	Thermal Power Plant	Natural Gas	150.000	40.000	5 Years and Continuing	–	17-Sep-2010
6	RojanaPower Co.,Ltd. (Phase 4)	Uthai, Ayutthaya	Thermal Power Plant	Natural Gas	121.135	50.000	5 Years and Continuing	–	26-Jul-2013
	The company requested to increase produciton					20.000		–	5-Jul-2014
				Total Capacity	814.135	288.000	MW		
	SPP Non-Firm contract cogeneration system that is pending the signing of contract								
7	PPT Global Chemical Ltd. (Phase 2)	Mueng, Rayong	Co-Generation Power Plant	Natural Gas	206.000	60.000	–	July-2014	–
				Total Capacity	206.000	60.000	MW		
	SPP Non-Firm contract renewable that were started commercial with EGAT								
8	Mitr Phol Bio-Power (Phuvian) Co.,Ltd. (Mitr Phol Sugar Group)	Nongrue, Khonkhan	Thermal Power Plant	Bagasses	27.000	6.000	5 Years and Continuing	–	11-Jun-1997
	The company requested to increase produciton					2.000			26-Jan-2010
9	U-Thong Industry (บริษัท น้ำตาลไฟน์ชัยมงคล จำกัด)	U-thong, Suphanburi	Thermal Power Plant	Bagasses	18.000	7.000	5 Years and Continuing	–	8-Feb-2000
10	Saraburi (บริษัท น้ำตาลสระบุรี จำกัด)	Wangmuang, Saraburi	Thermal Power Plant	Bagasses	29.500	8.000	5 Years and Continuing	–	4-Jan-2002
11	Thai Roong Ruang Industry Co.,Ltd. (Thai Roong Ruang Sugar Group)	Srithep, Petchaboon	Thermal Power Plant	Bagasses	29.500	4.000	5 Years and Continuing	–	21-Jan-2003
	The company requested to increase produciton					4.000			23-Jul-2008
12	Angvian (Ratchasima) (บริษัท อุตสาหกรรมอ่างเวียน จำกัด)	Keangsanamnang, Nakornratchasima	Thermal Power Plant	Bagasses	34.000	30.000	5 Years and Continuing	–	22-Aug-2003
13	The Kumphawapi Sugar Co.,ltd.	Kumphawapi, Udonthani	Thermal Power Plant	Bagasses	19.600	4.000	5 Years and Continuing	–	2-Apr-2004
	The 1st company requested to increase produciton					1.000			13-Dec-2005
	The 2nd company requested to increase produciton					1.000			30-Mar-2010
14	Thai Carbon Black Public Company Limited	Mueang, Angthong	Thermal Power Plant	Waste Gas	19.000	6.000	5 Years and Continuing	–	20-Jul-2006
	The company requested to increase 6MW before					6.000			
15	(บริษัท ราชบุรีพลังงาน จำกัด Ratchaburi Palangngan Co.,ltd) Ratchaburi Electricity Generating Holding Company Limited	Kongkrairat, Sukhothai	Thermal Power Plant	Natural gas is byproduct from crude oil production	1.950	1.723	5 Years and Continuing	–	27-Jun-2007
16	Khon Kaen Sugar Power Plant Company Limited.	Borploy, Karnchanaburi	Thermal Power Plant	Bagasses	65.000	22.000	5 Years and Continuing	–	30-Nov-2010
	The company requested to increase 8MW before								3-Nov-2011
	The company requested to increase produciton					8.000			1-Jul-2014
17	**Department** of Alternative Energy Development and Efficiency **Ministry of Energy,**	Makham, Chanthaburi	Hydro Power Plant	Waterpower	13.260	12.200	5 Years and Continuing	–	21-Mar-2011
18	Natural Energy Development Co.,Ltd.	Khoksamrong, Lopburi	Solar Power Plant	Solar energy	60.000	55.000	5 Years and Continuing	–	22-Dec-2011
19	DanChang Bio-Energy Co.,Ltd. (Phase3)	Danchang, Suphanburi	Thermal Power Plant	Bagasses and husk	32.000	25.000	5 Years and Continuing	31-Mar-2012	29-May-2012
20	Bangchak Petroleum Public Company Limited	Bangpa-in, Ayutthaya	Solar Power Plant	Solar energy	34.200	30.000	5 Years and Continuing	1-Nov-2011	16-Jul-2012
21	First Korat Wind Co.,Ltd. (Wind Energy Holding)	Dankhuntot, Nakornratchasima	Wind Power Plant	Wind Power	103.500	90.000	5 Years and Continuing	29-Aug-2012	14-Nov-2012
22	Mitr Phol Bio-Power (Kalasin) Co.,Ltd. (Mitr Phol Sugar Group)	Kuchinarai, Kalasin	Thermal Power Plant	Bagasses	32.000	28.000	5 Years and Continuing	15-Sep-2012	18-Jan-2013
23	K.R.2 Co.,ltd.	Dankhuntot, Nakornratchasima	Wind Power Plant	Wind Power	103.500	90.000	5 Years and Continuing	26-Nov-2012	8-Feb-2013
24	Kaset Thai Bio-Power Co.,Ltd. (KTIS Group)	Taklee, Nakornsawan	Thermal Power Plant	Bagasses	60.000	60.000	5 Years and Continuing	1-Apr-2013	7-Oct-2013
25	ea solar nakornsawan Co.,Ltd.	Thatago, Nakornsawan	Solar Power Plant	Solar energy	90.720	90.000	5 Years and Continuing	1-Dec-2013	1-Dec-2013
26	E S Power Co.,Ltd.	Watthananakorn, Sakaew	Thermal Power Plant	Bagasses	23.000	20.000	5 Years and Continuing	30-Oct-2013	21-Jan-2014
27	Uthai Thani Bio-Energy Co.,Ltd.	Sawang-arom, Uthai Thani	Thermal Power Plant	Bagasses	20.000	16.000	5 Years and Continuing	31-Jan-2014	11-Apr-2014
				Total Capacity	815.730	626.923	MW		

Table 3.2.5 List of SPPs (SPP Non-Firm Contract)

No.	Company	Location	Power Plant Type	Type of fuel	Installed Capacity (MW)	Contract amount of electric power (MW)	Term of agreement	SCOD	COD
	SPP Non-Firm contract renewable that were sign the contract but still not start commercial with EGAT.								
28	Sermsang palang ngan Co.,Ltd.	Khoksamrong, Lopburi	Solar Power Plant	Solar energy	40.000	40.000	5 Years and Continuing	8-Nov-2014	
29	Thai Roong Ruang Energy Co., Ltd. (Thai Roong Ruang Sugar Group)	Wangmuang, Saraburi	Thermal Power Plant	Bagasses	20.000	18.000	5 Years and Continuing	31-Oct-2014	
30	ea solar lampang Co.,Ltd.	Lampang	Solar Power Plant	Solar energy	90.720	90.000	5 Years and Continuing	1-Dec-2014	
31	khao kor wind power co.,ltd.	Khaokho, Petchabun	Wind Power Plant	Wind Power	60.000	60.000	5 Years and Continuing	21-Jan-2015	
32	Energy Absolute Public Company Limited	Prompiram, Pitsanulok	Solar Power Plant	Solar energy	90.720	90.000	5 Years and Continuing	1-Dec-2015	
33	Wind Energy Development Public Company Limited (Wayu Wind Farm Project)	Dankhuntot, Nakornratchasima	Wind Power Plant	Wind Power	59.200	50.000	5 Years and Continuing	1-Sep-2016	
34	TPI Polene Power Co.,Ltd.	Kheangkhoi, Saraburi	Thermal Power Plant	Garbage	60.000	55.000	5 Years and Continuing	1-Jul-2015	
35	Chaiyaphum Wind Farm Co.,Ltd.	Subyai, Chaiyaphum	Wind Power Plant	Wind Power	105.000	90.000	5 Years and Continuing	1-Dec-2016	
36	Greenobation Power Co.,Ltd. (Saranlom Wind Farm Project)	Dankhuntot, Nakornratchasima	Wind Power Plant	Wind Power	67.500	60.000	5 Years and Continuing	1-Sep-2016	
37	Teparak Wind Co.,Ltd.	Teparak and Dankhuntot,	Wind Power Plant	Wind Power	92.000	90.000	5 Years and Continuing	31-Jan-2016	
	(The wind power Korat project 02/1)	Nakornratchasima							
38	Tropical Wind Co.,Ltd.	Teparak, Nakornratchasima	Wind Power Plant	Wind Power	92.000	90.000	5 Years and Continuing	30-Jun-2016	
	(The wind power Korat project 02/2)	Tepsathit, Chaiyaphum							
39	K.R.S.3 Co.,Ltd.	Teparak, Nakornratchasima	Wind Power Plant	Wind Power	92.000	90.000	5 Years and Continuing	30-Jun-2016	
	(The wind power Korat project 02/3)	Tepsathit, Chaiyaphum							
40	Krissana Wind Power Co.,Ltd.	Dankhuntot and Sikhiu,	Wind Power Plant	Wind Power	94.500	90.000	5 Years and Continuing	30-Sep-2017	
		Nakornratchasima							
				Total Capacity	963.640	913.000	MW		
	SPP Non-Firm contract renewable that is pending the signing of the contract.								
41	Watabak Wind Co.,Ltd.	Tepsathit, Chaiyaphum	Wind Power Plant	Wind Power	62.100	60.000	5 Years and Continuing	8-Nov-2014	
42	TPI Polene Power Co.,Ltd. (Phase)	Kaengkhoi, Saraburi	Thermal Power Plant	Garbage	20.000	18.000	5 Years and Continuing	31-Oct-2014	
43	Energy Absolute Public Company Limited (Beach Turbine Project 1)	Ranod, Songkhla	Wind Power Plant	Wind Power	36.800	36.000	5 Years and Continuing	1-Dec-2014	
44	Energy Absolute Public Company Limited (Beach Turbine Project 2)	Huasai, Nakornsithammarat	Wind Power Plant	Wind Power	46.000	45.000	5 Years and Continuing	21-Jan-2015	
45	Energy Absolute Public Company Limited (Beach Turbine Project 2)	Pakpanang, Nakornsithammarat	Wind Power Plant	Wind Power	46.000	45.000	5 Years and Continuing	1-Dec-2015	
46	Nathalin Welstar Energy Co.,Ltd.	Wichianburi, Petchabun	Wind Power Plant	Wind Power	44.000	44.000	5 Years and Continuing	1-Sep-2016	
47	K R one Co.,Ltd.	Teparak, Nakornratchasima	Wind Power Plant	Wind Power	96.000	90.000	5 Years and Continuing	1-Jul-2015	
48	Korat Wind Energy Co.,Ltd. (Frindship wind farm project)	Sikhiu Nakornratchasima,	Wind Power Plant	Wind Power	52.500	50.000	5 Years and Continuing	1-Dec-2016	
49	Energy Absolite Public Company Limited (Hanuman 1 project)	Tepsathit, Chaiyaphum	Wind Power Plant	Wind Power	46.000	45.000	5 Years and Continuing	1-Sep-2016	
50	Energy Absolite Public Company Limited (Hanuman 5 project)	Tepsathit, Chaiyaphum	Wind Power Plant	Wind Power	48.300	48.000	5 Years and Continuing	31-Jan-2016	
	Energy Absolite Public Company Limited (Hanuman 8 project)	Nakornratchasima							
51	Energy Absolite Public Company Limited (Hanuman 8 project)	Tepsathit, Chaiyaphum	Wind Power Plant	Wind Power	57.500	45.000			
52	Energy Absolite Public Company Limited (Hanuman 0 project)	Tepsathit, Nongbuarahew, Chaiyaphum	Wind Power Plant	Wind Power	57.500	42.000	5 Years and Continuing	30-Jun-2016	
53	Energy Absolute Public Company Limited (Hanuman 10 project)	Bamnetnarong, Chaiyaphum	Wind Power Plant	Wind Power	92.000	80.000			
54	United Tanker Co.,Ltd.	Thayang, Petchburi	Wind Power Plant	Wind Power	95.000	85.000	5 Years and Continuing	30-Jun-2016	
55	Windchai Co.,Ltd.	Nikhomkhamsoi, Mukdahan	Wind Power Plant	Wind Power	52.250	45.000			
56	Subpud Energy 1 Co.,Ltd.	Wichianburi, Petchabun	Wind Power Plant	Wind Power	63.250	60.000	5 Years and Continuing	30-Sep-2017	
57	Subpud Energy 2 Co.,Ltd.	Wichianburi, Petchabun	Wind Power Plant	Wind Power	41.250	40.000			
				Total Capacity	956.450	878.000	MW		
				Grand Total Capacity	3,755.955	2,765.923	MW		

(2) IPP large-scale power plants

The following list of power plants has been created with reference to “The Future of Thai Power Generation and Commercial Opportunities for Japanese Companies (FY2013)” (Reference 1 in Chapter 2).

Table 3.3 List of IPPs

Power Plant	Owner	EPC	Gas Turbine	Equipment Capacity	Operation Start
Kaeng Koi	Gulf Electrical (EGCO 51%, J Power49%)	Alstom	Alstom GT26B2	1468	2007
Rahcaburi Power	Rahcaburi Power (Hongkong Electric 25%, Chubu Electric 15% Toyota Tsusho 10%, RATCH 25% PTT 15%, Shaha Union 10%)	Mitsubishi Heavy Industries	Mitsubishi Heavy Industries M701F	1400	2008
Chana (No. 1 generator)	EGAT	Siemens-Marubeni	Siemens (SGT5-4000F)	710	2008
South Bangkok	EGAT	Mitsubishi Heavy Industries	Mitsubishi Heavy Industries M701F	710	2008
Banba kong (No. 5 generator)	EGAT	Siemens-Marubeni	Siemens (SGT5-4000F)	710	2008
North Bangkok	EGAT	Hitachi, Sumitomo	GE (MS9001FA)	700	2010
Nong Seng	Gulf JP NS	Mitsubishi Heavy Industries	Mitsubishi Heavy Industries M701F4	1600	2014
Utai	Gulf JP UT	Mitsubishi Heavy Industries	Mitsubishi Heavy Industries M701F4	1600	2015
Wang Noi (No. 4 generator)	EGAT	Siemens-Marubeni	Siemens (SGT5-4000F)	769	2014
Chana (No. 1 generator)	EGAT	Siemens-Marubeni	Siemens (SGT5-4000F)	782	2014
North Bangkok (No. 2 generator)	EGAT	Alstom, Sumitomo	Alstom (GT26 upgrade)	850	2016
Kanom	KEGCO	Mitsubishi Heavy Industries	Mitsubishi Heavy Industries M701F5	977	2016

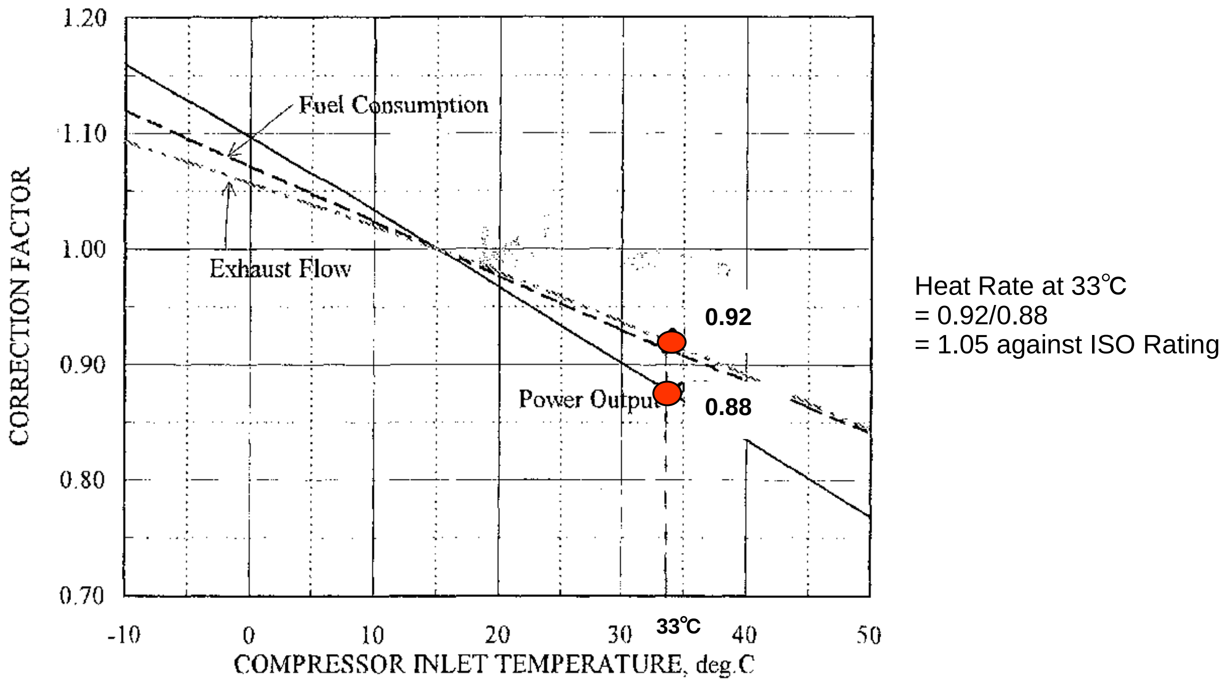
3.2 Gas turbine inlet cooling systems

A general feature of gas turbine generator equipment is that when the inlet temperature gets hot, the air, which is its working fluid, becomes dense and the combustion atmosphere's mass flow rate lowers, so output drops. Therefore, in summer when temperatures are high, while demand for electricity is higher, the capacity to supply it drops. The inlet cooling system lowers the inlet temperature, allowing the recovery of reduced output when the atmosphere is hot.

(1) Features of a gas turbine

The general features of a gas turbine are shown below.

Generally, a gas turbine is planned to operate at a temperature of 15°C, and the performance at a temperature of 15°C is pegged at 1.0, with output reducing as the temperature rises. For example, when the exterior temperature is 33°C, power generation output falls to 0.88. The gas turbine' s heat rate (the fuel consumption required to generate 1 kW) also worsens about 5%.



NB: The features of the above gas turbine will be different for each model

Fig. 3.1 Gas turbine features

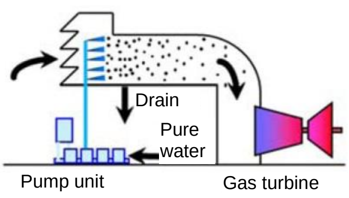
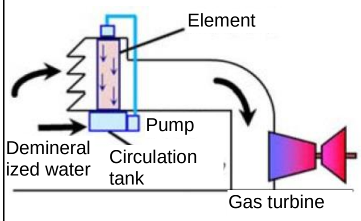
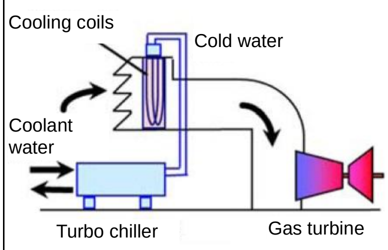
The gas turbine inlet cooling system increases output of the gas turbine by lowering its inlet temperature. The heat rate is improved by lowering the inlet temperature, but care needs to taken regarding inlet cooling coil pressure loss, so generally the planning assumes that the heat rate will not change.

(2) Types of inlet cooling systems for gas turbines

A general feature of gas turbine generator equipment is that when the inlet temperature gets hot, the air, which is its working fluid, becomes dense and the combustion atmosphere's mass flow rate lowers, so output drops. Therefore, in summer when temperatures are high, while demand for electricity is higher, the capacity to supply it drops. The inlet cooling system lowers the inlet temperature, allowing the recovery of reduced output when the atmosphere is hot. The following three types of inlet cooling systems are widely known.

(1) Fog system
(2) Evaporator system
(3) Chiller system

Table 3.4 Comparison of gas turbine inlet cooling systems. Source: Reference material 1

	Fog system	Evaporator system	Chiller system
Principle	A mist nozzle is installed after the inlet filter to directly spray pure water mist onto the incoming air. It cools by taking the heat of vaporization when the water evaporates.	An element is installed after the inlet filter, through which demineralized water is passed. It cools the air by taking the heat of vaporization when the incoming air passes through it.	Cooling coils are installed after the inlet filter, through which cold water, cooled using the turbo chiller, is passed. It cools the air through a heat exchange when the incoming air passes through the coils.
Structure			
Amount incoming air is cooled	Approx. 5°C (Atmospheric conditions: 30°C, 60% RH)	Approx. 5°C (Atmospheric conditions: 30°C, 60% RH)	Approx. 15°C (Atmospheric conditions: 30°C, 60% RH)
Gas turbine output increase	Approx. 3% @30°C, 60% RH	Approx. 3% @30°C, 60% RH	Approx. 9% @30°C, 60% RH

These can be divided into two types, depending on the differences in cooling methods. Fog systems (1) and evaporator systems (2) use the evaporation of moisture within the inlet to capture atmospheric heat and lower the inlet temperature, whereas chiller systems (3) cool through heat exchange. The features of each are compared in Table 1. Chiller systems are can lower temperatures to below the dew point if their cooling performance is appropriately increased. This difference is more obvious the higher the relative humidity, so in climate conditions which are hot and humid, like Japanese summers, installing a chiller system will allow comparatively greater output increases than for other inlet cooling systems.
This field survey studied the appropriateness of chiller systems.

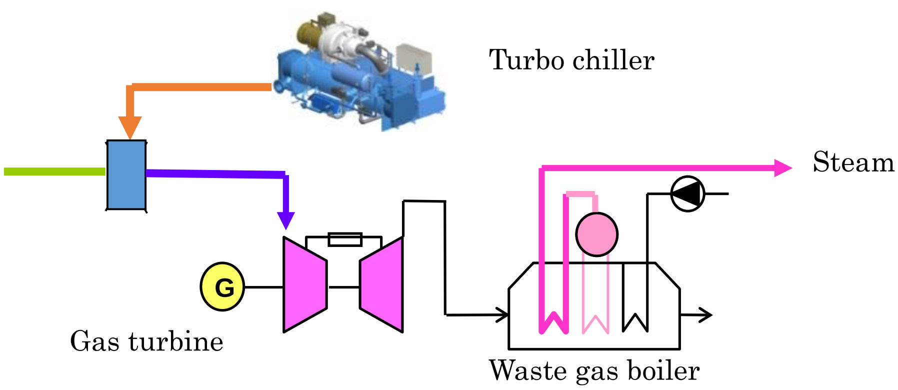


Fig. 3.2 Inlet cooling using a turbo chiller

3.3 Case examples of the application of gas turbine inlet cooling in Japan

Japan's summer is only about three months long, but gas turbine inlet cooling provides cases of the application of gas turbine inlet cooling systems as measures to counter power output declines in summer and to reduce the basic cost of electricity by reducing power demand loss in summer.

Examples from Japan are shown below.

(1) Examples of gas turbine output measurement

Operating data for a gas turbine operating in Shizuoka Prefecture was obtained and the external air temperature and gas turbine output plotted on Figure 3.3.

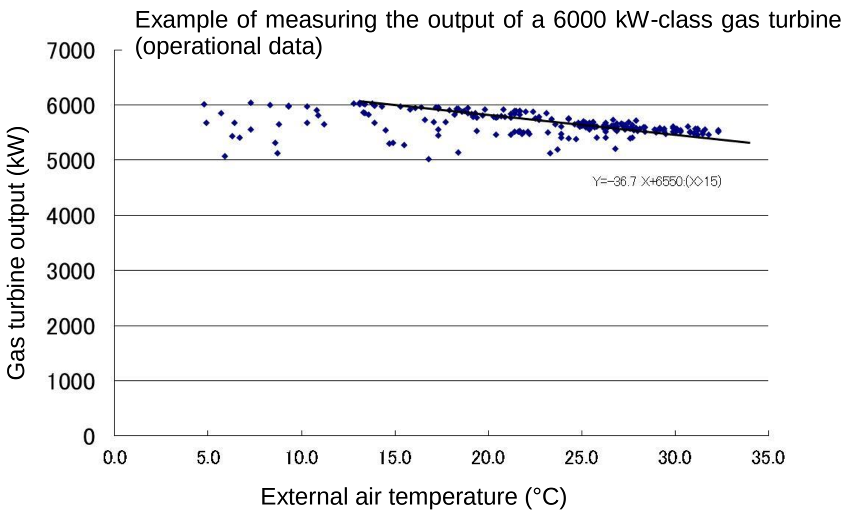


Fig. 3.3 Example of measuring gas turbine output

(2) Example of the application of inlet cooling in Japan

This is an example where a gas turbine inlet cooling system has been applied to a gas turbine for a US-made 20,000 kW-class aircraft engine in Kanagawa Prefecture.

1) Gas turbine output characteristics

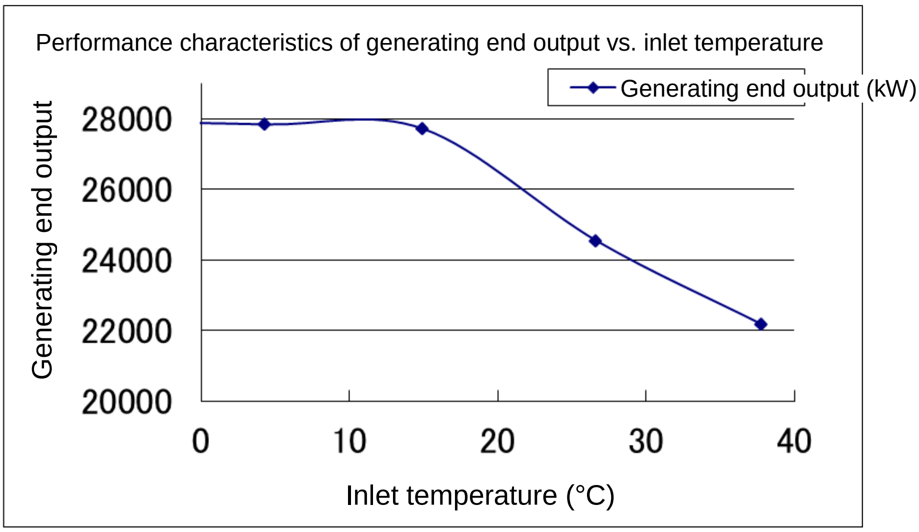


Fig. 3.4 Gas turbine output

2) Installation of air coolers in gas turbines

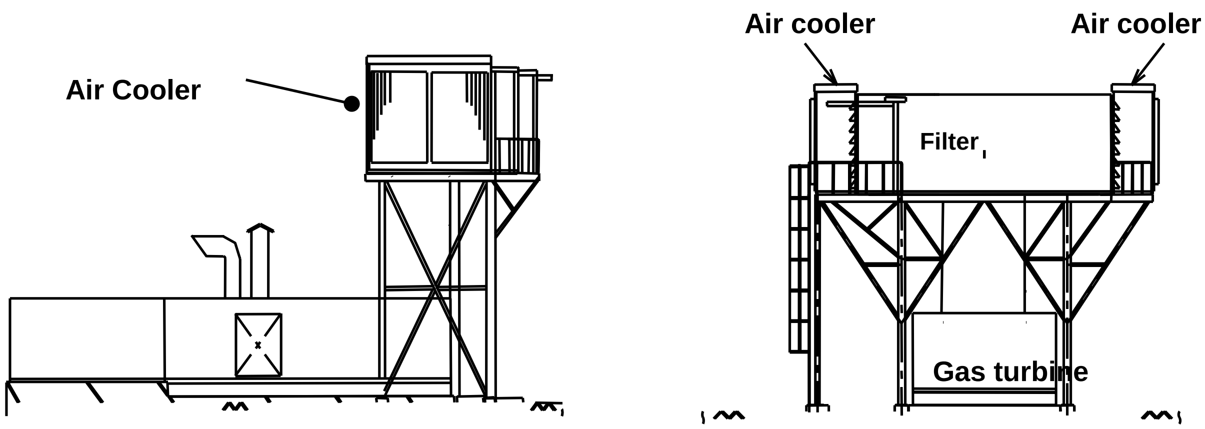


Fig. 3.5 Illustration of the installation of an inlet

3) Inlet chiller

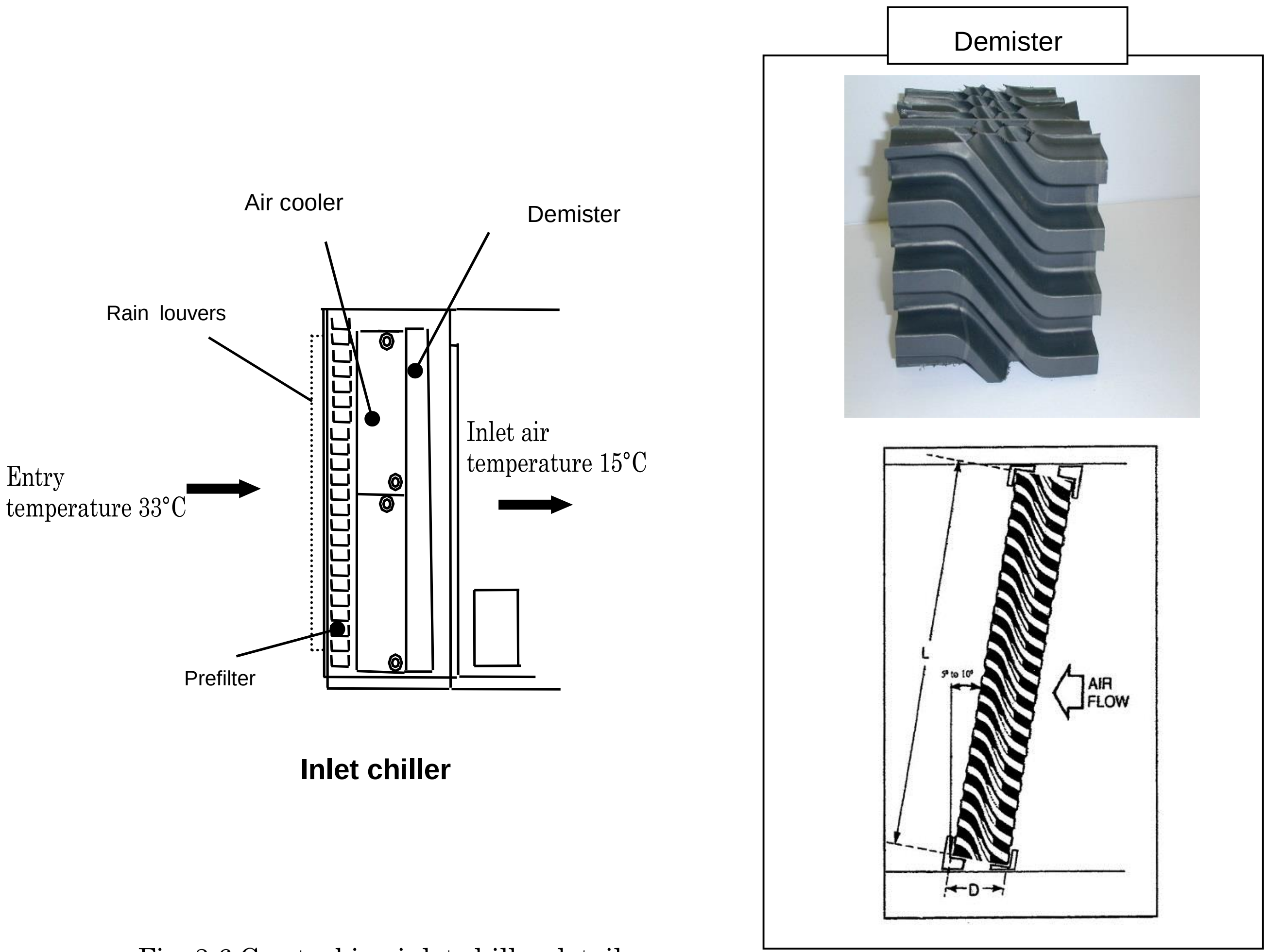


Fig. 3.6 Gas turbine inlet chiller details

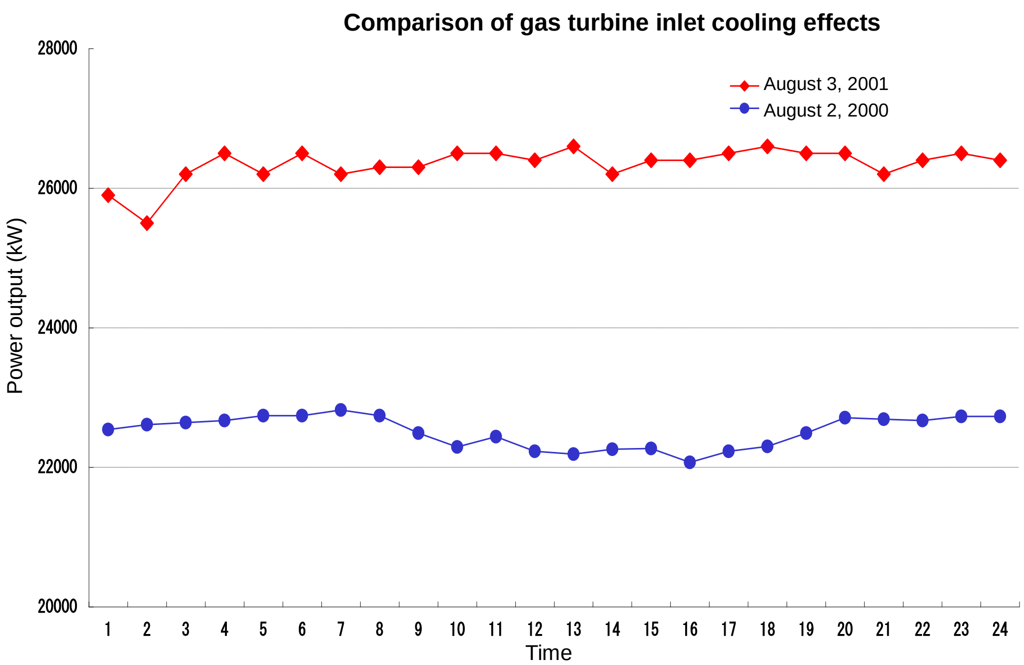
4) Example of inlet chiller installation

The inlet chiller is installed on the condition that the structure of the gas turbine itself is not modified.

There are detailed contract conditions between the gas turbine manufacturer and the owner, and so modifications were made in a way that did not infringe on these conditions.

Fig. 3.7 An inlet chiller attached to a gas turbine inlet

5) Example of measuring gas turbine output increase in summer



Unconditional output for inlet cooling		22,500	kW
Output status during inlet cooling operation		26,300	kW
Power output increase		3,800	kW
Daily output increase	Approx.	92,000	KWh/day

Fig. 3.8 Increases in power output for gas turbines

6) Comparison of generated amount for each inlet-cooled month in Japan

The following shows a comparison of the power generation output for each month when using inlet cooled operation in Japan.

The period when gas turbine inlet cooling is effective in Japan is between June and September, but this shows that it is effective even for short periods.

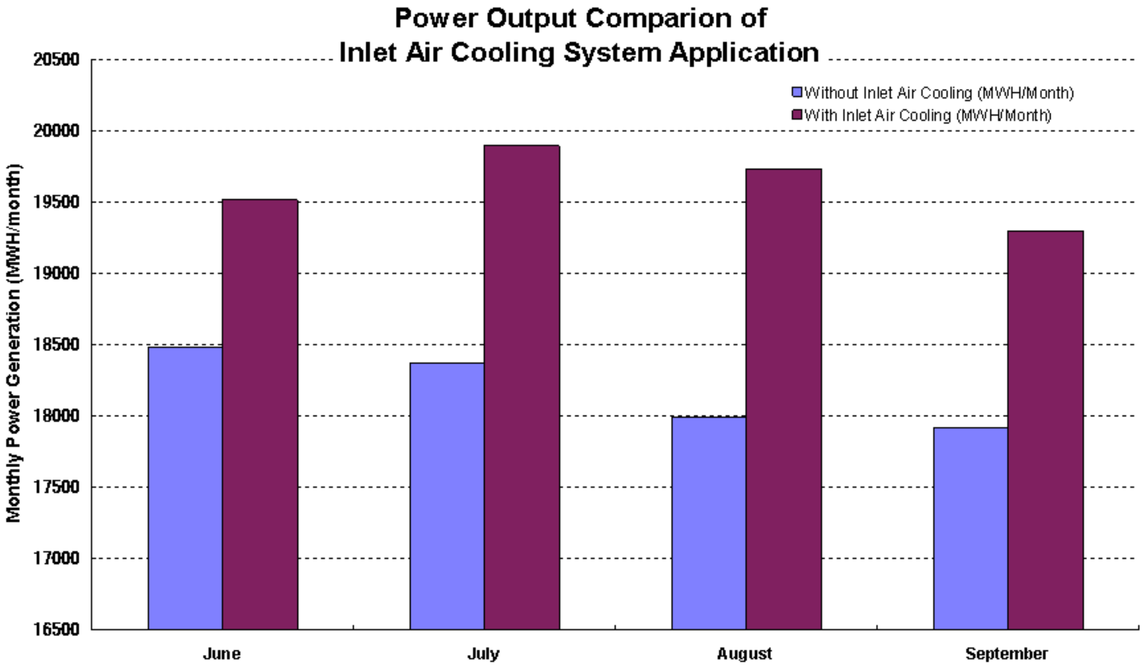


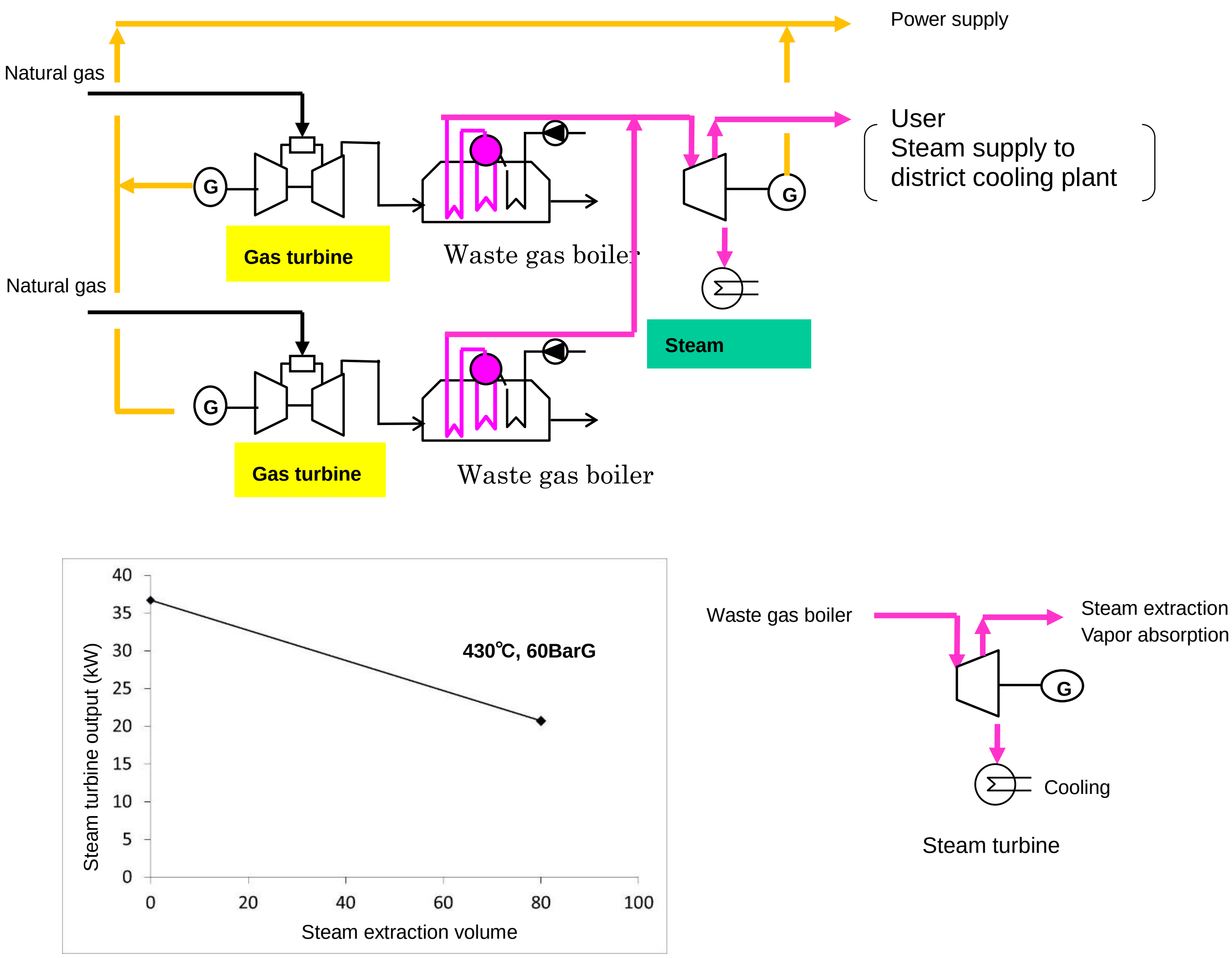
Fig. 3.9 Comparison of increases in generated

3.4 Cogeneration system steam turbine output improvements

The cogeneration system and SPP power generation equipment at BKK are operated using a steam turbine, which uses steam generated with a waste gas boiler. In addition to the steam turbine, steam is also supplied to the users (steam for operating the steam inlet chiller for the district cooling plant at BKK).

Generally, in a cogeneration system, steam is extracted from the interim stage of the steam turbine, and increasing the amount of steam extracted will lower the steam turbine's power output.

The district cooling plant at BKK uses steam extracted at the interim stage of the steam turbine to power the steam inlet chiller for the district cooling plant, and the cold-source equipment configuration for the district cooling plant has an affect on the efficiency of the cogeneration.



Typical example of a steam turbine using an SPP cogeneration system

Fig. 3.10 Improving steam turbine

In terms of improving the energy efficiency of the cogeneration system and the district cooling plant at BKK, studies will need to be made on whether creating a turbo chiller using cold coolant water or creating an inlet chiller will be more efficient.

Reference Materials

1) Keisuke Yoshida, Keita Fujii, Akihito Kunihiro, Yasui Tomita, "Turbo Chiller Inlet Cooling Systems for Large Gas Turbines for Power Generation," *GT Society*, May 2014 (Inlet Cooling Special)
2) Takanobu Komuro, Eisaku Ito, Takashi Sonoda, Yasui Tomita, Kohei Hidaka, Seiji Shibuya, "Increased Output of Gas Turbine Combined Power Generation Plants Through Inlet Cooling in High Ambient Temperatures," *Mitsubishi Juko Giho*, Vol. 47, No. 4 (2010), pp. 49-54.

Chapter 4 Conditions for the Application of Inlet Cooling Systems

4.1 Climate conditions in Thailand

Thailand's climate is a monsoon one, with stark differences between the rainy season and the dry season. The average annual temperature in Bangkok is 29.1°C and the average humidity is 76.2%, making it hot and humid year-round. March through May are the hottest months, when the outdoor temperatures can climb as high as 40°C.

The average temperature in the coolest month, December, is 17°C, and there are three seasons: the dry season from November to February, the hot season from March to May, and the green season (wet season) from June to October.

Data plotting the relationship between outdoor temperature and humidity in the Chonburi region of Thailand is shown below. The planning conditions for inlet cooling systems are believed to allow temperatures of 35°C and humidity of 40%. The Chonburi region has the greatest concentration of industrial estates in the country. The data below is data from the Thai Meteorological Department, plotting data using measurement values taken hourly for 365 days.

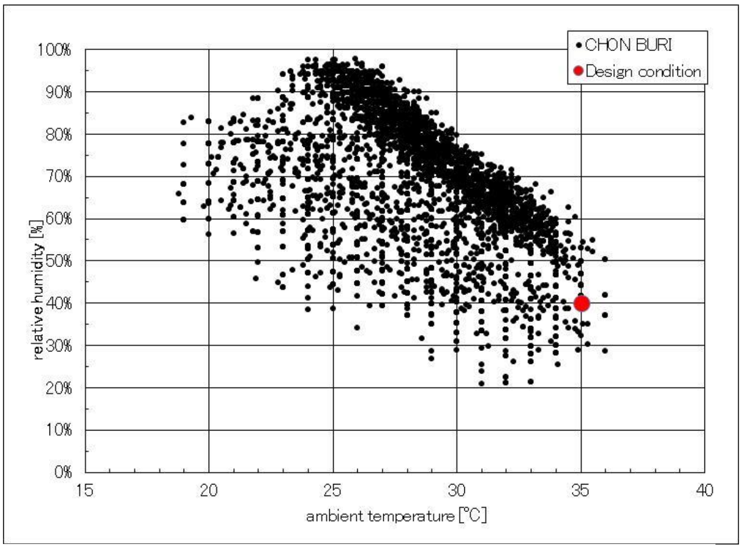


Fig. 4.1 Thai climate conditions

Source: 2008 NOAA climate data
Federal Climate Complex Data Documentation for Integrated Surface Data November 17, 2008
Location: Chonburi, Thailand

4.2 Natural gas costs

The results of interviews with the SPPs contacted for this survey regarding the purchasing costs of natural gas are shown below.

Company A is located near Bangkok and Company B 300 km from Bangkok, and the gas pipeline costs are believed to be assigned to the natural gas purchasing costs.

Table 4.1 Natural gas costs from interviews with SPPS

	Natural gas costs
Company A	320 Baht/MMBTU
Company B	346 Baht/MMBTU

These costs will now be compared with those of Japan and other nations (MMBTU = 25m3, 1Baht = 3.63 yen)

For Company A, it works out as 46.4/m^3.

A gas cost comparison for Thailand, Malaysia, China, and Japan is shown below.

Table 4.2 Comparison of natural gas costs in different countries

Country	Local gas unit	Yen conversion	Notes
Malaysia	Gas 16.07 RM/MMBTU	21.0	Gas Malaysia unit cost
Thailand	320 Baht/MMBTU	46.4	Interviews with SPPs
China	3RMB/M3	59.4	Individually investigated
Japan	-	82.4	T Gas Corporation Package Type 1

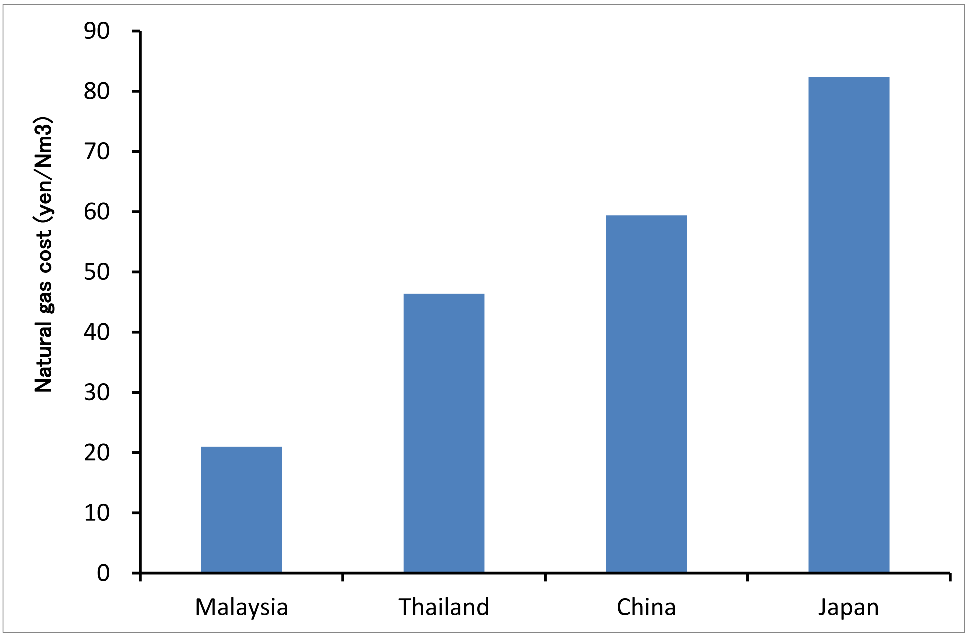


Fig. 4.2 Comparison of natural gas costs in different countries

Malaysia's gas costs are set lower than the market rate thanks to government subsidies.

4.3 Sales costs for generated power

The sales prices for power to EGAT and to industrial estates was obtained from interviews with SPPs.

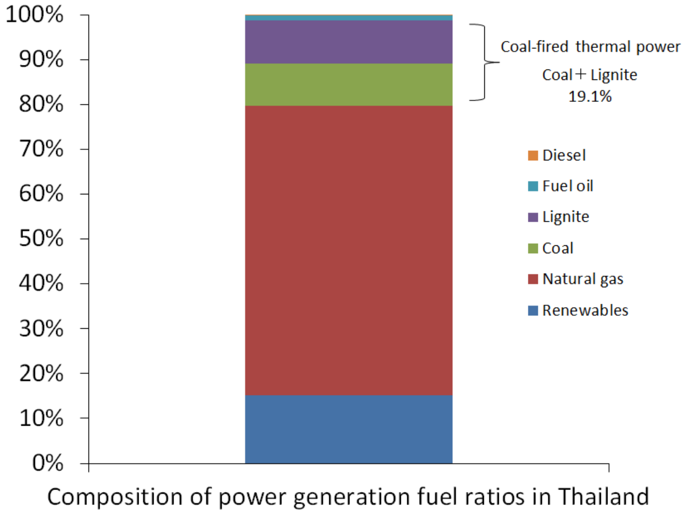
Table 4.3 Generated power costs for SPPs

	Electricity sale price to EGAT	Electricity sale price to industrial estates
Company A	2.95 Baht/kWh	3.35 Baht/kWh
Company B	Peak 3.7 Baht/kWh Off-Peak 2.9 Baht/kWh	Peak 3.5 Baht/kWh Off-Peak 2.1 Baht/kWh

4.4 IPP and SPP CO_2 emissions per unit

The ratio of fuel consumed through coal-fired power generation in Thailand is reported as around 19.1%.

Fuel type	Ratio (%)
Renewables	15.1
Natural gas	64.6
Coal	9.5
Lignite	9.6
Fuel oil	1.11
Diesel	0.1



Source: Summary of Thailand Power Development Plan 2012 - 2030 (PDP2010: REVISION 3)

Fig. 4-3. Power generation fuel ratio in Thailand

The CO_2 emissions per unit differs by fuel type and power plant generation efficiency. The CO_2 emissions per unit for current power generation efficiency and fuel type is shown below.

Table 4-4. CO_2 emissions per unit by power generation category

Category	Power generation efficiency	CO_2 emissions per unit kg-CO_2/kWh
Coal fired power generation	41%	0.864
Oil-fired power generation	41%	0.695
LNG-fired power generation	41%	0.476
SPP class gas turbine combined cycle power generation	52.7%	0.371
IPP class gas turbine combined cycle power generation	56.7%	0.344

Source:
Calculated from Reference Material 3) for CO_2 emissions per unit for thermal power generation, efficiency of gas turbine combined-cycle generation calculated by reporter, and calculated from Reference Material 4) Physical Properties of Natural Gas for gas turbine combined-cycle generation CO_2 emissions per unit.

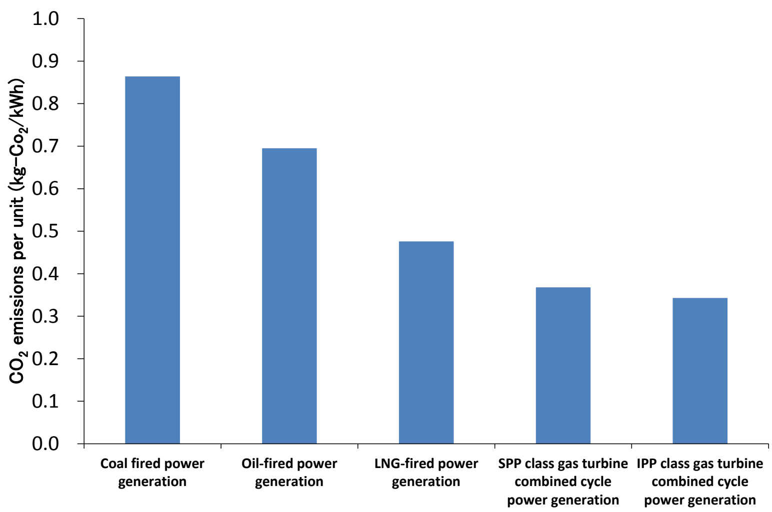


Fig. 4-4. CO_2 emissions per unit by power generation category

The assessment of the CO_2 reduction through the introduction of inlet cooling was based on the following two points.

(1) The CO_2 reduction effects through increasing the amount of energy generated from gas turbine combined-cycle power plants with low CO_2 emissions per unit and reducing the amount of energy generated from coal-fired plants.

(2) Effects from improving the efficiency of gas turbine heat rates.

4.5 Power CO_2 emissions per unit in Thailand

For the CO_2 emission volume to use in this field survey, it was decided to use the figures published by the **Thailand Greenhouse Gas Management Organization (Public Organization) (TGO; founded in 2007)**, an organ of the Thai government, as the TGO works as the organization for approving and checking CDM projects.

Table 4.5 Carbon dioxide emission factors for power generation in Thailand: Source 4)

CDM project type	Emission Factor (tCO_2/MWh)		
	$EF_{grid,OM}$	$EF_{grid,BM}$	$EF_{grid,CM}$
General project	0.5994	0.4231	0.5113

OM (Operating Margin):	The emission factor for existing power generation facilities. At present, the idea is to replace power generation facilities that are linked to the grid, and this will be used when considering the short-term impact.
BM (Build Margin):	The emission factor for the most recently-built power plants. The idea is to replace power plants that will be built in the future, and this will be used when considering the long-term impact.
CM (Combined Margin):	The average of the OM and the BM.

In this field survey, calculations used the TGO's OM of 0.5994 kg-CO_2/kWh

Reference Materials

1) *Concerning Thermal Power Generation*, Agency for Natural Resources and Energy, February 2012
https://www.env.go.jp/council/06earth/y0613-11/ref04.pdf
2) Takanobu Komuro, Eisaku Ito, Takashi Sonoda, Yasui Tomita, Kohei Hidaka, Seiji Shibuya, "Increased Output of Gas Turbine Combined Power Generation Plants Through Inlet Cooling in High Ambient Temperatures," *Mitsubishi Juko Giho*, Vol. 47, No. 4 (2010), pp. 49-54.
3) "Survey of Lifecycle CO_2 by Power Source," *Central Research Institute of Electric Power Industry News* No.468, August 2010.
4) Thailand Greenhouse Gas Management Organization (Public Organization): TGO, *Summary Report: The Study of Emission Factor for an Electricity System in Thailand 2010*
5) Japan Finance Corporation, Japan Bank for International Cooperation, *Guidelines for Measurement, Reporting, and Verification of Greenhouse Gas Emissions in the Japan Bank for International Cooperation's Global Environmental Protection Work*, Revised February 2011.

Chapter 5 SPP Businesses: Field Study for the Application of Inlet Cooling Systems for Gas Turbine Combined Cycle Generators

5.1 Studied SPP gas turbine combined cycle plants

Regarding the study of the application of inlet cooling systems to SPP gas turbine combined cycle generators, interviews were conducted with SPP businesses, getting them to note the gas turbine combined cycle generator equipment to be surveyed, and the CO_2 reduction amount and economics if inlet cooling equipment was brought in for their gas turbines was studied.

This study targeted the 40 MW-class equipment used by G Company and the 40 MW-class equipment used by S Company that are some of the most commonly-used types in Thailand.

With SPPs, the power that can be sold to EGAT is required to be no more than 90 MW, which businesses owning gas turbine combined cycle generation equipment between 110 MW and 120 MW do not have any merit as even if they bring in inlet cooling equipment and boost their output, they cannot sell all of the power unless the industrial estate's electrical load is at least around 40 MW. Therefore SPPs with sufficient load in industrial estates were selected.

5.2 Assessment of CO_2 reduction amounts through the introduction of inlet cooling systems

The effects of inlet cooling systems on gas turbine combined cycle generation equipment are considered to be two-fold: a. the increase in power with little emission of carbon dioxide, and b. the improvement of the generation heat rate for gas turbines.

[Effects of gas turbine inlet cooling]

a. Electrical power increases (increases in the amount of power used with low CO_2 emissions per unit)

Calculated using the following formulae.

$$EG_{GTINC} = EG_{GT}(Td) - EG_{GT}(T(m,d,h)) \quad (5.1)$$

$$EG_{STINC} = EG_{ST}(EG_{GT}(Td)) - EG_{ST}(EG_{GT}(T(m,d,h))) \quad (5.2)$$

$$EG_{INC} = EG_{GTINC} + EG_{STINC} \quad (5.3)$$

$$EG_{INCy} = \sum_{m=1to12} \sum_{d=1\ to\ 31} \sum_{h=1\ to\ 24} EG_{INC} \quad (5.4)$$

$$ER_{y,estimated} = EG_{INCy} \times (FE_{EL\ GRID} - FE_{EL\ COM})/1000 \quad (5.5)$$

EG_{GTINC} Gas turbine power output increase amount (kW)

$EG_{GT}(T)$ Gas turbine power output calculation function (kW)
where T is the inlet air temperature

EG_{STINC} Steam turbine power output increase amount (kW)

$EG_{ST}(EG_{GT}(T))$ Steam turbine power output calculation function (kW)

Used as the function for gas turbine output

$EG_{GT}(Td)$ Gas turbine power output at designed ambient temperature (15°C) (kW)

$T(m,d,h)$ Ambient temperature measurement value

EG_{INC} Combined power generation output increase amount (kW)

EG_{INCy} Annual power output increase (kWh/year)

$ER_{y,estimated}$ Annual CO_2 reduction volume (ton-CO_2/year)

$FE_{EL\ GRID}$ Grid power CO_2 emissions coefficient (kg-CO_2/kWh)

Default value Ch. 4, Table 4.5 $EF_{grid,OM}$ 0.5994 (kg-CO_2/kWh)

$FE_{EL\ COM}$ Combined cycle CO_2 generation coefficient (kg-CO_2/kWh)

Default value Ch. 4, Table 4.4 SPP class 0.371 (kg-CO_2/kWh)

y Calculation year

m Calculation month

d Calculation day

h Calculation hour

T Gas turbine design inlet air temperature

B Baseline

P Project

b. CO_2 reduction through improvements in gas turbine heat rates from inlet cooling

$$E_{DEC\ HR} = EG_{GT}(T(m,d,h)) \times (HR_{COM\ B} - HR_{COM\ P}) \div LHV_{FUEL} \times FE_{FUEL} \quad (5.6)$$

$$E_{DEC\ HR\ y} = \sum_{m=1\ to\ 12} \sum_{d=1\ to\ 30} \sum_{h=1\ to\ 24} E_{DEC\ HR} \quad (5.7)$$

$E_{DEC\ HR\ y}$ Amount of CO_2 reduction from gas turbine heat rate improvements (kg- CO_2/year)

$E_{DEC\ HR}$ Amount of CO_2 reduction from gas turbine heat rate improvements (kg-CO_2/h)

$HR_{COM\ B}$ Heat rate without inlet cooling (MJ/kWh)

$HR_{COM\ P}$ Heat rate with inlet cooling (MJ/kWh)

LHV_{FUEL} Natural gas calorific value (MJ/Nm3)

FE_{FUEL} Amount of CO_2 generated from natural gas (kg- CO_2/Nm3)

c. Economic benefits from increased power output due to inlet cooling

The annual power generation amount for combined cycle generation equipment is calculated in (5.1)- (5.4).

(1) Power purchase increases

Increases in profitability from power output increases are calculated according to the following formulae.

$$C_{EL\,INC\,y} = \sum_{m=1\,to\,12} \sum_{d=1to\,30} \sum_{h=1\,to\,24} EG_{INC} \times C_{EL\,UNIT} \tag{5.8}$$

$C_{EL\,INC\,y}$	Amount of increase in annual power purchased	(Bhat/year)
$C_{EL\,UNIT}$	Power unit cost	(Bhat/kWh)

(2) Fuel costs

$$FUEL_{INC} = EG_{GT}(T(m,d,h)) \times HR_{COM\,B} - EG_{GT}(Td) \times HR_{COM\,P}\ ) \div LHV_{FUEL} \tag{5.9}$$

$$C_{FUEL\,INC\,y} = \sum_{m=1\,to\,12} \sum_{d=1\,to\,31} \sum_{h=1\,to\,24} FUEL_{INC} \times C_{FUEL} \tag{5.10}$$

$FUEL_{INC}$	Increase in natural gas consumption	(Nm^3/h)
C_{FUEL}	Natural gas unit cost	($Bhat/Nm^3$)
$C_{FUEL\,INC\,y}$	Amount of increase in annual gas costs	(Bhat/year)

(3) Annual merits from the application of an inlet cooling system

$$\mathrm{IASC}_{\mathrm{INC\,y}} = C_{EL\,INC\,y} - C_{FUEL\,INC\,y} \tag{5..11}$$

$\mathrm{IASC}_{\mathrm{INC\,y}}$	Merits from the introduction of an inlet cooling system	(Bhat/year)

The amount of CO_2 generated and the economic effects are assessed through running simulations using characteristics data for gas and steam turbines as well as measurement data and ambient conditions (external air temperature and humidity) for 24 hours a day, 365 days a year.

5.3 SPP class gas turbine combined cycle generation equipment: Assessment of the application of inlet cooling systems

The results of studying the inlet cooling system with regard to the targeted SPP-class combined cycle generation equipment are as follows.

(1) Study materials

G Co.'s 40 MW-class devices x 2 + ST combined cycle generation equipment Materials 5.1

S. Co.'s 40 MW-class devices x 2 + ST combined cycle generation equipment Materials 5.2

(2) CO_2 reduction effects and expected return on investment (ROI)

System	CO_2 reduction	ROI
G Co. GT x 2 + ST combined cycle generation equipment	39,922 tons-CO_2/year	0.92 year
S Co. GT x 2 + ST combined cycle generation equipment	27,370 tons- CO_2/Year	1.67 year

As shown above, the CO_2 reduction effects differ even with the same scale of cogeneration system. The 40 MW-class equipment from G Company is an engine used in large-scale passenger aircraft by companies such as Airbus and Boeing (aircraft-use gas turbine). Generally, aircraft-use gas turbines show significant improvements in heat rate and generated output through the application of a gas turbine inlet cooling system, as they are highly susceptible to the effects of ambient temperatures.

The engines used by SPPs in Thailand are mainly the gas turbines listed above, and in addition are almost all the same 110 MW to 130 MW output capacity, so they can be estimated by engine types when studying the CO_2 reduction effects and return on investment effects.

5.4 Points to note regarding the application of SPP class gas turbine combined-cycle generation equipment inlet cooling systems

SPP power generation businesses sell up to 90 MW of electricity to EGAT as well as electricity, steam, and cold water to industrial estates. Therefore even if SPPs use inlet cooling systems and boost their outputs, the issue is whether a system that allows them to sell this extra power can be put into place.

Therefore it may not be possible to sell all the extra generated power, depending on the status of the electricity users in the industrial estate, even when it becomes possible to use inlet cooling systems for gas turbines.

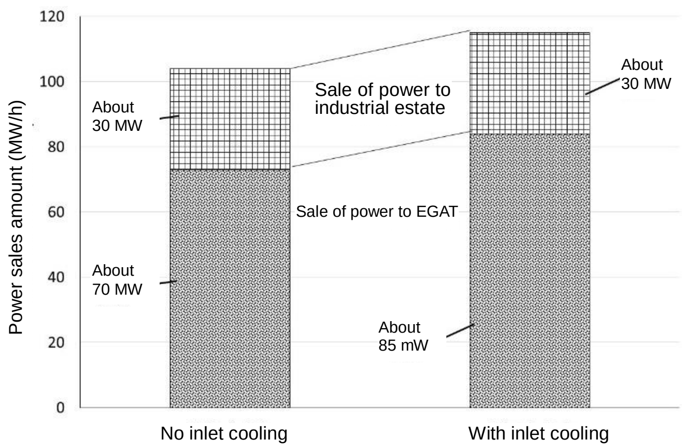


Fig. 5.1 Illustration of power sales for SPPs with gas turbine inlet cooling added

Materials 5.1

Model Case for the Application of Gas Turbine Inlet Cooling for G Company Product

1. Overview of the surveyed plant

The Thai company G Company, which operates SPPs in Thailand, has been asked to select a plant for the field survey. A study was done of the inlet cooling systems for the cogeneration system. The studied plant supplies steam and power to an industrial park.

The studied plant uses two 40 MW-class turbines made by G Company and a steam turbine. Refer to the attachment for details of the system and the results of the CO_2 reduction amount study.

Photo 1. Cogeneration system

Photo 2. Waste gas boiler

Photo 3. Generator

Photo 4. Gas turbine body

2. FS for Inlet Air Cooling (For the Thai domestic company G Company)

2.1. General

This document summarizes the power increase of the gas turbine combined power generation system of the Thai domestic company G Company.

2.2. Gas Turbine Combined Power Plant Configuration

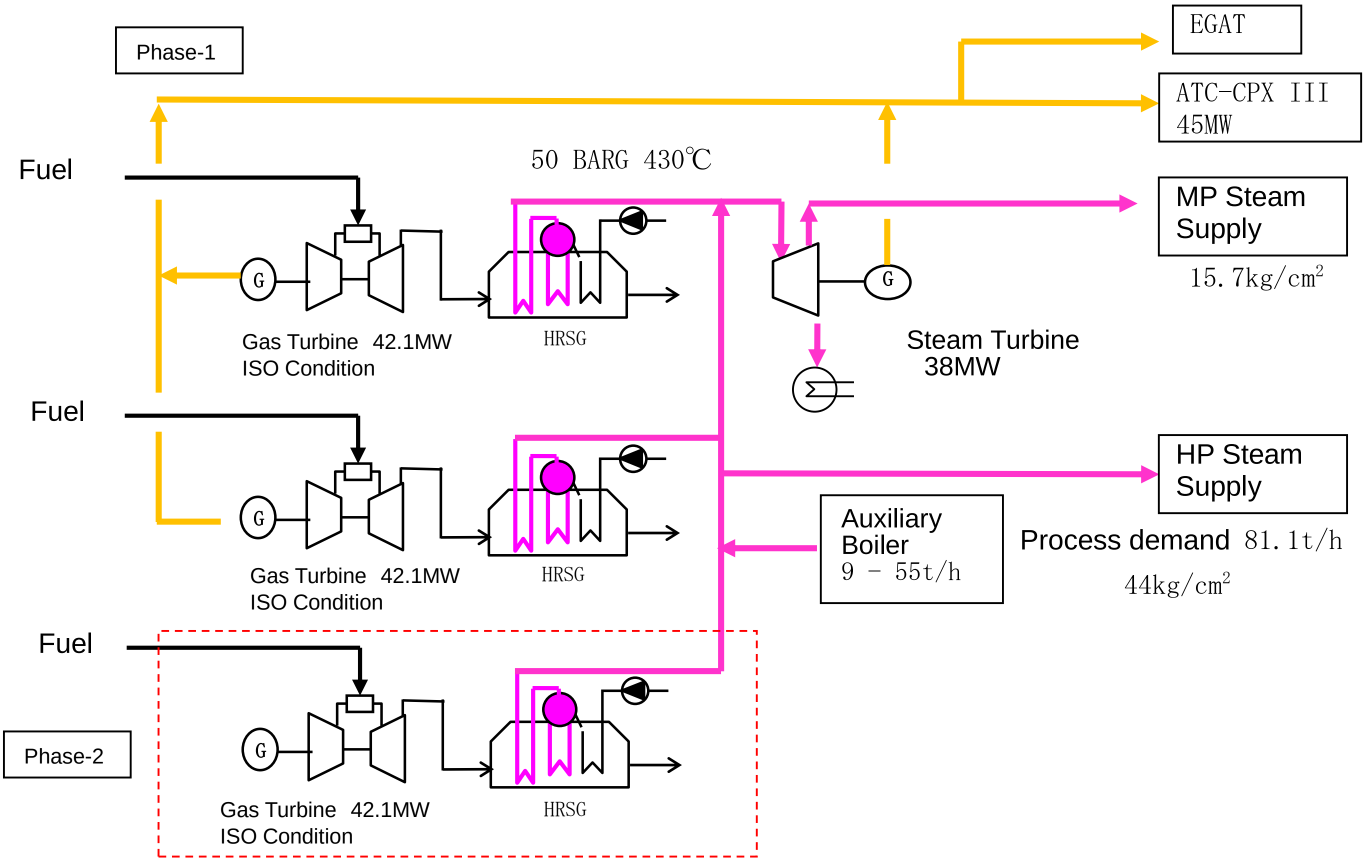


Fig. 1 Gas Turbine Cogeneration System

Plant steam consumption for G Co.

		Total	HP steam	MP steam
Maximum process steam demand	t/h	162.4	105.5	56.9
Normal process steam demand	t/h	108.9	81.1	27.8

Plant steam pressure and temperature for G Co.

		Operation	Design
HP steam pressure	kg/cm²(g)	44.0	48.0
HP steam temperature	°C	405	430
MP steam pressure	kg/cm²(g)	15.7	17.3
MP steam temperature	°C	259	280

2.3.Gas Turbine Data

General information shall be provide.

No.	Item	Information	Unit	Remarks
1	GT manufacture	G Company		
2	GT model	40 MW-class, 50 Hz		
3	Installed GT number	2	set	
4	Year of Start Operation	2009		
5	Rated power output	42100 kW@5163 rpm	kW	ISO condition
			kW	Site condition
6	GT design ambient temperature	35	°C	Site condition
7	GT design ambient humidity	76	%	Site condition
8	Combustion airflow at design condition	130	Kg/S	Site condition
9	Fuel consumption at design condition	-	Nm3/h	
10	GT power generation efficiency	Heat-rate (LHV) 11588 kJ/kWh	%	
11	HRSG Steam a. Temperature b. Pressure c. Steam Flow	 430 50 barg 140	 °C Mpa barg Ton/h	

2.4.Utility condition

The feasibility of GT inlet air cooling system shall be calculated.

Item	Data	Unit
Fuel combustion heat	902.7565	MMBTU/Nm3 LHV(dry) BTU/SCF
Fuel Price	346	Baht/MMBTU
Generated power selling price to EGAT	Peak = 3.7 Off-Peak = 2.9	Baht/kWh (*1)
Generating power selling price to industrial	Peak = 3.5 Off-Peak = 2.1	Baht/kWh (*1)
Water cost	Service water = 23.75	Baht/m3

2.5.GT Inlet Air Cooling Application

(1) Inlet temperature

By applying Gas Turbine Inlet Air Cooling System, compressor inlet temperature will be cooled down in the following condition.

	Inlet Temperature
Original Temperature	35°C
Gas Turbine Inlet air Cooling System	15°C

(2) Power Increase check

Cooling the inlet temperature from 35°C to 15°C is expected to increase the power by 14.6%.

(3) Heat Rate Improve

By applying inlet air cooling system, heat rate will be improved 3.7%.

2.6 Ambient air condition

The ambient temperatures of Thailand are plotted in Fig.4
The design temperature of inlet air cooling system can be decided at 35°C, 40%RH.

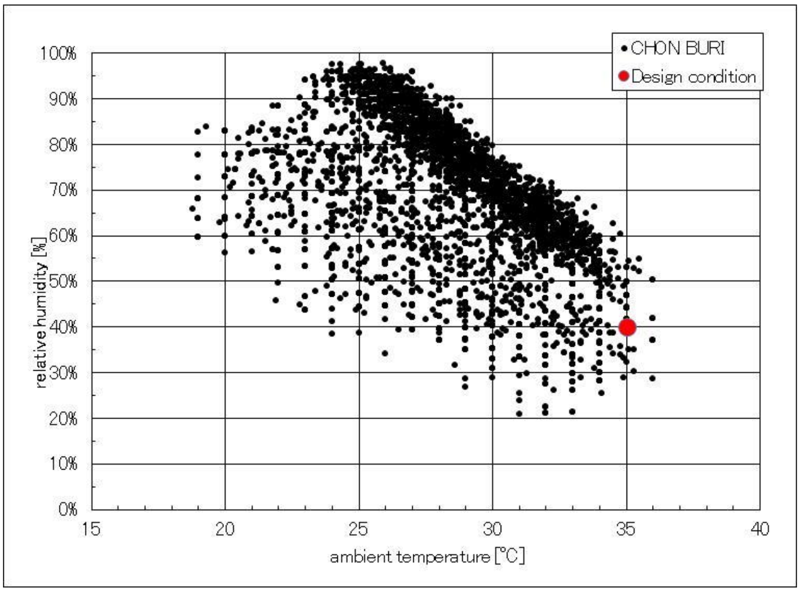


Fig.2 Ambient temperature conditions

2.7 Chiller system planning for inlet air cooling system

a. Inlet air condition of air cooling coil

GT design ambient temperature	35 degC
GT design ambient humidity	40%
Enthalpy of Intel Air	17kcal/kg

a. Outlet air condition of air cooling coil

GT design ambient temperature	15 degC
GT design ambient humidity	100%
Enthalpy of Intel Air	9.9kcal/kg

Combustion Air Flow in design : 130 kg/s (<= Is it total of two)

Combustion Air Flow with Inlet Air Cooling 130kg/s x 1.146 =149 kg/s

Required cooling capacity = 149kg/s x (17 kcal/kg - 9.9 kcal/kg) x 3600 /3024

= 1254 RT x 2 Gas Turbine
= 2508RT

2.8 Steam Turbine

Steam Turbine characteristic is shown as follows.

Steam	Steam Turbine	Remarks
100t/h	23000 kW	Ext Flow 0t/h
150t/h	37000 kW	Ext Flow 0t/h

Ratio of increase in steam amount vs. increase in power output
= (37000kW-23000kW)/ (150t/h-100t/h)
= 280kW/t

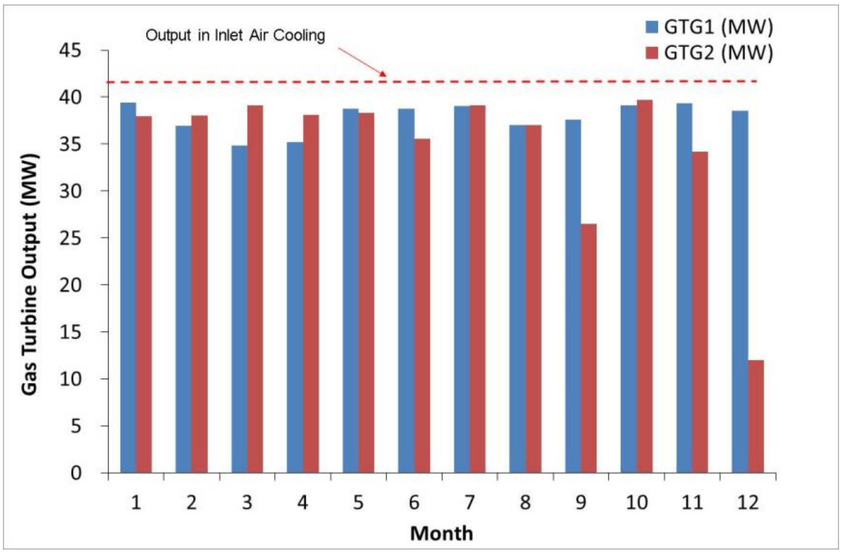
3. 2014 gas turbine output (Operation data)

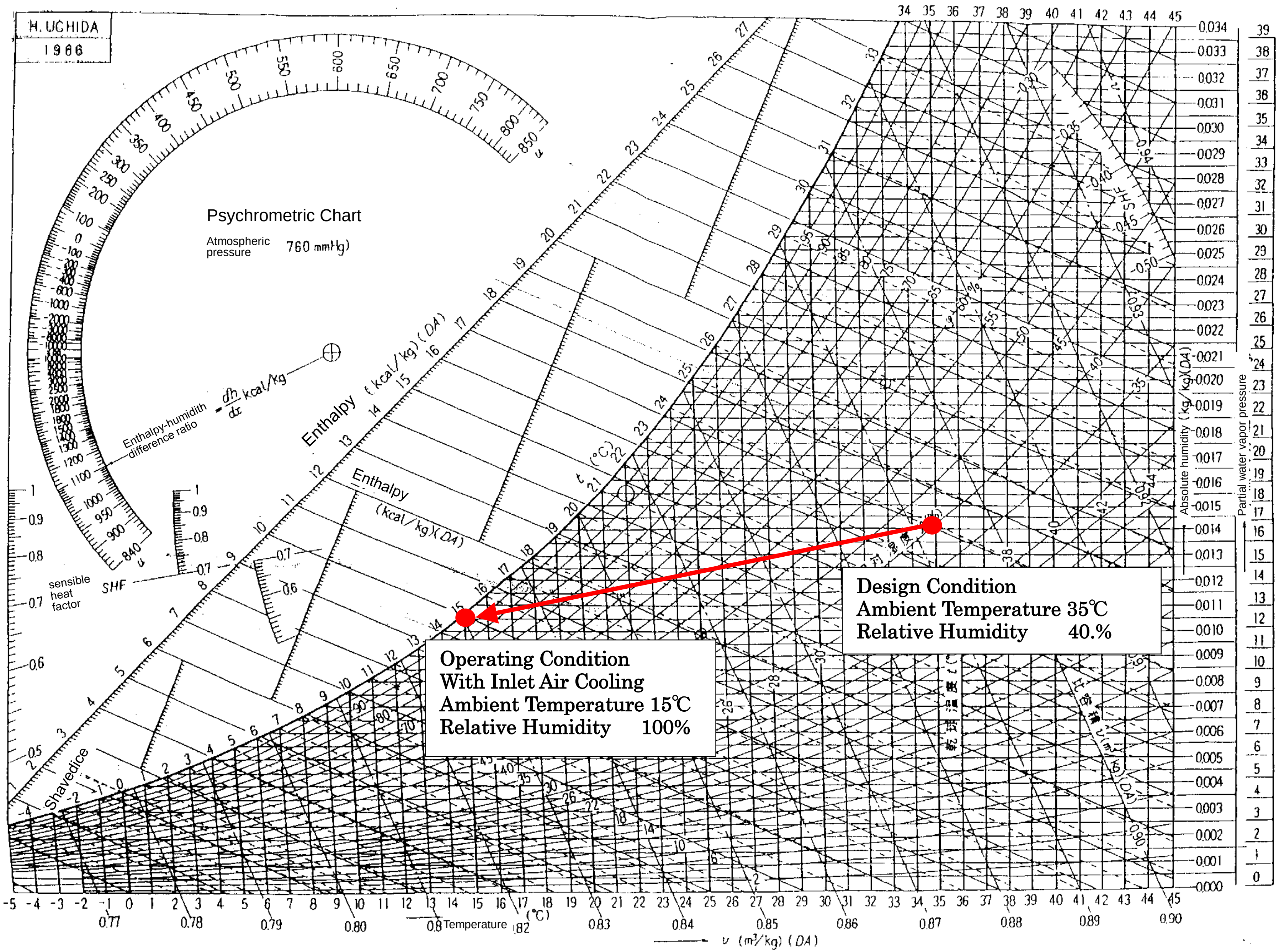
(1) Monthly Power Output

	GTG1 (kW)	GTG2 (kW)	STG (kW)
Jan	29,329,230	28,241,714	5,227,366
Feb	24,827,559	25,565,844	3,496,605
Mar	25,950,866	29,087,396	3,883,267
Apr	25,353,858	27,463,507	3,544,509
May	28,842,617	28,503,896	5,198,784
Jun	27,908,861	25,607,658	3,927,448
Jul	29,048,579	29,115,868	4,758,126
Aug	27,525,369	27,559,471	5,115,393
Sep	27,061,725	19,076,006	6,726,459
Oct	29,126,891	29,544,719	6,325,517
Nov	28,315,468	24,607,237	3,786,034
Dec	28,658,131	8,930,923	1,142,508

(2) Hourly Gas Turbine Output

	GTG1 (MW)	GTG2 (MW)
Jan-14	39.4	38.0
Feb-14	36.9	38.0
Mar-14	34.9	39.1
Apr-14	35.2	38.1
May-14	38.8	38.3
Jun-14	38.8	35.6
Jul-14	39.0	39.1
Aug-14	37.0	37.0
Sep-14	37.6	26.5
Oct-14	39.1	39.7
Nov-14	39.3	34.2
Dec-14	38.5	12.0



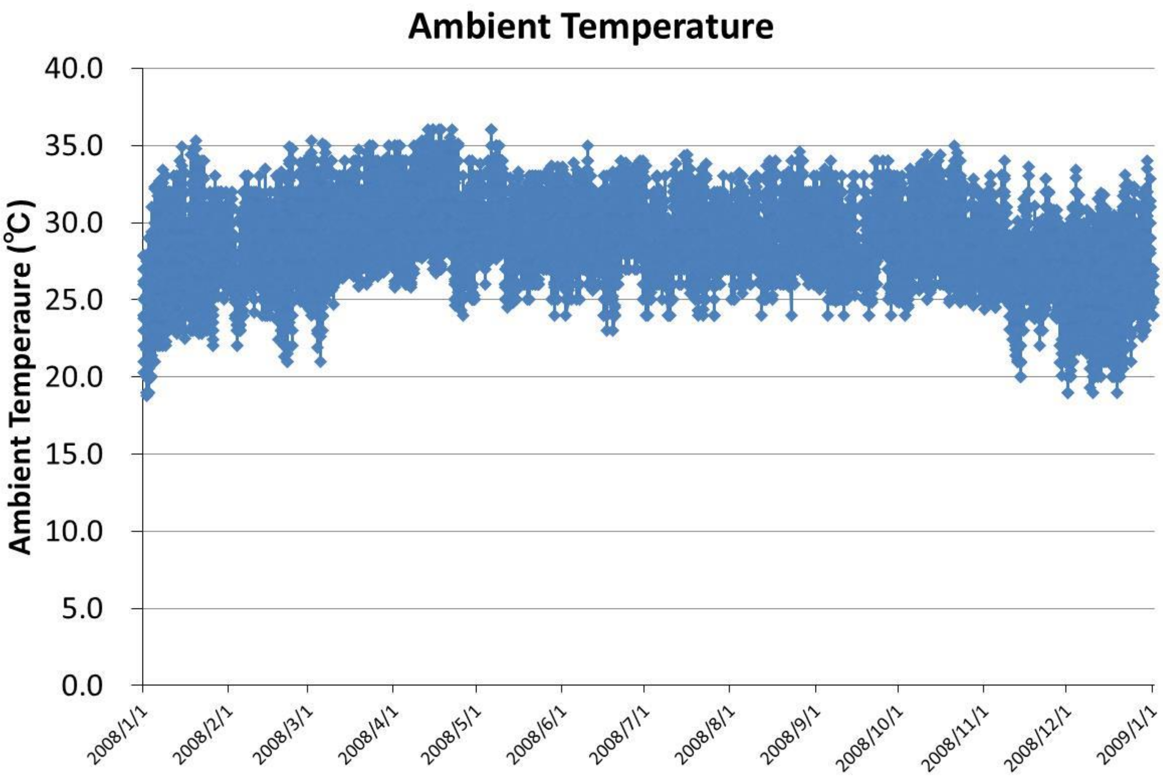


H. UCHIDA
1966
Psychrometric Chart
Atmospheric pressure 760 mmHg)
Enthalpy-humidity difference ratio
dh/dx kcal/kg
Enthalpy (kcal/kg)(DA)
sensible heat factor SHF
Shavedice
Absolute humidity (kg/kg)(DA)
Partial water vapor pressure
Temperature (°C)
v (m³/kg)(DA)
Design Condition
Ambient Temperature 35℃
Relative Humidity 40.%
Operating Condition
With Inlet Air Cooling
Ambient Temperature 15℃
Relative Humidity 100%

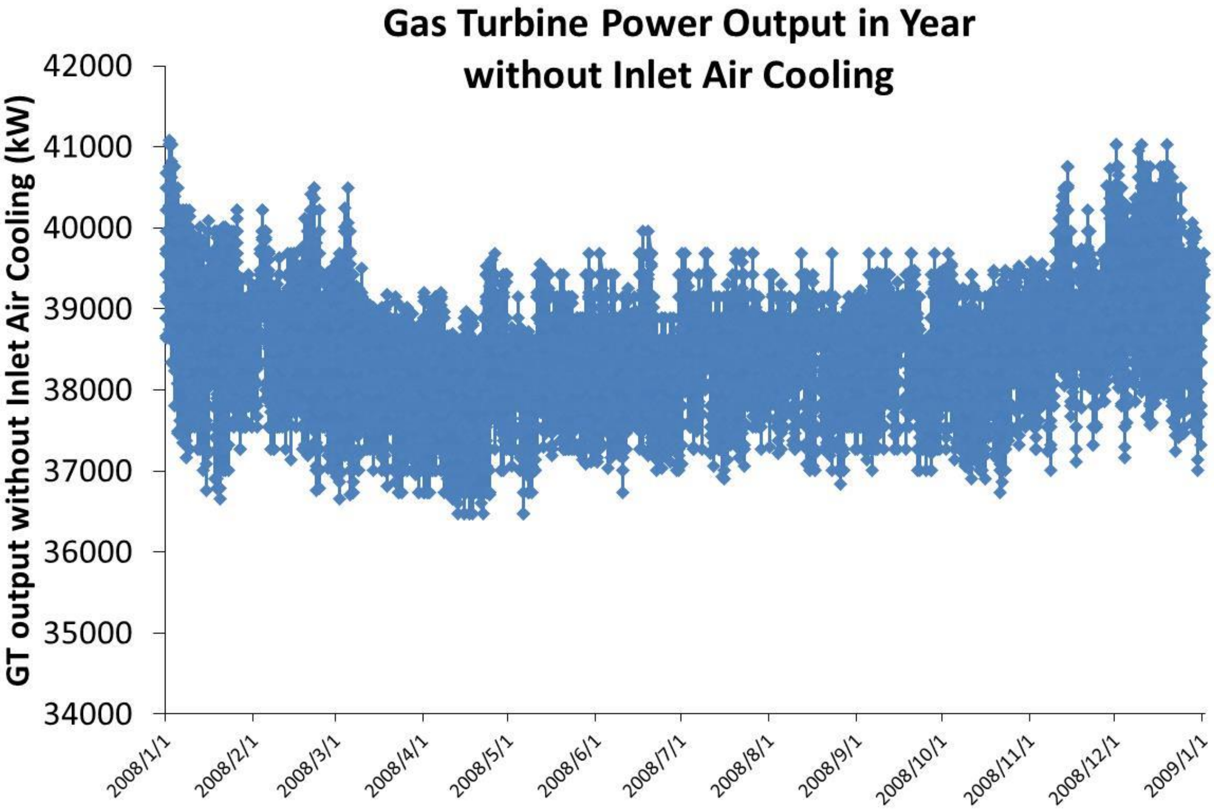
4　. Merit calculation of inlet air cooling system

The merits of using an inlet air cooling system are calculated by conducting simulations of a cogeneration system running 24 hours a day, 365 days a year, applying the annual climate conditions to the operating conditions of gas turbines using the formulae in (5.1) to (5.11).

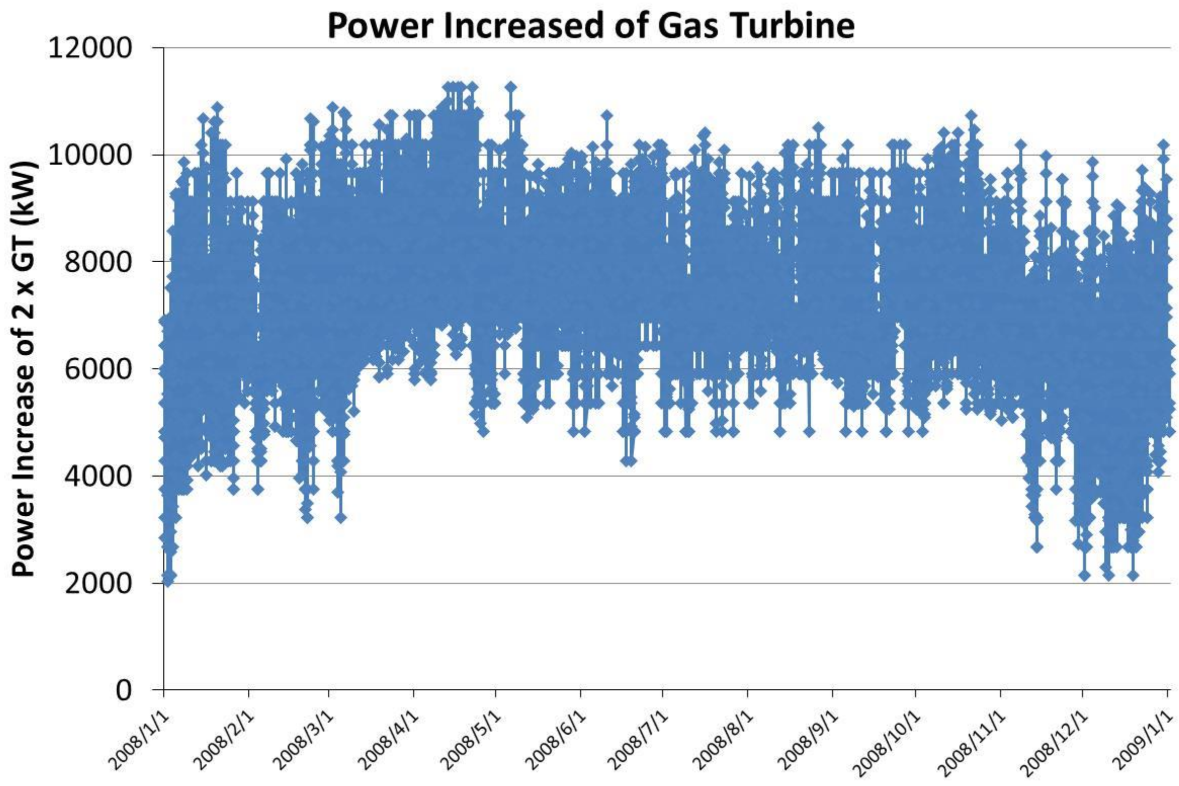
(1) Ambient Temperature



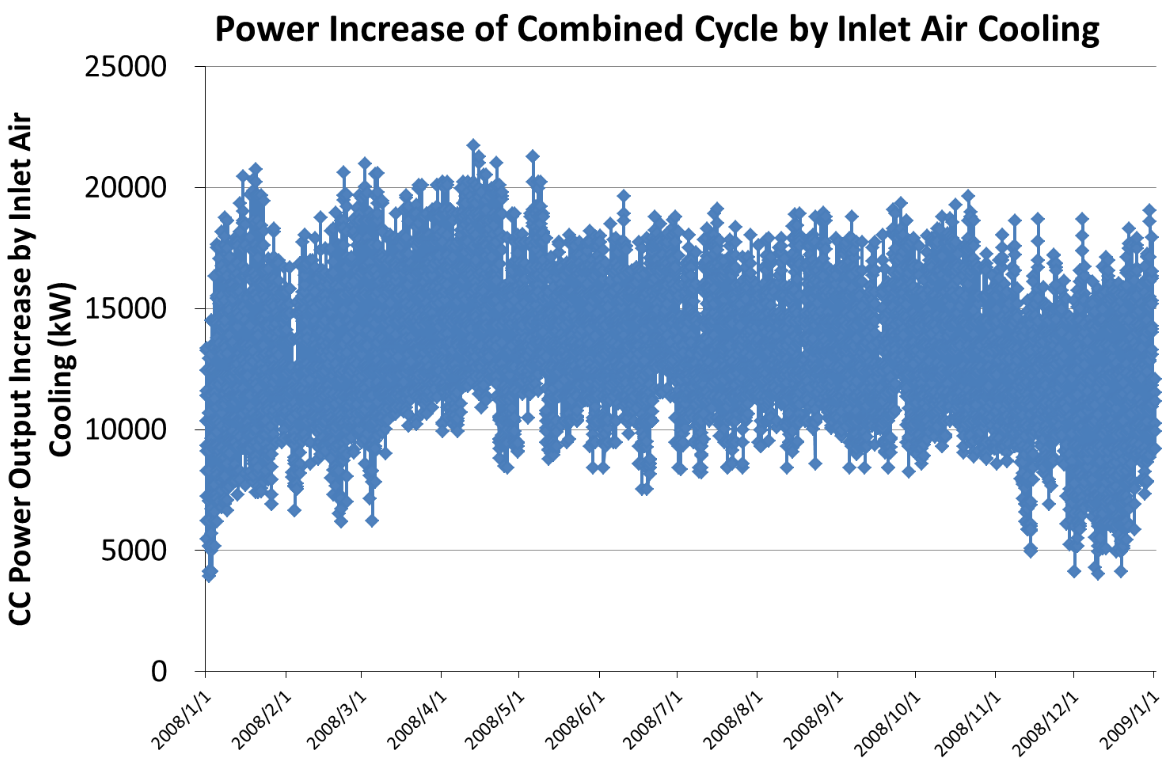
(2) Gas Turbine Output without Inlet Air Cooling System



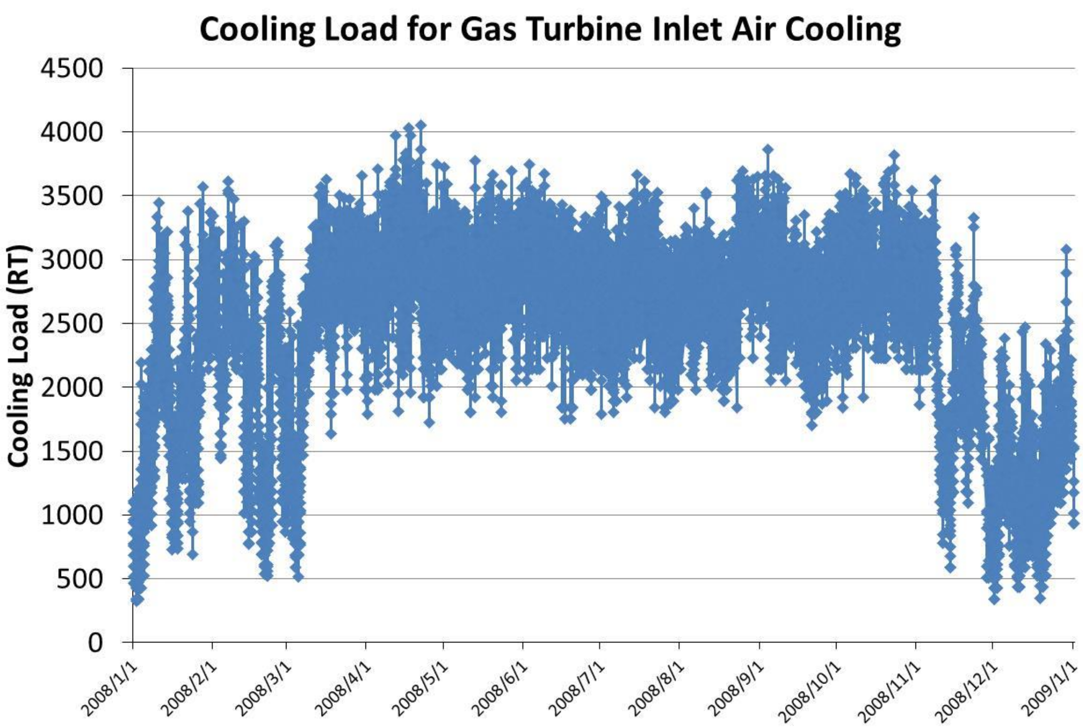
(3) Power Increase of Gas Turbine x 2 by Inlet Air Cooling System



(4) Combined Cycle power increase by Inlet Air Cooling



(5) Cooling Load by Inlet Air Cooling



[Merit of Gas Turbine Inlet Air Cooling System]

Based on the yearly combined system calculation, the merit of Gas Turbine Inlet Air Cooling System will be as follows.

Annual sales volume from the grid and annual generated amount before and after the application of the gas turbine inlet air cooling system.

Item	Before application	After application
GTCC annual generated power	1,073,475 MWh/ year	1,186,013 MWh/year
Sales from grid	112,538 MWh/ year	0 MWh/year
GTCC CO_2 emissions	415,117 tons - CO_2 / year	442,605 tons-CO_2/year
Grid CO_2 emissions	67,410 tons - CO_2 / year	0 tons-CO_2/year

Year Cost Merit of GT Inlet Air Cooling 212,082,599 Bhat/Year
CO_2 Reduction 39,922 ton- CO_2 /Year

Chiller System Capacity 4,000RT
Chiller Budgetary Cost 1,500US$/RT
Total Cost 6 mill-US$

Currency 32.57Bhat/US$

Chiller System	4000RT
Budgetary Cost for IACS	1500US$/RT US$6,000,000 195,420,000Bhat
Investment Recovery	0.97 Year

Materials 5.2

Model Case for the Application of Gas Turbine Inlet Cooling for S Company Product

1. Overview of the surveyed plant

A study was conducted on the economics issue after getting an SPP company with German investment to provide the planning requirements for the application of gas turbine inlet air cooling. The studied plant uses two 40 MW-class turbines made by S Company and a steam turbine. Refer to the attachment for details of the system and the results of the CO_2 reduction amount study. The client for this study owns five SPP power plants with the same specifications.

Rating	Gas Turbine	Steam Turbine	Max output	Designed external temp	Max power output	Average power demand	Designed steam supply	EGAT power supply	Industrial estate
142.1 MW	50 MW x 2	42.1 MW x 1	132 MW	15°C	128 MW	104 MW	30t/h	Av. 80 MW Max 90 MW	Av. 24 MW Max 38 MW

2. FS for Inlet Air Cooling for (for the German B Company)

2.1 General

This document summarizes the power increase of gas turbine combined power generation system of the German B Company.

2.2 Gas Turbine Combined Power Plant Configuration

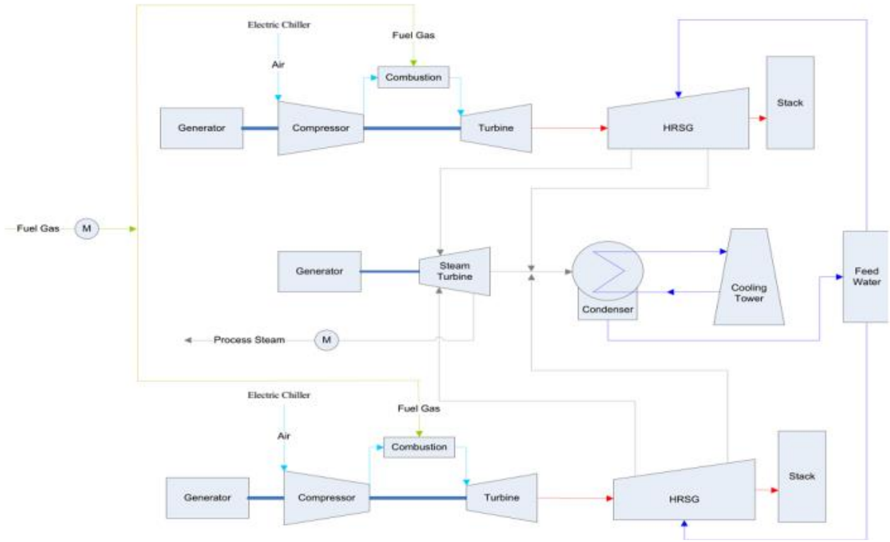


Fig. 1 Gas Turbine Combined Cycle Configuration

(1) Rated performance

No.	Item	Information	Unit	Remarks
1	GT manufacture	S Co/		
2	GT model	40 MW-class		
3	Installed GT number	2	set	
4	Year of Start Operation	2013		
5	Reted power output	48,845	kW	
6	GT design ambient temperature	15	degC	
7	GT design ambient humidily	76	%	
8	Combustion airflow at design condition	—	Kf/S	
9	Fuel consumption at design condition	9.256	SCF/kWh	
10	GT power generation Heat Rate (LHV)	9,727	kJ/kWh	
11	HRSG Steam (LP) a. Temperature b. Pressure c. Steam Flow	245.9 8.97 11.88	degC bara Ton/h	
12	HRSG Steam (HP) a. Temperature b. Pressure c. Steam Flow	514.2 79.3 64.56	degC bara Ton/h	

(2) Power Increased by Gas Turbine Inlet Air Cooling

The power output increase will be different by the ambient temperature but we can expect to see an increase in 8 MW power by cooling the inlet air temperature from 35°C to 15°C.

(3) Heat Rate Improvement

Heat rate will be improved from 10.09MJ/kW to 9.6MJ/kW (around 4.8%)

2.3 Steam Turbine Output Characteristic

Steam Turbine output is given below.

Steam turbine output 14MW at steam flow 50t/h
Steam turbine output 30MW at Steam flow 100t/h

Steam output increase rate = (30MW-14MW) / (100t/h – 50t/h) = 0.32MW/ton-steam

2.4 Required Air Cooling Capacity

(1) Air Flow

As there was no air flow condition, we assume air flow 3.55kg/MW based on LM6000

Air flow = 3.55kg/MW x 47MW = 166.85kg/s

(2) Ambient air condition

The ambient temperature of Thai country is plotted in fig.2

The design temperature of inlet air cooling system can be decided 35℃ 40%.

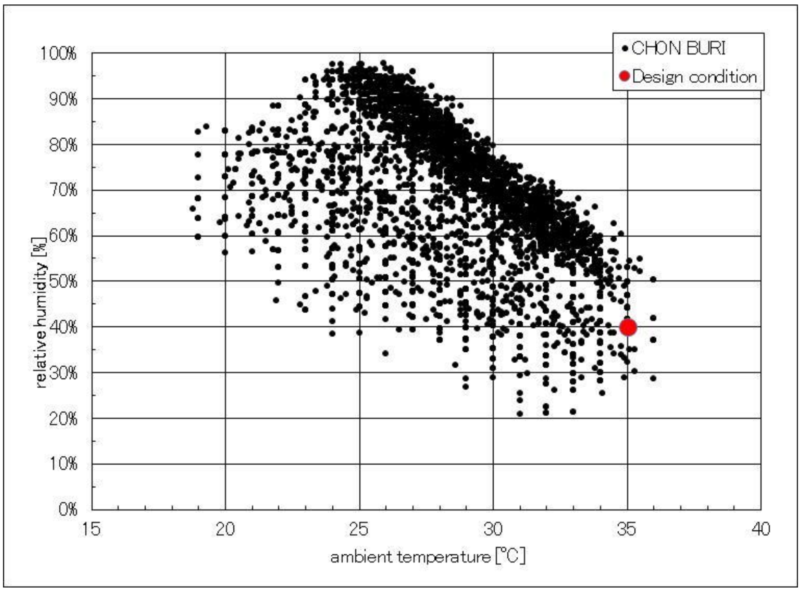


Fig.2 Ambient temperature condition

2.5 Chiller System planning for Inlet Air Cooling System

a. Inlet air condition of air cooling coil

GT design ambient temperature	35 degC
GT design ambient humidity	40%
Enthalpy of Intel Air	17kcal/kg

a. Outlet air condition of air cooling coil

GT design ambient temperature	15 degC
GT design ambient humidity	100%
Enthalpy of Intel Air	9.9kcal/kg

Combustion Air Flow with Inlet Air Cooling 130kg/s x 1.146 =149 kg/s x 1 Gas Turbine

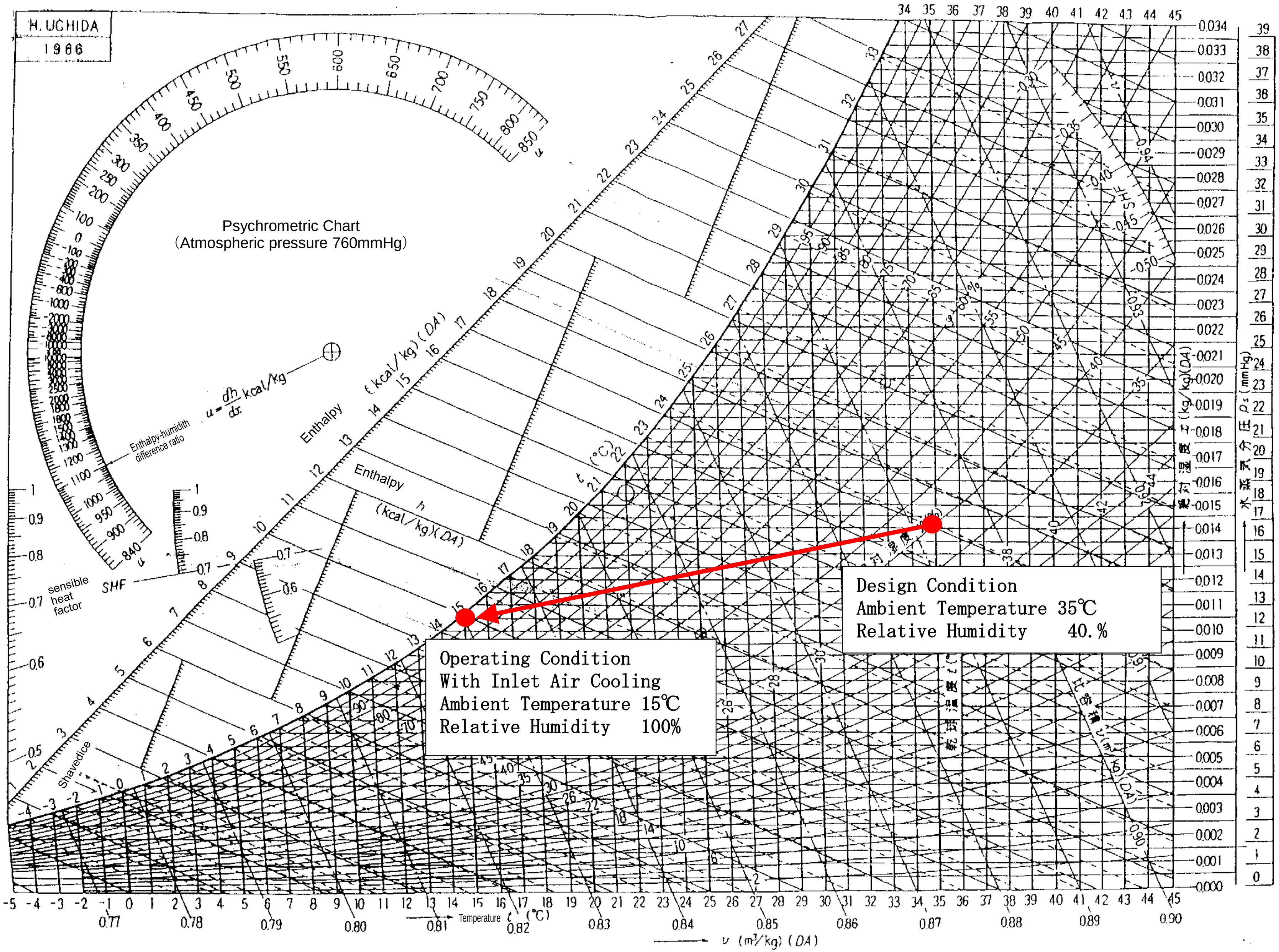
Required cooling capacity = 166.85kg/s x (17 kcal/kg - 9.9 kcal/kg) x 3600 /3024

= 1410 RT x 2 Gas Turbine
= 2800RT

2.6 Utility condition

The feasibility of GT inlet air cooling system shall be calculated. Messer. You are requested to provide the following condition.

Item	Data	Unit
Average fuel heating value (HHV)	996	MMBTU/SCF
Fuel Price	320	Baht/MMBTU
Generated power selling price to EGAT	2.95	Baht/kWh (*1)
Generating power selling price to industrial	3.35 (for 11kV)	Baht/kWh (*1)
Water cost	20	Baht/m3

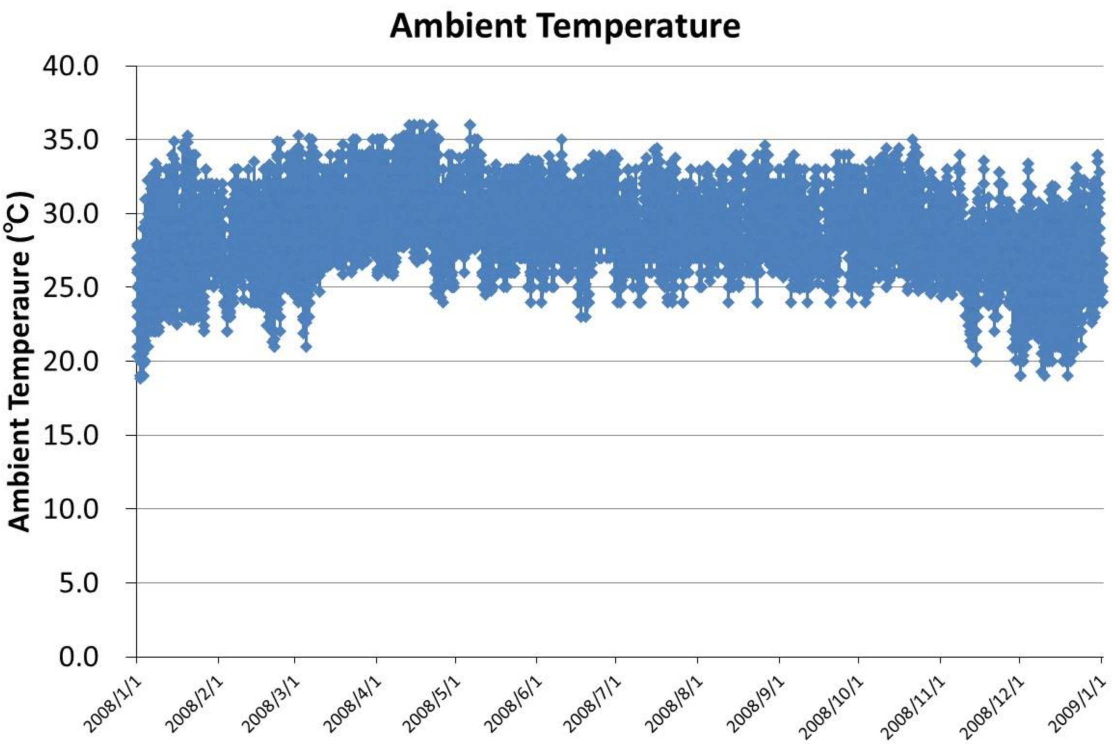


H. UCHIDA
1986
Psychrometric Chart
(Atmospheric pressure 760mmHg)
Enthalpy-humidith difference ratio
sensible heat factor
SHF
Shavedice
Enthalpy
Enthalpy
h (kcal/kg)(DA)
Design Condition
Ambient Temperature 35℃
Relative Humidity 40.%
Operating Condition
With Inlet Air Cooling
Ambient Temperature 15℃
Relative Humidity 100%
Temperature t (°C)
v (m³/kg)(DA)

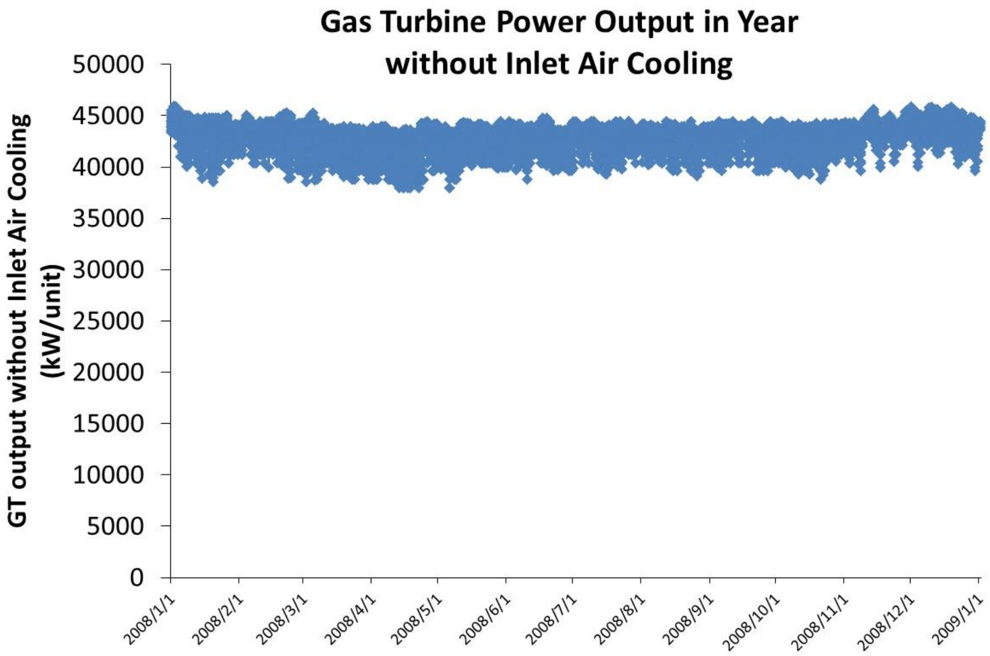
2.7 Merit calculation of Inlet air cooling system

The merits of using an inlet air cooling system are calculated by conducting simulations of a cogeneration system running 24 hours a day, 365 days a year, applying the annual climate conditions to the operating conditions of gas turbines using the formulae in (5.1) to (5.11).

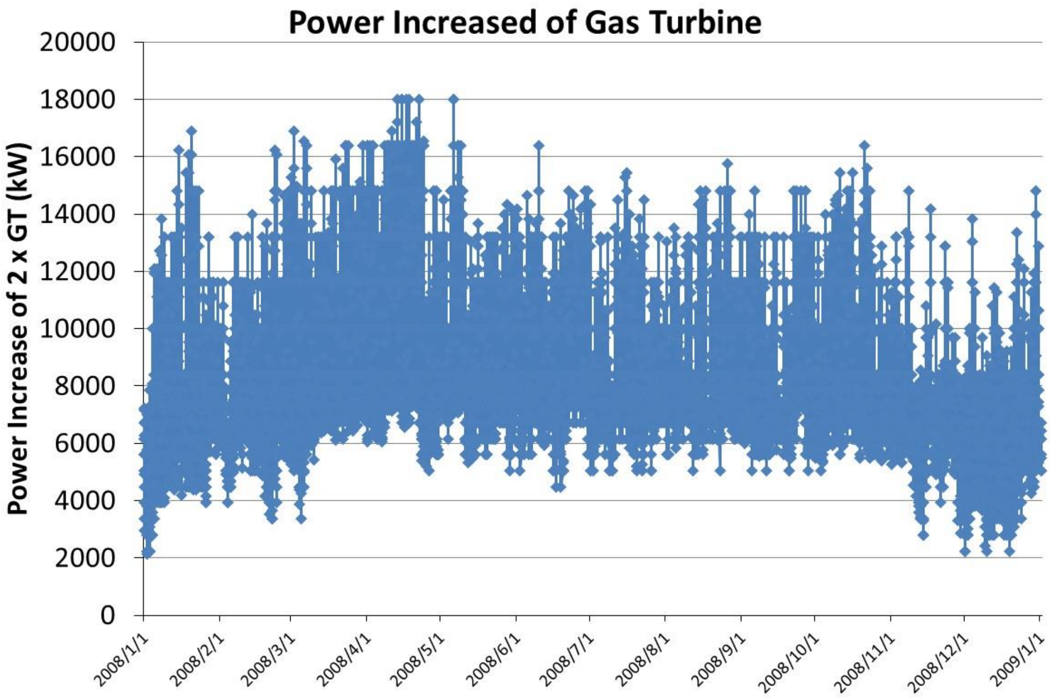
(1) Ambient Temperature



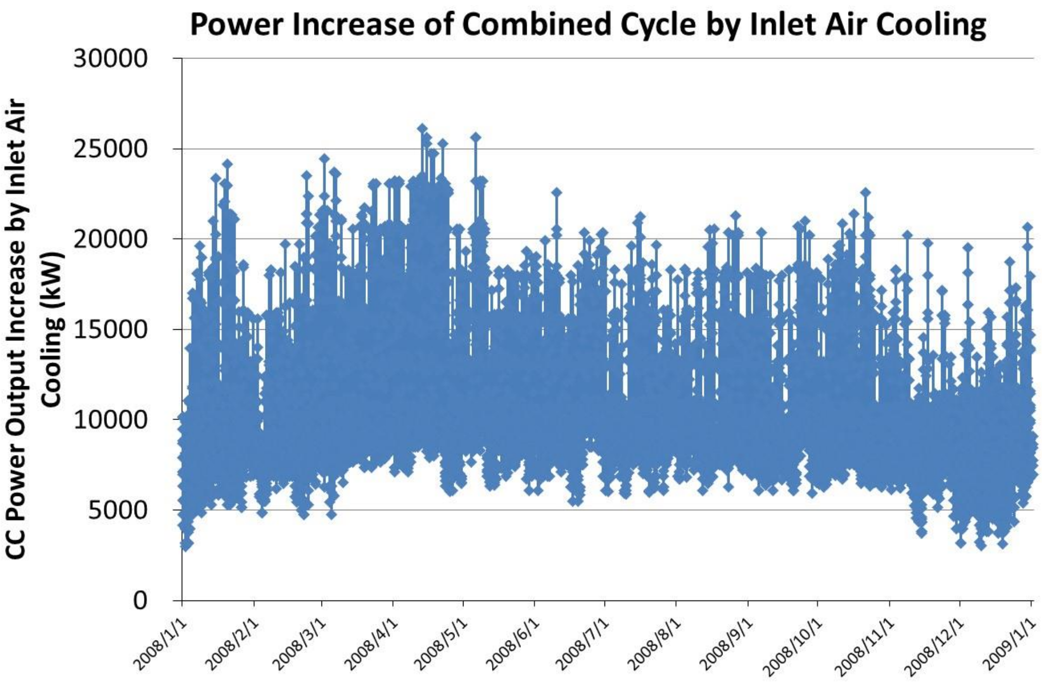
(2) Gas Turbine Output without Inlet Air Cooling System



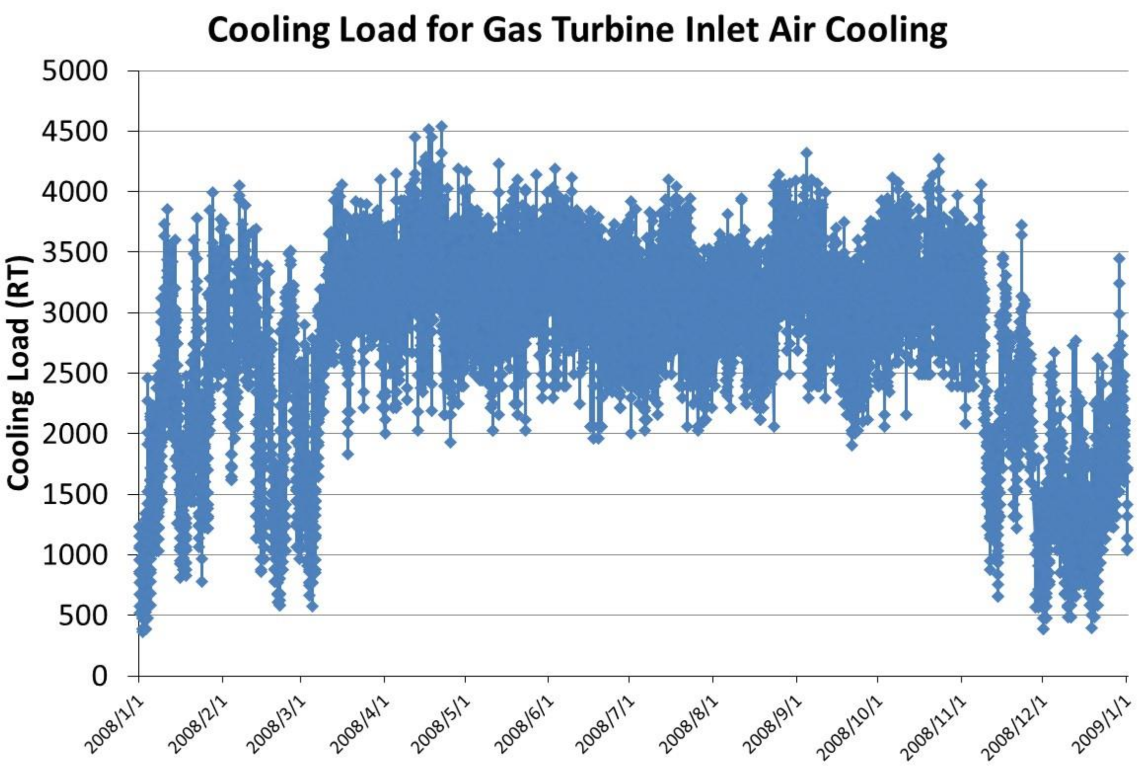
(3) Power Increase of Gas Turbine x 2 by Inlet Air Cooling System



(4) Combined Cycle power increase by Inlet Air Cooling



(5) Cooling Load by Inlet Air Cooling



[Merit of Gas Turbine Inlet Air Cooling System]

Based on the yearly combined system calculation, the merit of Gas Turbine Inlet Air Cooling System will be as follows.

Annual sales volume from the grid and annual generated amount before and after the application of the gas turbine inlet air cooling system.

Item	Before application	After application
GTCC annual generated power	979,872 MWh/year	1,070,316 MWh/year
Sales from grid	90,444 MWh/year	0 MWh/year
GTCC CO_2 emissions	396,611 tons- CO_2/year	423,417 tons- CO_2/year
Grid CO_2 emissions	54,176 tons- CO_2/year	0 tons- CO_2/year

Year Cost Merit of GT Inlet Air Cooling 117,110,352 Bhat/Year
CO_2 Reduction 27,370 ton- CO_2/Year

Chiller System Capacity 4,000RT
Chiller Budgetary Cost 1,500US$/RT
Total Cost 6 mill-US$

Currency 32.57Bhat/US$

Chiller System	4000RT
Budgetary Cost for IACS	1500US$/RT
	US$6,000,000
	195,420,000Bhat
Investment Recovery	1.67Year

・Chapter 6　Drawing up of MRV Methodology (draft) and PDD (draft)

6.1 MRV Methodology (draft)

(1) Title of Methodology

"Application of Inlet Air Cooling System to Cogeneration Plant at IPP and SPP"

(2) Definition of Terms

Term	Definition
Gas Turbine Combined Power Generation System	A power generation system designed to efficiently generate power by driving steam turbines using the exhaust heat after power is generated by gas turbines.
Inlet Air Cooling System	In a gas turbine power generation system, this is designed to increase power generation by increasing the intake air volume through cooling the intake air with a chiller.
Cogeneration Plant	In a power generation plant using fossil fuel, this is designed to generate power and supply heat (hot water,
IPP	Independent Power Producer
SPP	Small Power Producer

(3) Outline of the Methodology

1) GHG reduction means

By adding an inlet air cooling system to the existing gas turbine combined power generation system, its power generation will be increased. As the carbon dioxide trip generation rate of a gas turbine combined power generation system is greatly improved compared to that of the utility grid in general, the carbon dioxide generation amount will be reduced by replacing the electricity power from the utility grid with the amount of power generation increased by the inlet air cooling system.

In addition, the carbon dioxide emissions will also be reduced, as the generation efficiency of the gas turbine combined power generation system is improved and the fuel consumption is reduced by decreasing the intake air temperature in the inlet air cooling system.

2) Calculation method of baseline emission

- The baseline emission is defined as the carbon dioxide emissions caused by the fuel used for power generation at a target gas turbine combined power generation system.

3) Basic concept of the project emission

- The project emission is defined as the amount obtained by subtracting the carbon dioxide generation amount reduced at the utility grid side when the increased amount of power generation through an inlet air cooling system is supplied to the utility grid, from the carbon dioxide emission when the inlet air cooling system is added to the target gas turbine combined power generation system.
- The increased amount of power generation through an inlet air cooling system is defined as the net increased amount of power generation that is obtained by

subtracting the consumed power (such as the power for driving chillers) under the project scenario from the actually increased amount of power generation.

4) The referenced MRV methodology

J-MRV	The Guideline for Measurement, Reporting, Verification of the Reduction Amount of Greenhouse Gas Emission in the Global Environmental Conservation Business of the Japan Bank for International Cooperation

(4) Requirements for Qualification

This methodology is applicable to a project satisfying all of the following requirements.

Requirement 1: The target power generation system shall be an SPP or IPP gas turbine combined cycle power generation system installed in Thailand.

Requirement 2: The target system shall be a gas turbine power generation system with an inlet air cooling system.

Requirement 3: The target system shall be capable of selling the electricity, increased by the added inlet air cooling system, to the utility grid or demanders in the vicinity.

(5) Emission Source and GHG Type

1) Baseline emission

Emission Source	Type of GHG
The emission caused by fuels consumed for power generation at a gas turbine combined power generation system	CO_2

2) Project emission

Emission Source	Type of GHG
The emission that is obtained by subtracting the emission from the increased power under a project activity assumed to be generated in the country using an average means, from the emission caused by the fuels consumed for power generation in the gas turbine combined cycle power generation system added with an inlet air cooling system in the project activity.	CO_2

(6) Setting and Calculation of the Baseline Emission

The baseline emission can be calculated as follows:

$$BE_y = BE_{FUEL,COM\,y} \quad (6.\ 1.\ 1\text{−}1)$$

where, $BE_{FUEL,COM\ y}$ can be calculated as follows:

$$BE_{FUEL,COM\ y} = EG_{B\,y} \text{ x } FE_{EL\ COM\ B} \quad (6.\ 1.\ 1\text{−}2)$$

$$EG_{B\,y} = EG_{GT\,B\,y} + EG_{ST\,B\,y} \quad (6.\ 1.\ 1\text{−}3)$$

$$EG_{GT\,B\,y} = \underset{m\quad d\quad h}{\text{©©©}} EG_{GT\,B}\ (T(m,d,h)) \quad (6.\ 1.\ 1\text{−}4)$$

$$EG_{ST\,B\,y} = \underset{m\quad d\quad h}{\text{©□□}} EG_{ST\,B}\ (EG_{GT}(T(m,d,h)) \quad (6.\ 1.\ 1\text{−}5)$$

Parameter	SI Unit	Description
BE_y	tCO_2/yr	The baseline emission in the year y
$BE_{FUEL,COM\ y}$	tCO_2/yr	CO_2 emission caused by the fuels used for power generation in the gas turbine combined power generation system for the baseline in the year y
$EG_{□□y}$	MWh/yr	The annual amount of power generation in the gas turbine combined power generation system for the
$EG_{GT\,B\ y}$	MWh/yr	The annual amount of power generation by gas turbines for the baseline
$EG_{ST\,B\ y}$	MWh/yr	The annual amount of power generation by steam turbines for the baseline
$FE_{EL\ COM\ B}$	tCO_2/MWh	CO_2 emission factor of power in the gas turbine combined power generation system for the baseline
$T(m,d,h)$	K	The intake air temperature of a gas turbine

(7) Calculation of the Project Emission

The project emission can be calculated as follows:

$$PE_y = PE_{FUEL\ COM\,y} - PE_{EL,GRID\,y} \quad (6.\ 1.\ 1\text{−}6)$$

where, $PE_{FUEL\ COM\,y}$, $PE_{EL,GRID\,y}$ can be calculated as follows:

$$PE_{FUEL,COM\,y} = EG_{P\,y} \text{ x } FE_{EL\ COM\ P} \quad (6.\ 1.\ 1\text{−}7)$$

$$PE_{EL,GRID\,y} = EG_{INC\,y} \text{ x } FE_{EL\ GRID} \quad (6.\ 1.\ 1\text{−}8)$$

$$EG_{INC\,y} = EG_{P\,y} - EG_{B\,y} - EC_{TURBO} \quad (6.\ 1.\ 1\text{−}9)$$

$$EG_{P\,y} = EG_{GT\,P\,y} + EG_{ST\,P\,y} \qquad (6.\,1.\,1\text{–}10)$$

$$EG_{GT\,P\,y} = \sum_{m}\sum_{d}\sum_{h} EG_{GT\,P}\,(Td) \qquad (6.\,1.\,1\text{–}11)$$

$$EG_{ST\,P\,y} = \sum_{m}\sum_{d}\sum_{h} EG_{ST\,P}\,(EG_{GT\,P}(Td)) \qquad (6.\,1.\,1\text{–}12)$$

Parameter	SI Unit	Description
PE_y	tCO_2/yr	CO_2 emission for the project in the year *y*
$PE_{FUEL\ COM\ y}$	tCO_2/yr	CO_2 emission caused by the fuels consumed at a gas turbine combined power generation system for the project in the year *y*
$PE_{EL,GRID\ y}$	tCO_2/yr	CO_2 emission when the amount of power generated under the project and increased in the
$EG_{INC\ y}$	MWh/yr	The annual amount of power generation that is increasing in the project activity
EC_{TURBO}	MWh/yr	The amount of power consumed by the turbo chiller operating for an inlet air cooling in the project
$FE_{EL\ GRID}$	tCO_2/MWh	CO_2 emission factor of the average power supplied from the utility grid
$EG_{P□□y}$	MWh/yr	The annual amount of power generation by the gas turbine combined power generation system for the project
$EG_{GT\,P\,y}$	MWh/yr	The annual amount of power generation by gas turbines for the project
$EG_{ST\,P\,y}$	MWh/yr	The annual amount of power generation by steam turbines for the project
Td	K	The design temperature for the gas turbine inlet air

(8) Leakage

Leakage shall not be considered unless any noticeable effect is identified.

(9) Calculation of the GHG Emission Reduction Amount

The GHG emission reduction amount can be calculated as follows:

$$ER_y = (BE_y - PE_y) \times ETA_{OPE} \times ETA_{LOAD} \qquad (6.\,1.\,1\text{–}13)$$

Parameter	SI Unit	Description
ER_y	t CO_2 /yr	The estimated CO_2 emission reduction amount in the year *y*
ETA_{OPE}	—	Operation rate of the project system in the year *y*
ETA_{LOAD}	—	Load factor of the project system in the year *y*

(10) Explanation of Data as Fixed Values, Parameters, and Subscripts

For (6) and (7) mentioned above, the data to be fixed in advance and its source, as well as parameters and subscripts are described in the following table.

Parameter & Subscript	SI Unit	Description
x	-	Crediting period
y	-	A certain years (1 to x) during the crediting period
m	-	Month
d	-	Days
h	-	Hours
B	-	Baseline
P	-	Project
T	K	Air inlet temperature
Td	K	Design inlet temperature
EL	-	Electric power
$FUEL$	-	Fuel
COM	-	Combined power generation system
GT	-	Gas turbine
ST	-	Steam turbine
$GRID$	-	Utility grid
INC	-	Increased amount
ETA	-	Ratio
$LOAD$	-	Load
OPE	-	Operation

(11) Data Parameters to be Monitored

For (6) and (7) mentioned above, the data parameters that should be monitored to calculate the GHG emission reduction amount are as follows:

Parameters	SI Unit	Description
$FE_{EL\ GRID}$	tCO_2/MWh	CO_2 emission factor for the average electric power supplied by the grid - Default value (0.599 t- CO_2 /MWh)
$FE_{EL\ COM\ B}$	tCO_2/MWh	CO_2 emission factor for the electric power from the gas turbine combined power generation system for the baseline
$FE_{EL\ COM\ P}$	tCO_2/MWh	CO_2 emission factor for the electric power from the gas turbine combined power generation system for the project

T	K	Gas turbine air inlet temperature - Measurements by a thermometer
$EG_{B\,y}$	MWh/yr	The annual amount of power generation of the gas turbine combined power generation system for the baseline - Calculated back from the annual amount of power generation for the project and the air inlet temperature T
ETA_{OPE}	—	Operation rate of the project system in the year y - Operation record of the power generation system
ETA_{LOAD}	—	Average load factor of the project system in the year y - Operation record of the power generation system
$FE_{EL\,COM\,P}$	tCO_2/MWh	CO_2 emission factor for the electric power from the gas turbine combined power generation system for the project - Deduced from the annual amount of power generation and the fuel consumptions described in the power generation system record

(12) Monitoring Plan and Monitoring Report

CO2 Emission Factor of Fuel (LNG)

Sheet (and Effect Evaluation Sheet)

Target Plant Name		Unit	Parameter	Source, etc.
Ⅰ.Effect of Inlet Air Cooling				
1. Calculation Result of Reduction Amount for Emission				
Reduction Amount for Emission		tCO2/yr	$ER_{y,estimated}$	
2. Selected Default Values, etc				
System Operation Rate		–	ETA_{OPE}	
System Load Factor		–	ETA_{LOAD}	
Calorific Value of Fuel (LNG)		TJ/Gg(MJ/kg)		J-MRV Guideline
CO2 Emission Factor of Fuel (LNG)		kgGHG/TJ		J-MRV Guideline
CO2 Emission Factor of Fuel (LNG)		$tCO_2/Nm3$		
Average CO2 Emission Factor of Grid	0.599	tCO_2/MWh	$FE_{EL\ GRID}$	＊1
CO2 Emission Factor of Baseline Power Generation System		tCO_2/MWh	$FE_{EL\ COM\ B}$	
CO2 Emission Factor of Power Generation System for Project Activity		tCO_2/MWh	$FE_{EL\ COM\ P}$	
3. Calculation Result of Baseline Emission				
Baseline Emission		tCO_2/yr	BE_y	
Baseline Annual Power Generation Amount		MWh/yr	$EG_{B\ y}$	
Baseline Generation Efficiency		%		
CO2 Emission Factor for Baseline Power Generation System		tCO_2/MWh	$FE_{EL\ COM\ B}$	
Baseline Fuel Consumption		Nm3		
Calorific Value of Fuel for Baseline (LHV)	38.06	MJ/Nm3		＊1
CO2 Emission Factor of Fuel for Baseline	2.070	$kg\text{-}CO_2/Nm3$		＊1
4. Calculation Result of Emission in Project Activity				
Emission in Project Activity		tCO_2/yr	PE_y	
Emission from Fuel Used for Power Generation in Project Activity		tCO_2/yr	$PE_{FUEL\ COM\ y}$	
Annual Power Generation Amount in Project Activity		MWh/yr	$EG_{P\ y}$	
Generation Efficiency in Project Activity		%		
CO2 Emission Factor of Power Generation System in Project Activity		tCO_2/MWh	$FE_{EL\ COM\ P}$	
Project Fuel Consumption		Nm3/yr		
Calorific Value of Fuel for Project (LHV)	38.06	MJ/Nm3		＊1
CO2 Emission Factor of Fuel for Project	2.070	$kg\text{-}CO_2/Nm3$		＊1
Emission when Increased Power Generation in Project Activity is Supplied from Grid		tCO_2/yr	$PE_{EL,GRID\ y}$	
Annual Power Generation Amount Increased in Project Activity		MWh/yr	$EG_{INC\ y}$	
Average CO2 Emission Factor of Grid	0.599	tCO_2/MWh	$FE_{EL\ GRID}$	＊1

＊1:TGO Report SUMMARY REPORT THE STUDY OF EMISSION FACTOR FOR ELECTRICITY GENERATION OF THAILAND IN YEAR 2010

(Yellow cell) Monitoring Item

6.2 PDD (draft)

Joint Crediting Mechanism Project Design Document Form

Note: This JCM Project Design Document (PDD) is drafted as the result of the GEC's JCM Feasibility Study Programme in JFY2013. Therefore, this draft PDD is not officially approved by any governments involved in JCM, and is subject to change in the future.

A. Description of Project

A.1. Name of Project

Application of Inlet Air Cooling System to Gas Turbine Cogeneration Plant at IPPs, SPPs

A.2. Outline of Project and Applicable Technology and/or Actions

The purpose of the proposed JCM project is, for a cogeneration plant in Thailand and a local cooling plant at the Thai international airport, to improve energy efficiency by introducing an inlet air cooling system for gas turbines and a highly efficient turbo chiller, and to reduce energy-derived carbon dioxide emissions.

Specifically, the effect and feasibility of the following two types of systems are examined.

(1) With SPPs and IPPs as the target in Thailand, an inlet air cooling system will be added to the gas turbines to increase power output of the combined power generation system and improve generation efficiency, as well as to reduce carbon dioxide emissions through power supply with less CO2 trip generation rate to the utility grid.

(2) With the local cooling plant at the Suwannaphum Suvarnabhumi International Airport as the target of a typical cogeneration plant, the existing absorption chiller will be replaced by a turbo chiller to increase the amount of power generation using the surplus steam, and electricity with less CO2 trip generation rate will be supplied to the grid to reduce carbon dioxide emissions.

A.3. Implementation Location of the Project (incl. longitude and latitude)

Country	Thailand
State or Province	Suwannaphum Suvarnabhumi, Bangkok
Longitude and Latitude	Long. 100 deg. and 34 min. east, Lat. 13 deg. and 44 min. north

A.4. Participants in the Project

Thailand	To be decided
Japan	Research Institute of Global Environmental Strategies, Mitsubishi Heavy Industries, Ltd.

A5 Duration of the Project

Starting of Project	To be decided
Estimated duration of the project	10 years

A6 Contribution from Advanced Countries

In this project, Japan will provide advanced technologies for high-efficient power generation and chiller system. In addition, know-how on application and operation technologies for efficiency improvement of the similar systems will also be taken over.

B. Application of Approved Methodology

B.1. Selection of Methodology

Applicable Methodology	JCM-JP-**-***
Version number	Ver. **

B.2. Explanation on How the Project will Satisfy Qualification Requirements of the Approved Methodology

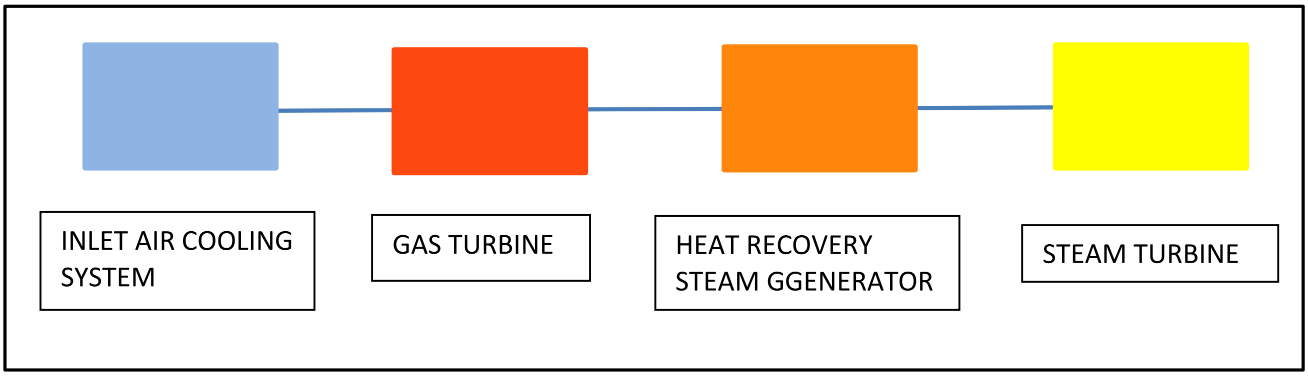
Qualification Criteria	Explanation of the Methodology	Project Information
Criterion 1	The target power generation system shall be an SPP or IPP gas turbine combined cycle power generation system in Thailand.	In Thailand, Thai companies have been developing many SPP businesses in partnership with overseas companies, and thus there are many candidate systems.
Criterion 2	The target system shall be applicable for an inlet air cooling system added to the gas turbine power generation system.	Many of SPP business operators have adopted a gas turbine plant that is applicable for inlet air cooling.
Criterion 3	The target system shall be capable of selling the increased electricity, which is obtained from the added inlet air cooling system, to the utility grid or to the demanders in the vicinity.	The inlet air cooling system is a proven and established technology in Japan.

C. Calculation of the Emission Reduction Amount

C.1. All Emission Sources and Relevant Greenhouse Gases Relating to the Project
All emission sources of greenhouse gases relating to the JCM project

Current Emission	
Emission Source	Greenhouse Gas
Fuel for power generation	CO_2
Project Emission	
Emission Source	Greenhouse Gas
Fuel for power generation	CO_2

C.2. Chart of All Emission Sources and Monitoring Points Relating to the Project



C.3. Estimated Amount of

Emission Reduction in Each Year (for each target plant)

Year	Current Emissions (tCO_{2e})	Evaluation of Emissions after Project Implementation (tCO_{2e})	Estimated Phenomenon in Emissions (tCO_{2e})
1st Year	410,000	390,000	20,000
2nd Year	410,000	390,000	20,000
3rd Year	410,000	390,000	20,000
4th Year	410,000	390,000	20,000
5th Year	410,000	390,000	20,000

D. Evaluation on Environmental Effects

Legal Request for the Project on Environmental Effect Evaluation	N/A

E. Discussions with Local Stakeholders

E.1.Request from Local Stakeholders

N/A

E.2. Summary and Review of Comments Received

No requests have been received.

F. References

N/A

Reference lists to support descriptions in the PDD, if any.

Monitoring Sheet (and Effect Evaluation Sheet)

Target Plant Name	SPP-A	SPP-B	Unit	Parameter	Source, etc.
I .Effect of Inlet Air Cooling					
1. Calculation Result of Reduction Amount for Emission					
Reduction Amount for Emission	27333.1	39887.2	tCO2/yr	$ER_{y,estimated}$	
2. Selected Default Values, etc.					
System Operation Rate	1.0	1.0	—	ETA_{OPE}	
System Load Factor	1.0	1.0	—	ETA_{LOAD}	
Calorific Value of Fuel (LNG)	38.06	38.06	MJ/Nm3		＊1
Average CO2 Emission Factor of Grid	0.599	0.599	tCO_2/MWh	$FE_{EL\ GRID}$	＊1
3. Calculation Result of Baseline Emission					
Baseline Emission	397,155	415,689	tCO_2/yr	BE_y	
Annual Baseline Power Generation Amount	979,872	1,073,475	MWh/yr	$EG_{B\ y}$	
CO2 Emission Factor of Baseline Power Generation System	0.405	0.387	tCO_2/MWh	$FE_{EL\ COM\ B}$	
Baseline Fuel Consumption	191,862,558	200,815,870	Nm3		
Calorific Value of Fuel for Baseline (LHV)	38.06	38.06	MJ/Nm3		＊1
CO2 Emission Factor of Fuel for Baseline	2.070	2.070	kg-CO_2/Nm3		＊1
4. Calculation Result of Emission in Project Activity					
Emission in Project Activity	369,822	375,802	tCO_2/yr	PE_y	
Emission from Fuel Used for Power Generation in Project Activity	423,998	443,212	tCO_2/yr	$PE_{FUEL\ COM\ y}$	
Annual Generation Amount in Project Activity	1,070,316	1,186,013	MWh/yr	$EG_{P\ y}$	
CO2 Emission Factor of Power Generation System in Project Activity	0.396	0.374	tCO_2/MWh	$FE_{EL\ COM\ P}$	
Project Fuel Consumption	204,830,100	214,112,054	Nm3/yr		
Calorific Value of Fuel for Project (LHV)	38.06	38.06	MJ/Nm3		＊1
CO2 Emission Factor of Fuel for Project	2.070	2.070	kg-CO_2/Nm3		＊1
Emission When Generation Amount Increased in Project Activity is Supplied to Grid	54,176	67,410	tCO_2/yr	$PE_{EL,GRID\ y}$	
Annual Generation Amount Increased in Project Activity	90,444	112,538	MWh/yr	$EG_{INC\ y}$	
Average CO2 Emission Factor of Grid	0.599	0.599	tCO_2/MWh	$FE_{EL\ GRID}$	＊1

＊1:TGO Report SUMMARY REPORT THE STUDY OF EMISSION FACTOR FOR ELECTRICITY GENERATION OF THAILAND IN YEAR 2010

Reference value

Measurement value (Predicted value)

Attachments

PDD Revision History

Version	Year and month date	Contents revised
01.00	March 3, 2015	First Edition

・Chapter 7 Specific Financing, Construction, and Operation Plan, Implementation System, etc. for Project Implementation

Specific financing, construction, and operation plan, implementation system and so on are examined for project implementation.

7.1 Implementation Process of Gas Turbine Inlet Air Cooling system

The project for the SPP gas turbine inlet air cooling system in Thailand is assumed as follows:

(1) Qualification for JCM requirements for SPP business operators of the gas turbine inlet air cooling system

Table-7.1 Considerations on Qualification for SPP Gas Turbine Inlet Air Cooling System

Qualification	Detailed Requirement	Explanation for the Project
Requirement 1	・Qualification of the proposed project and applicability of the JCM methodology to the project shall be easily determined by a "checklist".	An explanation for MRV and PPD is presented in Chapter 8 of this FS.
Data (Parameter)	・Project participants shall be able to understand the data necessary for calculating the amount of emission reduction and absorption of greenhouse gases through the JCM methodology, using a parameter list. ・Default values of the nation and those specific to the sectors shall be provided in advance.	When the gas turbine inlet air cooling system is applied to the SPP power generation system, the following action will allow for evaluation of the effective reduction amount. - Existing power generation system All operation records are made from the central monitoring system. - Added gas turbine inlet air cooling system A monitoring device and an operation recorder will be installed Thailand Greenhouse Gas Management Organization (Public Organization): TGO publishes the CO2 trip generation rate of power generation in Thailand every year.
Calculation	- With a previously prepared spreadsheet, the amount of greenhouse gas emission reduction and absorption can be automatically calculated according to the methodology, by filling in the values corresponding to the parameters.	An explanation for MRV and PPD is presented in Chapter 8 of this FS.

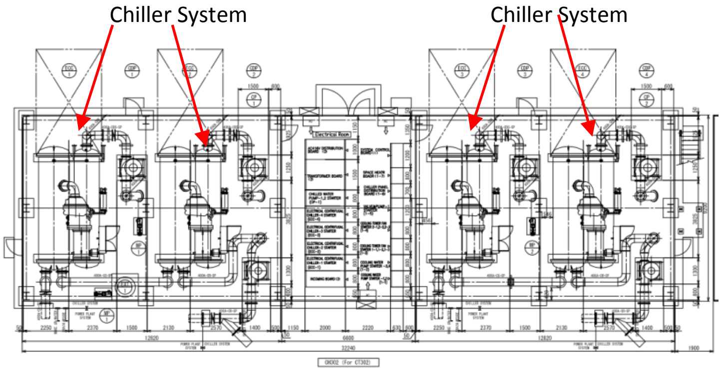
As mentioned above, qualification for the JCM requirements is considered to be satisfied by SPP business operators in applying the gas turbine inlet air cooling system.

(2) For this feasibility study, only two types of gas turbines for SPP power generation operators are available in Thailand, and each of them has an inlet air cooling system with the cooling capacity of 14.1 MW (4,000 RT).

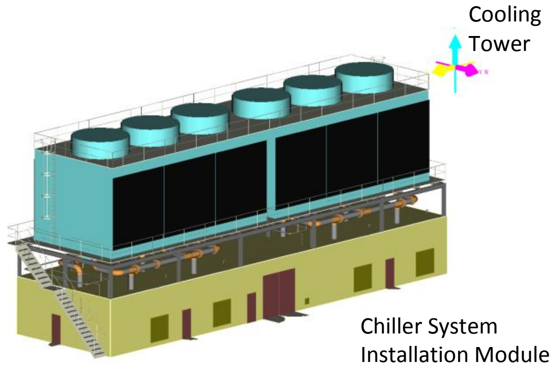
Characteristics of two types of the gas turbines (manufactured by G Company in the U.S and S Company in Germany) have already been analyzed in this feasibility study, and a detailed design can be accomplished for the inlet air cooling system.

Equipment No.	Equipment Name	Desicription		No. of Units
ECC−1,3,5,7	Turbo Chiller	Capacity Chilled Water Flow Rate Chilled Water Temperature Cooling Water Flow Rate Cooling Water Temperature	1000RT x 4 units 432m3/h Inlet 13℃/Outlet 6℃ 710m3/h Inlet 30℃/Outlet 35℃	4
CT−1,4	Cooling Tower	Cooling Water Flow Rate Cooling Water Flow Rate Wet Bulb Temperature	750m3/h 35℃/30℃ 28℃	4
CP−1,4	Chilled Water Pump	Chilled Water Flow Rate Pump Head	432m3/h 40mAq	4
CDP−1,8	Cooling Water Pump	Cooling Water Flow Rate Pump Head	730m3/h 30mAq	4

The gas turbine inlet air cooling system shall be of a modular unit composed of chiller systems, pumps, and a cooling tower.



Arrangement of Chiller Systems in the Gas Turbine Inlet Air Cooling System Module



Gas Turbine Inlet Air Cooling System Module

Fig. 7.1 Outline Image for SPP Gas Turbine Inlet Air Cooling System

(3) Schedule for Inlet Air Cooling System

Generally, a project schedule depends on the delivery time of equipment. The manufacturing schedule of the major equipment is as follows:

Equipment Type	Duration of Manufacturing
Chiller System	6 months
Pump	4 months
Cooling Tower	4 months
Power Substation	6 months

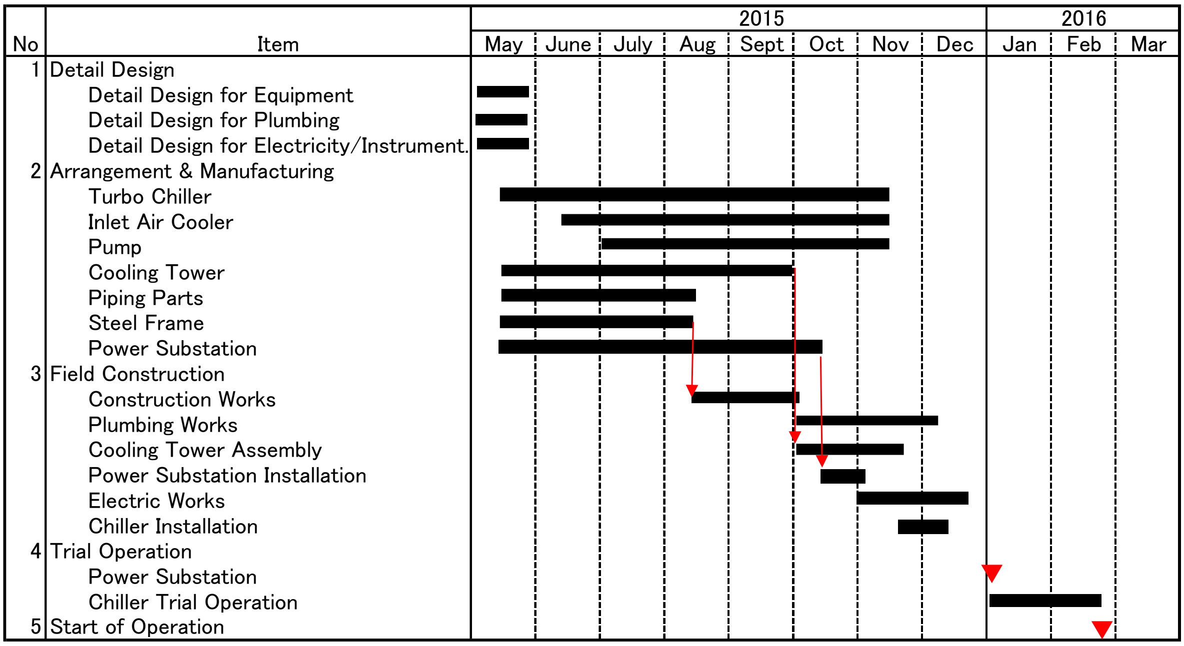
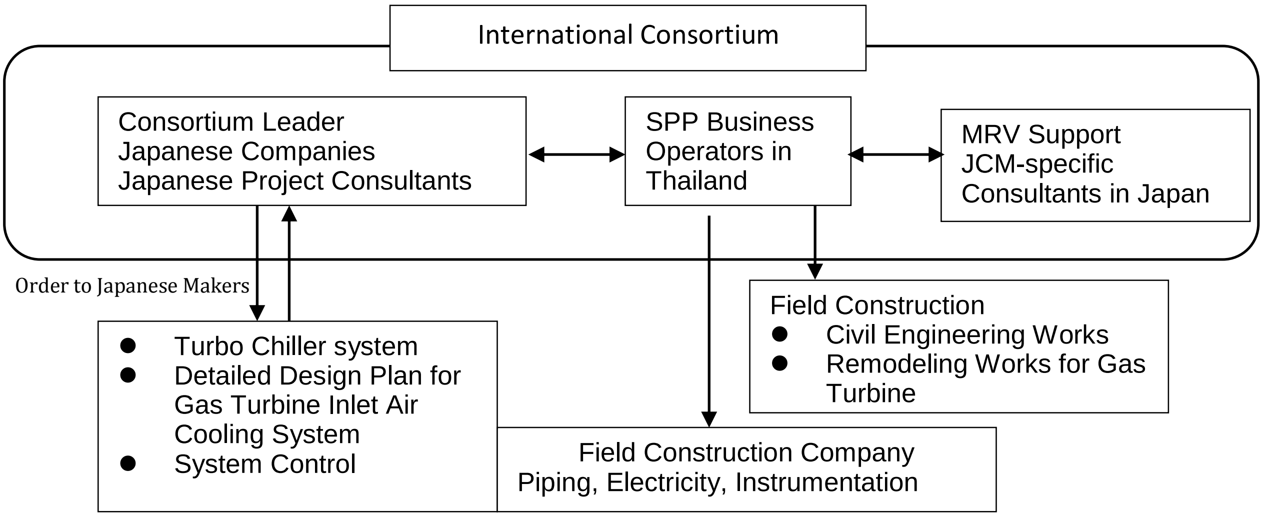


Fig. 7.2 Construction Schedule for SPP Gas Turbine Inlet Air Cooling System

7.2 Implementation System

For the gas turbine inlet air cooling system, the equipment that cannot be procured in Thailand and other ASEAN countries include turbo chiller systems, inlet air cooling systems, and system control systems; however, others can be procured there.

In implementation, the following structure is supposed to be built.



[Considerations on the structure mentioned above]

1) Reliability in the ordering system to Japanese manufacturers for the major equipment.
   such as turbo chiller systems and control systems, as well as ensuring of quality
2) Construction works, etc.
   Ordering to the field construction companies

7.3 Financing Plan

In starting up of the JCM subsidy business, it will be a problem to secure the implementation cost shared by customers, accounting for 50% of the fund. As companies implement their business on the following steps in general, about six months are required to implement the project through the internal approval.

1. Development of a plant/equipment investment plan by the drafting division
↓
2. Application for budget by the drafting division
↓
3. Assessment by the budget investment management division
↓
4. A next-year budget meeting
↓
5. Budget determination (approved by the board of directors)

As SPP business operators need to find the prospect of securing their own funds for 50% so as to roll out a subsidy business using the JCM subsidy at present, it will be important to secure the time and budget for clearing this problem. Business profitability evaluation is shown on the next page.

Simple Calculation for Business Profitability

Fual Gas cost	320 TBH/MMBTU
LHV	36400 kJ/Nm3
	11.0 TBH/Nm3

Peak time electricity price	2.95 Bht/kWh
Off Peak time electricity price	2.95 Bht/kWh

Peak Time	09.00 AM to 10.00 PM.
Off Peak Time	10.00 PM to 09.00 AM

Yearly Power Sales Increase	90,444,442 kWh/Year
Grid Co2 emission Factor	0.599 kg/kWh
SPP Co2 emission Factor	0.368 kg/kWh
Yearly CO2 Reduction	20,893 ton-CO2/Year

Inlet Air Cooling System	4000 RT
Budgetary Cost	1500 US$/RT
Project Cost without JCM	US$6,000,000
	195,420,000 Bhat
Project Cost with JCM	97,710,000 Bhat
Investment Recovery with JCM	0.83 Year

Yearly Power Sales Increase	266,811,104 Bhat/Year
Fuel Cost Increase	149,700,752 Bhat/Year
Power Sales Income Increase	117,110,352 Bhat/Year

Cerrency	119.5 Yen/US$
	3.69 Yean/Baht
	32.57 Bhat/US$

The profitability, in case of subsidy use this project, it is shown as follows.

Years since completion

Depreciation Cost Duration 5 years/Straight-line method/Terminal value 10%

Baht

Year	0	1	2	3	4	5	Total
Actual Investment	97,710,000						
subvention	97,710,000						
Investment	195,420,000						
Operation Cost of GT Inlet Air Cooling							
Fuel Cost		149,700,752	149,700,752	149,700,752	149,700,752	149,700,752	748,503,762
Maintenance		3,252,033	3,252,033	3,252,033	3,252,033	3,252,033	16,260,163
Depreciation		17,587,800	17,587,800	17,587,800	17,587,800	17,587,800	87,939,000
Cost Increase		170,540,585	170,540,585	170,540,585	170,540,585	170,540,585	852,702,925
Income							
Power Sales Increase		266,811,104	266,811,104	266,811,104	266,811,104	266,811,104	1,334,055,521
Yearly Profit		96,270,519	96,270,519	96,270,519	96,270,519	96,270,519	481,352,596

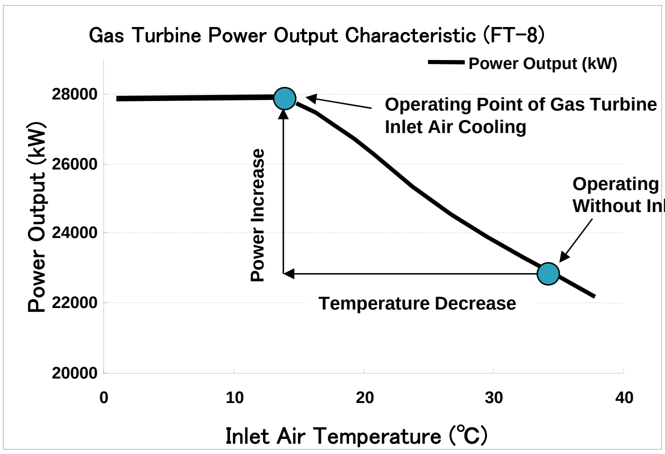
(Note) Actual effect is necessary continuous evaluation based on actual operating condition.

Feasibility Study Report
of
Inlet Air Cooling System Study
for
SPP Power Plant

Mechanism of Gas Turbine Inlet Air Cooling System

Gas Turbine Power Output will be determined by Inlet Air Temperature.

If inlet air temperature rise ,Gas Turbine Power Output will decrease



Gas Turbine Inlet Air System

Cool down inlet air temperature by chiller

Power Output Increase

By Gas Turbine Characteristic

Merit of Gas Inlet Air Cooling System

Merit of Inlet Air Cooling System (Technical)

Gas Turbine Type	Power Output At 35℃	Power Output At 15℃	Power Increase
LM 6000	36.6MW	42MW	5.4MW
GT-800	39MW	47MW	8MW

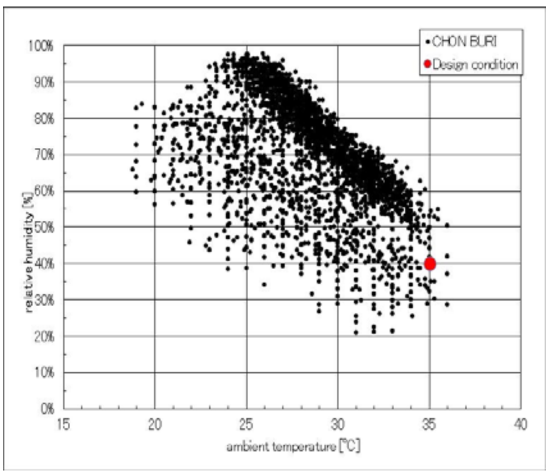
- Steam Turbine Output also increased proportion to GT output
- Heat Rate is also improved by 3.7% - 4.0%

Merit of Inlet Air Cooling System (Commercial)

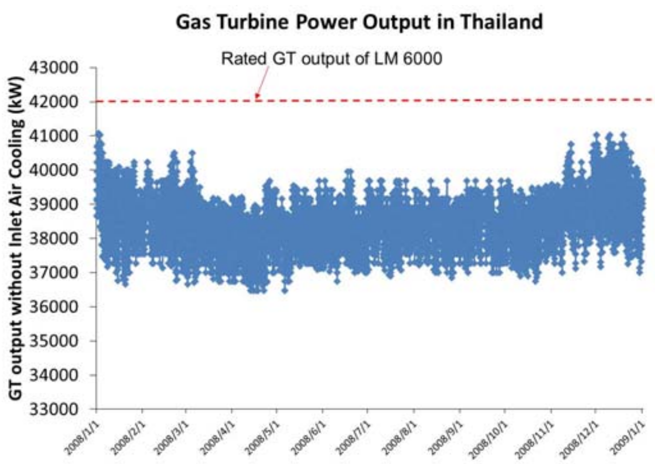
- Construction and Start up will be within 1 Year
- Inlet Air Cooling Investment rate may be half of power plant.

Climate Condition and Gas Turbine Output

The climate condition in Thailand is high temperature and performance and power generation of Gas Turbine combined cycle power plant are affected by the climate.



Yearly ambient temperature and humidity

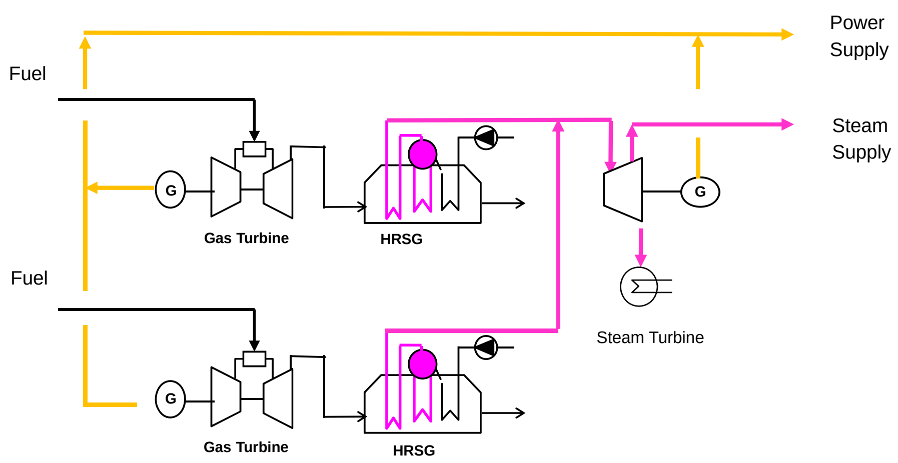


Gas Turbine power generation

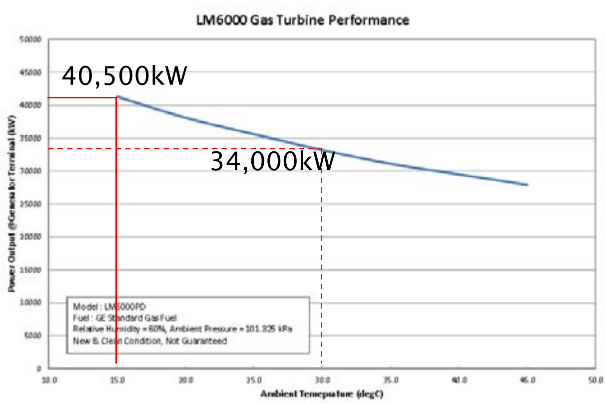
Gas turbine in Thailand can not achieve the rated output by high temperature.

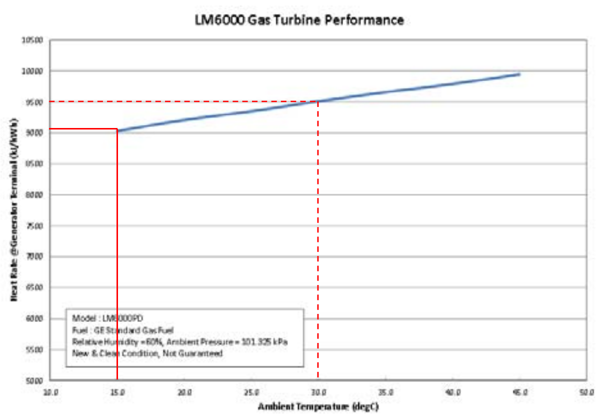
SPP in Thai Land

There are many SPP using LM6000 & GT-800 in Thailand which capacity is 110MW.



LM6000 Performance Characteristic





6500kW /GT power increase can be expected. (40,500kW – 34,000kW)

19% Power Increase

Power Generation

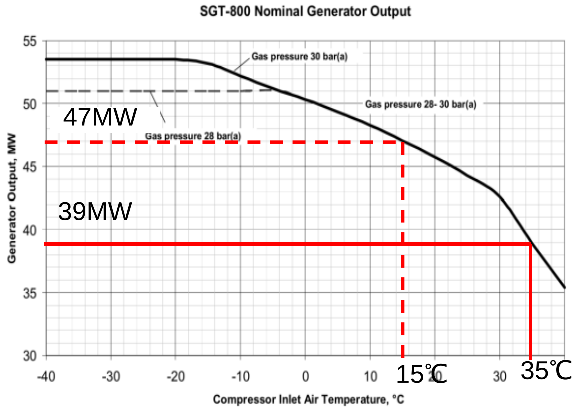
Heat Rate at 30℃ 9,500kJ/kWh

Heat Rate at 15℃ 9,050kJ/kW

4.5% Efficiency Increase

Heat Rate

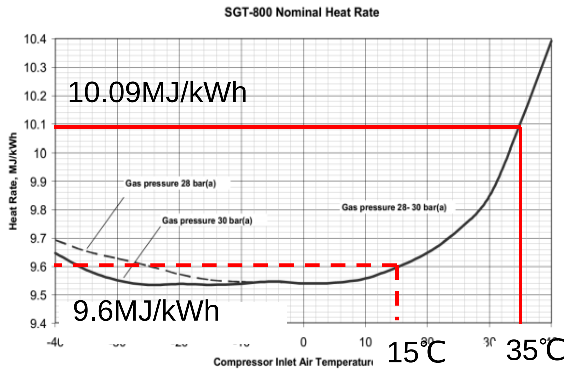
GT-800 Performance Characteristic



8000kW /GT power increase can be expected

20% Increase

Power Generation



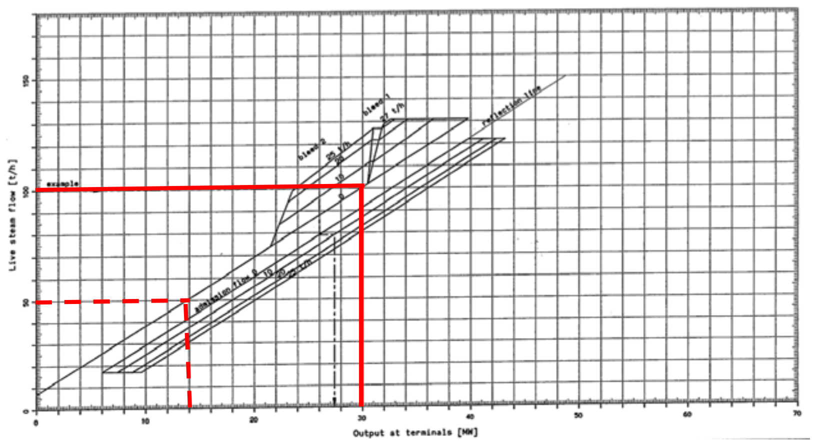
Heat rate will be improved

from 10.09MJ/kW to 9.6MJ/kW (around 4.8%)

Heat Rate

Steam Turbine Characteristic (GT-800)

HRSG Steam (LP)		
a. Temperature	245.9	degC
b. Pressure	8.97	bara
c. Steam Flow	11.88	Ton/h
HRSG Steam (HP)		
d. Temperature	514.2	degC
e. Pressure	79.30	bara
f. Steam Flow	64.56	Ton/h

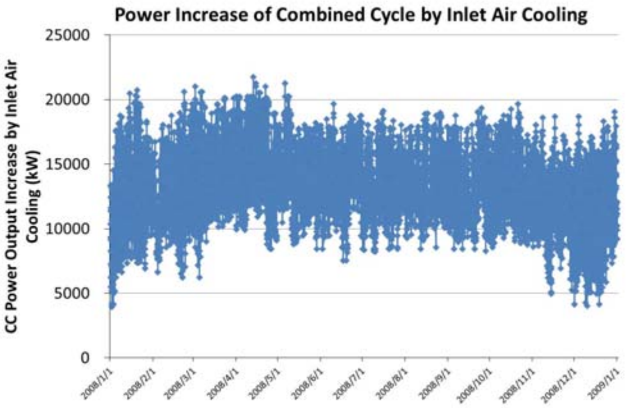


Steam turbine output 14MW at steam flow 50t/h

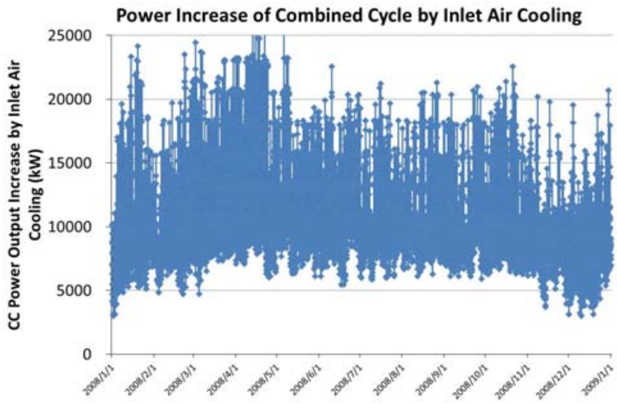
Steam turbine output 30MW at Steam flow 100t/h

Yearly Power Increase

The power generation increase of combined cycle power plant were calculated based on the ambient temperature data of Thailand.



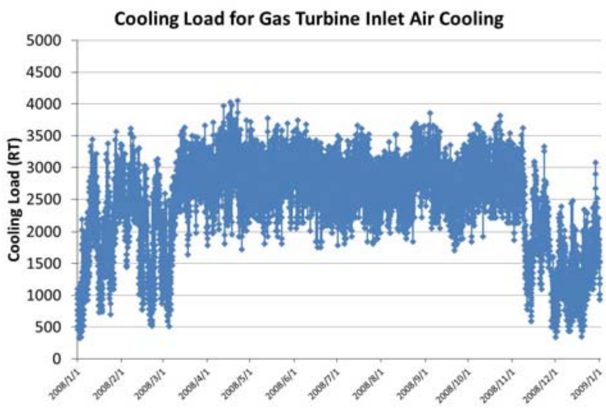
LM 6000



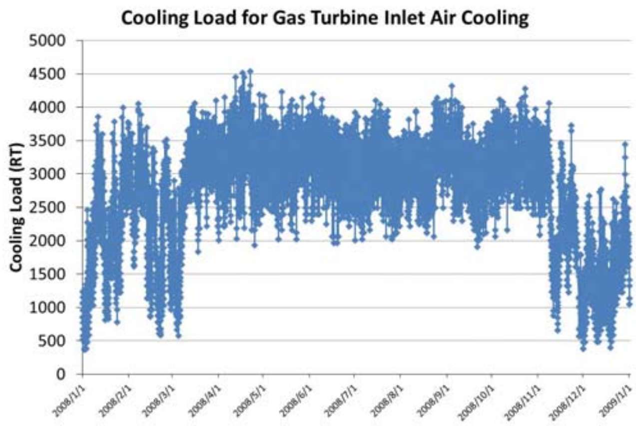
GT-800

Cooling Load for GT x 2 + ST x 1 combined cycle

The cooling load of inlet air cooling system is calculated.



LM 6000



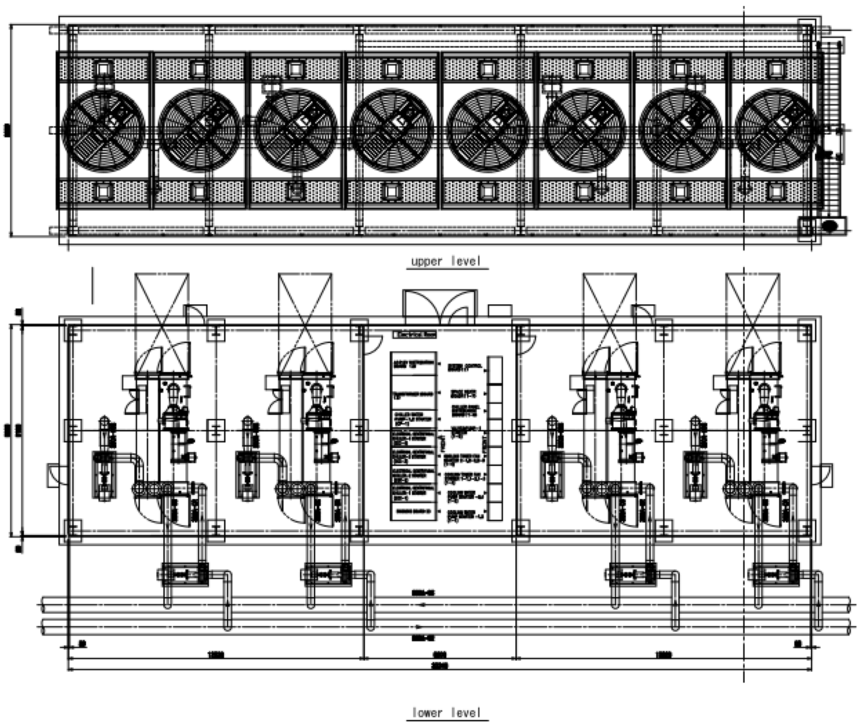
GT-800

The chiller capacity of each gas turbine type can be 4000RT .

Chiller for Gas Turbine Inlet Air Cooling System

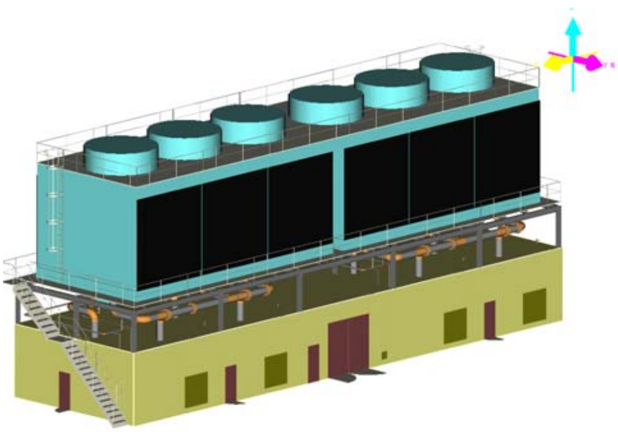
Cooling tower Level

Chiller Level

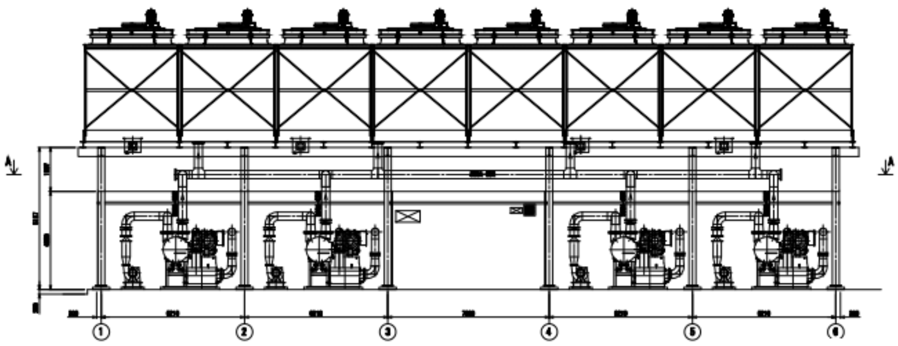


Size 32m x Width 9.2m x 10mH

Chiller for Gas Turbine Inlet Air Cooling System

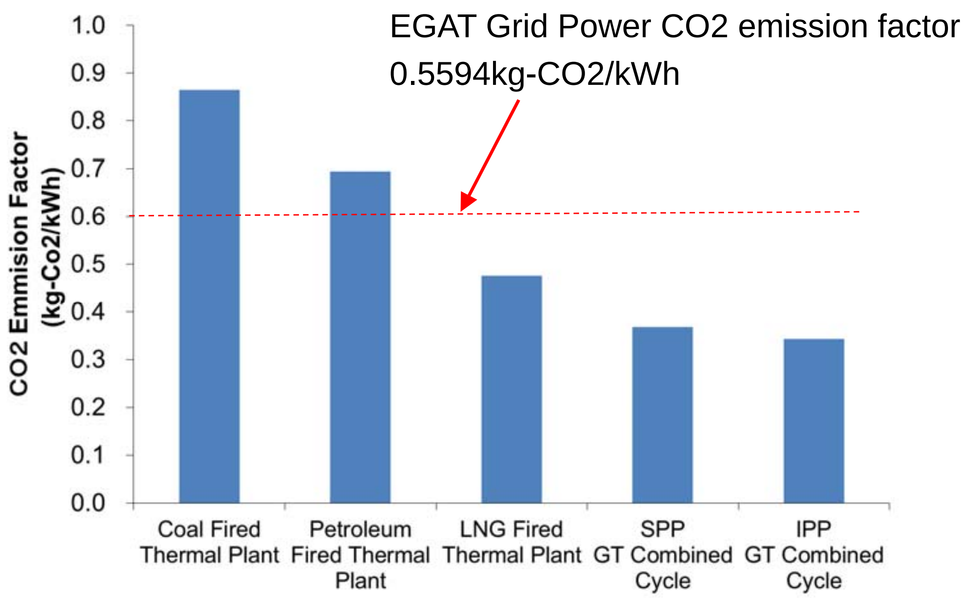


Inlet Air Cooling System 3D Image



Effectiveness of CO2 Reduction for GT inlet air cooling for SPP

CO2 reduction by low CO2 emission power increase of SPP.



CO2 emission of power generation

Effectiveness of CO2 Reduction for GT inlet air cooling in SPP

System	Power Sales Increase	CO2 Reduction
LM 6000 GT x 2 + ST x 1 Combined Cycle	112,538,090 kWh/Year	39,922 ton-CO2/ Year
GT-800 GT x 2 +ST x 1 Combined Cycle	90,444,442 kWh/Year	27,370ton-CO2/Year

Investment and Profit Analysis of
GT Inlet Air Cooling System (GT-800 Case)

Fual Gas	320 TBH/MMBTU
LHV	36400 kJ/Nm3
	11.0 TBH/Nm3

Peak time electricity price	2.95 Bht/kWh
Off Peak time electricity price	2.95 Bht/kWh

Peak Time	09.00 AM to 10.00 PM.
Off Peak Time	10.00 PM to 09.00 AM

Yearly Power Sales Increase	90,444,442 kWh/Year
Grid Co2 emission Factor	0.599 kg/kWh
SPP Co2 emission Factor	0.368 kg/kWh
Yearly CO2 Reduction	20,893 ton-CO2/Year

Inlet Air Cooling System	4000 RT
Budgetary Cost	1500 US$/RT
Project Cost without JCM	US$6,000,000
	195,420,000 Bhat
Project Cost with JCM	97,710,000 Bhat
Investment Recovery with JCM	0.83 Year

Yearly Power Sales Increase	266,811,104 Bhat/Year
Fuel Cost Increase	149,700,752 Bhat/Year
Power Sales Income Increase	117,110,352 Bhat/Year

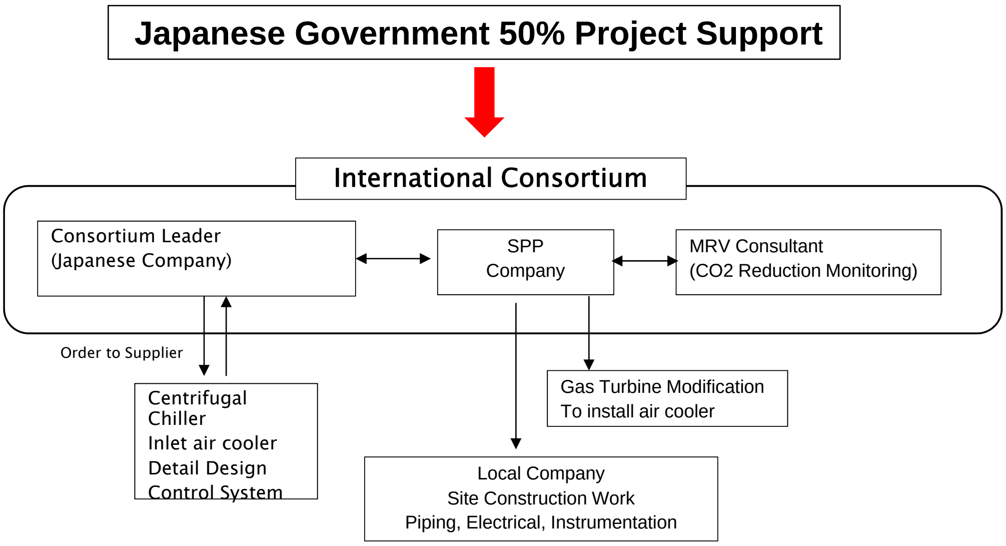
- Investment Recovery will be 0.83 year with JCM Support

Operation of
GT Inlet Air Cooling System (GT-800 Case)

Baht

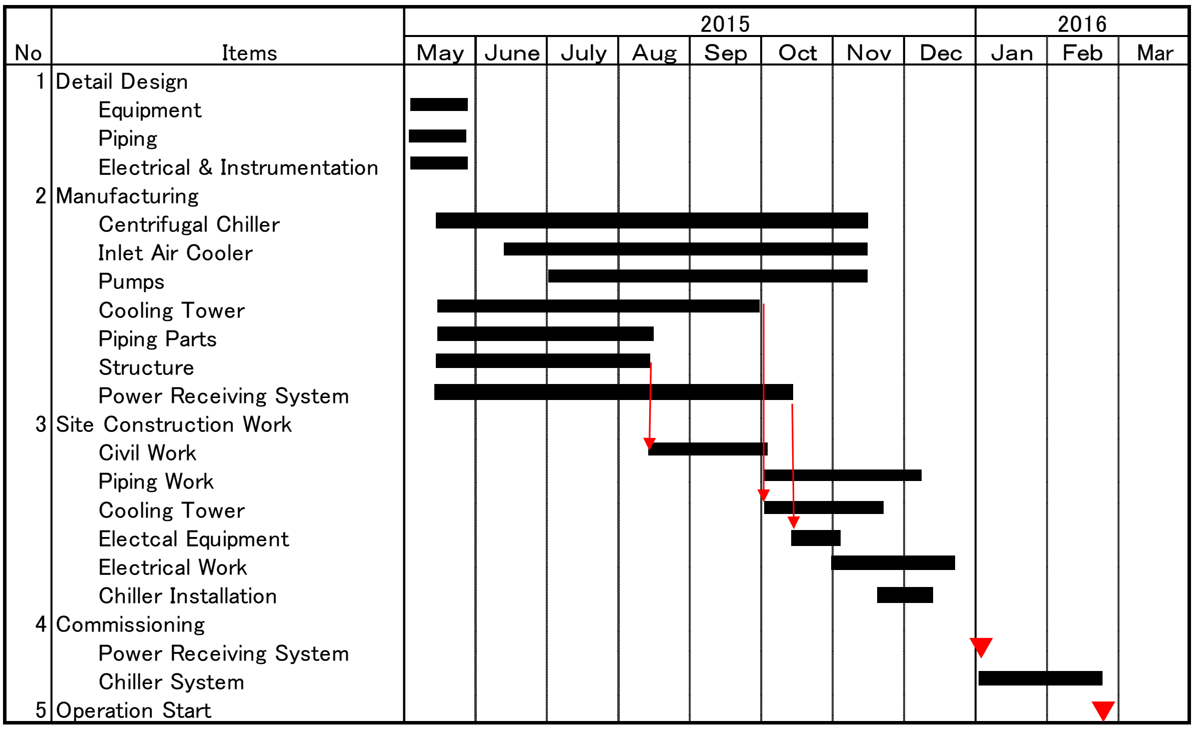
Year	0	1	2	3	4	5	Total
Investment	97,710,000						
Operation Cost of GT Inlet Air Cooling							
Fuel Cost		149,700,752	149,700,752	149,700,752	149,700,752	149,700,752	748,503,762
Maintenance		3,252,033	3,252,033	3,252,033	3,252,033	3,252,033	16,260,163
Depreciation		17,587,800	17,587,800	17,587,800	17,587,800	17,587,800	87,939,000
Cost Increase		170,540,585	170,540,585	170,540,585	170,540,585	170,540,585	852,702,925
Income							
Power Sales Increase		266,811,104	266,811,104	266,811,104	266,811,104	266,811,104	1,334,055,521
Yearly Profit		96,270,519	96,270,519	96,270,519	96,270,519	96,270,519	481,352,596

Organization for project execution

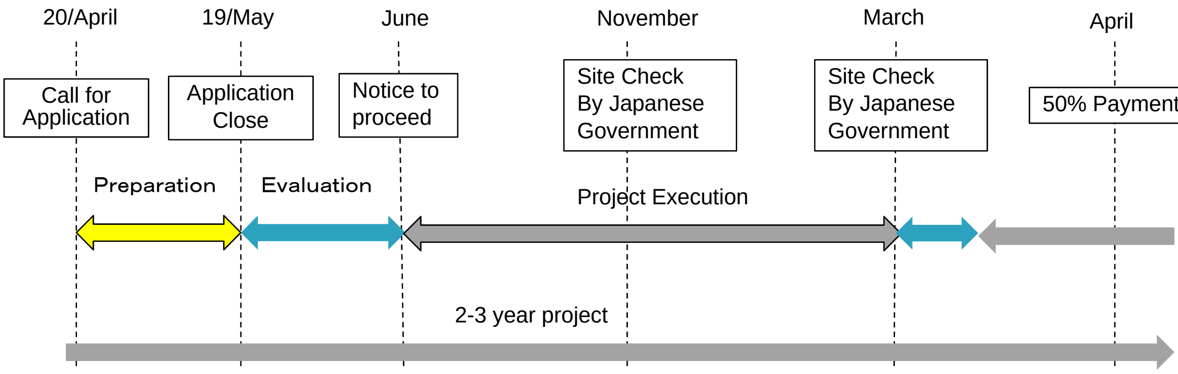


Project Schedule to much the fiscal year

Construction will be completed within year.



Expected Schedule of JCM application

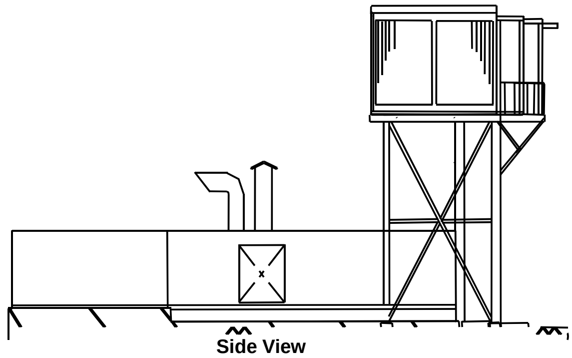


MRV (Measurement , Reporting and Verification)

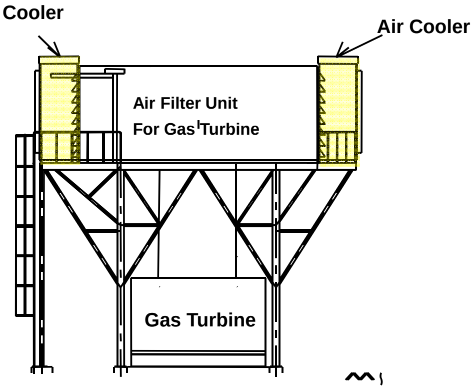
- **CO2 Reduction report must be submitted to Japanese Government**
- **Japanese company (MHI) will handle to submit the report.**

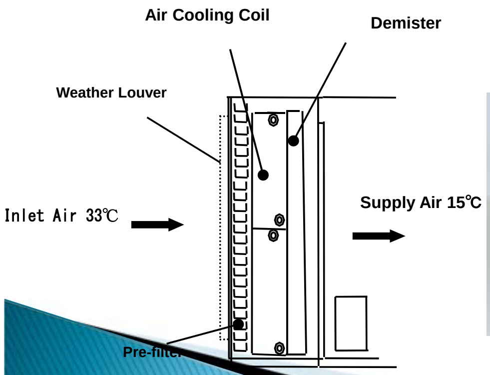
Installation of Air Cooler

How to Install Air Cooler



Side View





Demister

Chiller Module