**MRV Demonstration Study (DS) using a Model Project 2012 Final Report**

### 「Waste Heat Recovery System with Cogeneration」
*(implemented by Smart Energy Co., Ltd.)*

<table>
<thead>
<tr>
<th>Study Partners</th>
<th>District Cooling System and Power Plant Co., Ltd. (DCAP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location Project/Activity</td>
<td>Bangkok, Thailand</td>
</tr>
<tr>
<td>Category Project/Activity</td>
<td>Waste Heat Utilization</td>
</tr>
<tr>
<td>Description Project/Activity</td>
<td>DCAP plant is providing electricity, chilled water to Bangkok Suvarnabhumi International Airport and its adjacent facilities by utilizing waste heat from gas turbine and steam absorption chillers to reduce CO2 emissions. The plant generates an electricity from gas-turbine and high-temperature waste heat from gas turbine utilized to steam turbine for generating an electricity. Residual steam used to generate chilled water with absorption chillers.</td>
</tr>
</tbody>
</table>

### Eligibility Criteria

1. This methodology is applicable for the project using waste heat, discharge to the atmosphere following its primary usage in absence of the project activity. (Common to all calculation methods)
2. Electric chillers replaced with this project shall be without malfunction. After the project implementation the electric chillers are either to be disposed, used for chilled water’s demand control and or used for back-up purposes. (Renovation project with calculation method 1, 2, 3 & 4)
3. Absorption shall use steam and has a better performance than double-effect. (Common to all calculation methods)
4. Heat source shall use either gas-turbine or gas-engine. (Common to all calculation methods)
5. If the project uses ex-ante chiller’s operational record to derive PCF, the record shall be furnished longer than 3 months. (Renovation project with methods 1 & 2)
6. The project shall identify rated electricity consumption of gas turbine and/or waste heat recovery steam turbine. (Renovation project with method 2 & 4)
7. The project shall continuously record and monitor production amount of chilled water, and chilled water’s inlet/outlet temperature. (Common to all calculation methods)
8. Project’s emission factor for electricity shall be smaller than grid electricity’s emission factor. (Renovation project with all methods)
9. Project’s emission factors for heat and electricity shall be smaller than grid electricity’s emission factor. (Greenfield project)
10. Absorption chiller shall be inspected periodically by vendor or equivalent. (Common to all methods)

### Reference Scenario and Project/Activity Boundary

Reference scenario for renovation project is to supply chilled water with an electric chillers powered by grid-electricity. For green-field project an electric-chillers powered by gas-turbine/gas-engine to supply electricity and chilled water. Project’s boundary includes gas-turbine, waste-heat recovery steam turbine and chillers but excludes demand side cooling facilities.

### Calculation Method Options

Calculation method should be chosen by either the project is greenfield or renovation project. For renovation project, the option split by either the project has a historical operation record of electric chiller, and further split whether direct measurement of replaced equipments would be performed.
Greenfield project does not have any option. In total, 5 calculation options are available.

### Default Values set in Methodology

For renovation project without data of rated capacity of electric chillers, PCF shall be determined as 0.504kWh/USRT or COP 7.00 as a default value. The value is 20% higher than the Ministry of Energy of Thailand’s minimum COP standard in 2009, 0.620kWh/USRT. The value is also 7% higher than the representing value of an actual installation in/around 2010 by considering project’s additionality to BAU cases. For green-field project, a default value of system efficiency is set at 5 1.9% which are derived from Thailand’s Small Power Producer’s average energy efficiency in cogeneration facility including chilled water production.

### Monitoring Method

Continuous hourly monitoring is performed for key parameters which includes, production amount of chilled water, average temperature of inlet and outlet of chilled water. Amount of power generation, amount of electricity sold to the grid, amount of gas consumption are measured automatically, and then accumulated with monthly basis by DCS. (Common to all calculation options) Amount of electricity consumptions of gas turbine and a waste heat recovery steam turbine shall be recorded monthly and measured value are accumulated monthly.

### Result of Monitoring Activity

The study conducted monitoring for 6 chillers (4 Absorption, 2 Electric) among 17 (11 and 6 respectively) chillers of DCAP. The study made a further analysis on DCAP’s operational record in September 2012 and prepared as a monitoring record for verification by third party. Hourly data is recorded and accumulated monthly basis. Amount of power generation, amount of electricity sold to the grid, and amount of gas consumption are measured automatically and accumulated with monthly basis. Amount of electricity consumption of gas turbine and a waste heat recovery steam turbine are recorded hourly and accumulated monthly basis.

### GHG Emissions and its Reductions

Annual GHG emission amount is estimated to be 371,873tCO2, based on the monitoring data for the 6 chillers. GHG emission reduction amount is 55,886tCO2 with an option 1 of methodology while 47,364tCO2 with an option 4.

### Method and Result of Verification

Bureau Veritas Thailand (BVT) is appointed as a verifier and performed monitoring data verification. Throughout this study, BV commented that BOCM/JCM needs to define its own assurance level and to develop document templates to make verification effectively and efficiently. BOCM/JCM also need s to clarify project’s additionality and eligibility conditions to claim its credit’s legitimacy in contrast to CDM.

### Environmental Impacts

The DCAP facility has been operating as a vital utility supply facility of Suvanmabhum airport since its commission. The facility meets relevant Thailand’s environmental standards in operation. Adjacent land area is left for future expansion of the airport. Taking these things considered, the facility has minimum environmental impacts.

### Promotion of Japanese Technology

Absorption chillers and gas turbine with waste heat recovery facility should be packaged in order to introduce to market. The package could be attractive to utility supplier particularly which locate along side of gas pipeline developed by PTT in/around.

### Sustainable Development in Host Country

To harmonize economic development with emission reductions and energy efficiency is one of the targets in the 5-year national policy of Thailand. This type of project could contribute to reduction of GHG emissions through energy efficient utility supply to the major industrial/commercial buildings which are developed in economic growth in Thailand.
Study Title: MRV Demonstration Study using a Model Project
“Waste Heat Recovery System with Cogeneration”

Study Entity: Smart Energy Co., Ltd.

1. Study Implementation Scheme

   District Cooling System and Power Plant Co., Ltd. (DCAP)
   - Entity using Japanese made machineries and employing Japanese technology
   - Collecting operation data
   A.T. Tri Co., Ltd.
   - Reference Case scenario development
   - Monitoring data collection
   Nippon Koet Co.,
   - Collecting data of Japanese technology and exploring promotion possibilities
   Bureau Veritas Certification Thailand
   - Performing verification and submitting verification report

2. Overview of Project/Activity

(1) Description of Project/Activity Contents:

   There is a large demand of chilled water and cool air throughout the year in Thailand. Industrial facilities, such as shopping mall, hospital, factory and office building, produces chilled water generally with central-controled electric chillers. DCAP established in 2006, as a joint venture of EGAT, PTT and MEA, supplies chilled water, electricity and steam to the Suvarnabhumi International Airport’s terminal buildings and related facilities. DCAP realizes cascade energy use, by generating electricity with a gas turbine and turbine's waste heat utilizes for waste heat recovery steam generation. A residual steam is used for chilled water production by an absorption chiller. The project reduced CO2 emission with two ways. First, to replace carbon-intensive grid electricity to less carbon-intensive waste heat-based electricity. Second, chilled water produced via waste heat utilized absorption chillers instead of electric chillers.

(2) Situations of Host Country:

   GHG emissions in Thailand has been increasing in accordance with a steady economic growth. So far, Thailand has successfully registers 83 CDM projects, but substantial number of projects are failed to reach CDM registration. The country is introducing domestic schemes such as Crown Standard, T-VER and T-VETS to valuate pro-environmental projects including failed CDM project of its environmental performance.

   Thai government actively promotes emission reduction and energy savings. Ministry of Energy is regulating an energy consumption of more than 6,000 designated factories and entities since 1992, and obliges to report their emissions under the scheme. Emission reduction in industrial sector is regarded as an important topic as that of in transportation sector.

   On supply side, Natural gas accounts for 64% of primary energy consumption of the country. PTT, a responsible entity of natural gas supply, promotes natural gas
utilization in Thailand. PTT is constructing gas pipelines in Bangkok and vicinity to realize “Gas City” program. DCAP is also receiving natural gas via PTT pipeline. PTT develops 770 km of gas pipeline to supply natural gas to industrial parks, large scale commercial facilities and shopping malls.

(3) Complementarity of the CDM:

In Thailand, although three CDM project to improve energy efficiency in cement industry facility have been running, no project has been registered under energy efficiency category of facilities in other sectors. This convergence can be considered as a flip-side of the high-standard of operation of facilities in Thailand. DCAP project was also the first large scale utility plant at the time of 2006, and had a difficulty in proving its innovation and advancement in relative manner for registration as CDM project.

The approved UN CDM methodologies, for instance AM0084 and ACM0012, could not comprehensively cover the technology employed by DCAP. As a result, the DCAP project calls for a development of new methodology.

(4) Initial Investment for the Model Project:

DCAP project has started its operation when Suvarnabhumi International Airport opened in 2006. The project costs of similar facilities are unpredictable For the reference, the DCAP project’s initial cost was US$10.28 Mil.

3. Contents of the Study

(1) Issues to be Addressed in the Study:

① Definition of waste heat
Define “waste heat” and coefficient of waste heat.

② Absorption chillers’ market presence
Collect information relating to operating absorption chiller’s performance to strategize absorption chillers presence in Thai market. If an absorption chiller failed to penetrate, identify that reason.

③ Relevance of reference scenario
Identify popular practices of Thailand’s industrial facilities to generate heat, electricity and chilled water. Particularly what kind of heat sources are used instead of grid electricity?

④ Setting of efficiency default parameters of absorption/electric chiller
Examine quantitative threshold (i.e. COP and/or PCF) to prove project’s additionality for the sake of promotion of Japanese products.

⑤ Implication of system efficiency of cogeneration plant
To retain project’s additionality, the project examines an appropriate system efficiency to accelerate Japanese product’s promotion.

⑥ Examine relevance of COP and other parameters relating to efficiency
Try to examine if a specification value of COP is higher than actual operation record and if large scale chiller shows the same manner.

⑦ Monitoring activity of the DCAP
Identify frequency of monitoring of chilled water production and chilled water temperature. The research also compares DCAP and general utility supply plants in
(2) Process to Solve the Issues in the Study:

The demonstration study conducts literature survey and interviewing to chiller manufacturer/users in Thailand. Site survey had conducted 6 times during the period, mainly visit and interview DCAP. In DCAP, the study team confirms the configuration of the equipment, monitoring systems and QA/QC procedures. A.T.Tri, a local partner of Smart Energy, is managing communication between DCAP and conduct reference scenario identification. Nippon Koei K.K. is involving research of Japanese products penetration in Thai-market and also researched marketing strategy of the Japanese products.

1. Definition of waste heat
   Confirmed that approved CDM methodologies did not count emission factors of the waste heat. The Study defined waste heat as “heat primarily used in gas turbine and released to the atmosphere in the absence of the project”.

2. Absorption chillers’ market presence
   Collected information from 19 large industrial faculties, and identified the absorption chiller’s market would be limited to the industrial park along side of the gas pipeline. Also found out that two SPP projects plan to introduce absorption chillers.

3. Relevance of reference scenario
   Information collected from 19 facilities revealed that almost all of the facilities produced chilled water with electric chillers powered by grid electricity. Interviewed to chiller manufacturers, and confirmed that the combination of gas turbine and electric chillers is popular for SPP’s cogeneration projects.

4. Setting of efficiency default parameters of absorption/electric chiller
   As eligibility criteria for BOCM/JCM project, COP at 1.30 has been set for absorption chillers based on Thailand’s energy efficiency standard. COP at 7.0 has been set for electric chiller for calculation of reference emission, considering possible engineering innovation.
   The Study identified that energy efficiency of a standard cogeneration system, catering electricity, chilled water and steam reaches 51.9%.

5. Examination of relevance of COP and other monitoring parameters relating to efficiency
   Analyzed actual performance data of electric chillers in DCAP. identified that those chillers accounted about 90% of COP designed specification described in catalogue.

6. Monitoring activity of the DCAP
   Confirmed that co-generation projects with Japanese-made facilities introduced highly effective monitoring &recording equipments with DCS.

4. Results of MRV Demonstration Study

(1) GHG Emission Reduction Effects by the Implementation of Project/Activity:

DCAP generates steam via waste heat from gas turbine to improve efficiency. Residual steam lead to absorption chillers to generates chilled water. DCAP facility composed from followings;
Gas turbine 42MW x 2 units, IHI
Waste heat steam generator 12MW unit
Absorption chillers 2,100 USRT x 8 units, Hitachi
1,500USRT x 3 units, Ebara
Electric chillers 2,000USRT x 6 units

Emission factor of electricity generation of the plant is 0.465 t-CO2/MWh which is lower than that of grid electricity (0.511 t-CO2/MWh) higher than grid electricity. An electric chiller in DCAP plant requires about 1MW of electricity for production of one USRT, while absorption chillers consume minimal electricity. These can bring emission reduction.

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas Consumption (a)</td>
<td>559,376</td>
<td>1000SCF</td>
</tr>
<tr>
<td>Emission Factor of natural Gas (b)</td>
<td>0.0554</td>
<td>t-CO2/1000SCF</td>
</tr>
<tr>
<td>Amount of Electricity Generation (Net) (c)</td>
<td>66,603</td>
<td>MWh</td>
</tr>
<tr>
<td>Grid Emission Factor (a)(b)+(c)</td>
<td>0.4653</td>
<td>t-CO2/MWh</td>
</tr>
</tbody>
</table>

The Study refers to approved CDM methodology AM0084 “Installation of cogeneration system supplying electricity and chilled water to new and existing consumers”. The GHG emission reduction relies on replacement of electric chillers to absorption chiller. The emission reduction amount is measured as a product of cooling effect (USRT) generated by absorption chiller and an efficiency of electric chillers or coefficient to derive an electricity consumption of reference scenario. Cooling effect is a product of chilled water amount, specific heat, and a difference of inlet-and outlet water temperature.

\[
CE_{\text{chil,abs,} y} = \sum_{m} \sum_{l=1}^{L} 7.9 \times 10^4 \times CW_{\text{abs,m,l}} \times C_P \times \left[ T_{\text{CW,abs,in,m,l}} - T_{\text{CW,abs,out,m,l}} \right]
\]

Where

- \(CE_{\text{chil,abs,} y}\) : Amount of absorption chiller’s chilled water (USRT)
- \(CW_{\text{abs,m,l}}\) : Amount of Chilled water production in monitored period (t)
- \(C_P\) : Specific Heat( \(= 4.1868 \times 10^{-3}\) ) (TJ/USRT)
- \(T_{\text{CW,abs,in,m,l}}\) : Average inlet chilled water temperature in monitoring period(°C)
- \(T_{\text{CW,abs,out,m,l}}\) : Average outlet chilled water temperature in monitoring period (°C)
- \(L\) : Monitoring Frequency
- \(m\) : Absorption chiller introduced
- \(7.9 \times 10^4\) : Conversion factor from heat to refrigerant amount

Greenfield project considers a standard cogeneration system consisting of gas
turbine and electric chillers. A difference of efficiencies between that of a standard system and project’s system results in GHG emission reduction.

(2) Eligibility Criteria for MRV Methodology Application:

① Waste heat discharge to the atmosphere following its primary usage. 
   (Applied to both of renovation and greenfield project)

② Electric chillers replaced with this project shall be without malfunction. After the project implementation the electric chillers are either to be disposed, used for chilled water’s demand control and or used for back-up purposes. 
   (Applied to renovation project)

③ Absorption chiller shall use steam and has a better performance than double-effect. 
   (Applied to both of renovation and greenfield project)

④ If the project uses ax-ante chiller’s operational record to derive PCF, the record has to demonstrate longer than 3 months. 
   (Applied when historical PCF is adopted in the calculation method 1 and 2 for renovation project)

⑤ Heat source shall be either gas-turbine or gas-engine. 
   (Applied to both of renovation and greenfield project)

⑥ The project shall identify rated electricity consumption of gas turbine (or gas engine) and waste heat recovery steam turbine. 
   (Applied to the calculation method 2 and 4 for renovation project)

⑦ The project shall record chilled water amount, chilled water’s inlet/outlet temperature shall be continuously monitored and recorded. 
   (Applied to both of renovation and greenfield project)

⑧ Emission factor of electricity generation (t-CO2/MWh) of the Project shall be equal or less than that of grid electricity. 
   (Applied to renovation project)

⑨ Emission factor of cogeneration system (e.g gas turbine and chiller) of the Project (t-CO2/MWh) should be lower than that of grid electricity 
   (Applied to greenfield project)

⑩ Absorption chiller shall be inspected periodically by service vendor or equivalent. 
   (Applied to both of renovation and greenfield project)

In order to retain project’s additionality, the project shall utilize heat, which are discharged to atmosphere in case an absence of the project activity.① Replacement of old electric chillers is “Business as Usual (BAU)” scenario and replaced electric chillers need to be controlled to avoid leakage emissions. Given considerations on interview and hearing results replaced electric chillers are usually remained as a back-up or continuously used as to balance chilled water supply. ② Ensuring project’s additionality, entire system, generator and chiller are needed to demonstrate high efficiency. ③⑧⑨ When calculating reference chiller’s efficiency, at least 3 months long data has to be used to taking into consider seasonality fluctuation. ④ The heat source of the project shall be gas-engine, but not a boiler to obtain waste heat with a high-temperature. ⑤ Among the monitoring parameters, amount of chilled water production and inlet/outlet water temperatures are monitored continuously and
recorded continuously. Study team understand that utility supply projects with Japanese participation in Thailand are mostly employing monitoring system for plant control and is able to monitor critical parameters. (7) The methodology stipulates a Japanese O&M to promote Japanese products and services.

(3) Calculation Method Options:

Option tree is illustrated as follows:

Calculation option tree is divided by greenfield project and renovating project (Energy efficiency improvement project). As for a renovating project, the option further split whether the project has a measured efficiency data or catalog specification data for electric chillers operating prior to the project implementation, and then splits whether the project measure electricity consumptions of ex-post gas turbines, waste recovery steam generator and electric chillers. For a Greenfield project, there is no further options. Thus, in total 5 options are prepared for this methodology.

(4) Necessary Data for Calculation:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Monitoring (M) / Project Unique Value (S) / Default Value (D)</th>
<th>DCAP Project</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Emission</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Amount of Natural Gas Consumption (1000SCF)</td>
<td>• M (for all options)</td>
<td>• Monitored Automatically and recorded in Daily Operational Record</td>
<td></td>
</tr>
<tr>
<td>2. Emission Factor of Natural gas (tCO2/1000SCF)</td>
<td>• D (for all options)</td>
<td>• To be determined in BOCM (1.02tCO2/1000SCF)</td>
<td>• TGO (0.0554tCO2/1000SCF)</td>
</tr>
<tr>
<td>Reference Emission</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. (Replaced) Electric Chiller’s electricity consumption (MWh)</td>
<td>• M</td>
<td>• Monitored and</td>
<td>• Defined for individual</td>
</tr>
<tr>
<td>Water Production (t)</td>
<td>Recorded Hourly</td>
<td>Chiller</td>
<td>Recorded Hourly</td>
</tr>
<tr>
<td>---------------------</td>
<td>----------------</td>
<td>---------</td>
<td>----------------</td>
</tr>
<tr>
<td>3.2 Inlet/Outlet Chilled Water Temperature (°C)</td>
<td>M (for all options)</td>
<td>-</td>
<td>-</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Ex-ante Electric Chiller Efficiency (PCF or COP)</th>
<th>Continuous Monitoring Data Available</th>
<th>Recorded Hourly</th>
<th>Defined for Individual Chiller</th>
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</thead>
<tbody>
<tr>
<td>M or S (for option .1&amp;2)</td>
<td>D (for option p.3&amp;4)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Optional Electric Chillers’ Electricity Consumption (MWh)</th>
<th>Recorded Hourly</th>
<th>Monitored and Recorded Hourly</th>
<th>Defined for Individual Chiller</th>
</tr>
</thead>
<tbody>
<tr>
<td>M (for all options)</td>
<td>-</td>
<td>-</td>
<td>-</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Electricity Consumption of Absorption Chiller (MWh)</th>
<th>Recorded Hourly</th>
<th>Defined for Individual Chiller (Same way as 3.1-3.2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M (for all options)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Electricity Consumption of Gas Turbine (MWh)</th>
<th>Recorded Hourly</th>
<th>Defined for Individual Chiller (For Op2,4, Rated Value Shall Be Defined.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M (for option.1&amp;3)</td>
<td>S (Rated Capacity × M (Operation Hours (for option 2&amp;4))</td>
<td>-</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Electricity Consumption of WHSG Turbine (MWh)</th>
<th>Recorded Hourly</th>
<th>Defined for Individual Chiller (Rated Value Shall Be Notified in Case of Option 2 &amp; 4. Monitored Monthly and Accumulated Yearly.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M (for option.1&amp;3)</td>
<td>S (Rated Capacity × M (Operation Hours (for option 2&amp;4))</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Generated Electricity of Gas Turbine (MWh)</th>
<th>Recorded Hourly</th>
<th>Monitored Monthly and Accumulated Yearly</th>
</tr>
</thead>
<tbody>
<tr>
<td>M (for all options)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Generated Electricity of WHRS (MWh)</th>
<th>Recorded Hourly</th>
<th>Monitored Monthly and Accumulated Yearly</th>
</tr>
</thead>
<tbody>
<tr>
<td>M (for all options)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grid Emission Factor (tCO2/MWh)</th>
<th>TGO’s Latest Data (0.511t-CO2/MWh, 2012)</th>
<th>Recorded Hourly</th>
<th>Defined for Individual Chiller</th>
</tr>
</thead>
<tbody>
<tr>
<td>D (for all options)</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<table>
<thead>
<tr>
<th>Natural Gas’s Lower Heat Value (GJ/1000SCF)</th>
<th>1.02 GJ/1000SCF. TGO (2009)</th>
<th>Recorded Hourly</th>
<th>Defined for Individual Chiller</th>
</tr>
</thead>
<tbody>
<tr>
<td>D (for all options)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Specific Heat (TJ/ton °C)</th>
<th>4.1868×10^6</th>
<th>Recorded Hourly</th>
<th>Defined for Individual Chiller</th>
</tr>
</thead>
<tbody>
<tr>
<td>D (for all options)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conversion Coefficient from Heat Value to Refrigerant</th>
<th>7.9 x 10^4</th>
<th>Recorded Hourly</th>
<th>Defined for Individual Chiller</th>
</tr>
</thead>
<tbody>
<tr>
<td>D (for all options)</td>
<td>-</td>
<td>-</td>
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</table>

<table>
<thead>
<tr>
<th>Conversion Coefficient of Heat Value to Electricity</th>
<th>0.2778</th>
<th>Recorded Hourly</th>
<th>Defined for Individual Chiller</th>
</tr>
</thead>
<tbody>
<tr>
<td>D (for all options)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conversion Coefficient from Electricity to Heat</th>
<th>3.6</th>
<th>Recorded Hourly</th>
<th>Defined for Individual Chiller</th>
</tr>
</thead>
<tbody>
<tr>
<td>D (for all options)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
(5) Default Value(s) Set in MRV Methodology:

Followings are default values employed in the research;

① Efficiency of ex-ante electric chillers replaced by the project

Value : 0.502kWh/USRT (where COP = 7.0)

Reference: Sourced from Ministry of Energy’s minimum requirement for electric chiller’s performance and a hearing from chiller operators. The Ministry’s guideline, suggests the minimum efficiency standard as 0.62kWh/USRT for chiller’s capacity more than 500USRT. On the other, the hearing to chiller operators’ revealed that the efficiency is about 0.54kWh/USRT for installations in/around 2010, (the maximum was 0.524kWh/USRT COP=6.71). A conservative estimation of 0.502kWh/USRT (COP=7.0) was set for BOCM/JCM.

② Energy efficiency of standard cogeneration system including electric chiller as reference for greenfield project

Value : 51.9%

Reference: Interviewed major cogeneration projects in Thailand to estimate energy efficiency. Data from seven SPP projects suggested that energy efficiency of the system which supplied chilled water by electric chillers could be 51.9%.

③ Grid electricity’s emission factor

Value : Latest value of combined margin emission factors derived from TGO’s latest survey. The value considering project other than wind and solar. In December 2012, the value is 0.511tCO2/MWh.

Reference : Refer to latest survey result of TGO.

④ Natural gas emission factor

Value : 0.0554 tCO2/1,000SCF

Reference: Annual grid emission carbon intensity survey conducted and publicized by TGO. The value derived from annual survey 2010.

⑤ Lower calorific value of natural gas

Value: 1.02 GJ/1000SCF

Reference: Annual grid emission carbon intensity survey conducted and publicized by TGO. The value derived from annual survey 2010.

⑥ Specific heat

Value : 4.1868 × 10⁻⁶ TJ/ton of chilled water ℃

Reference : International Table Calorie”

(6) Setting of Reference Scenario and Project/Activity Boundary:

For Renovation project in existing facilities, Reference scenario is as follows;

➢ An existing facility such as large-scale factory, commercial building and etc
which generate chilled water by electric chillers using grid electricity. For Greenfield project Reference scenario is as follows:

- New facility which introduces co-generation system (i.e. using gas turbine or gas engine to generate electricity, and electric chiller to generate chilled water) with standard efficiency.

Project includes grid-electricity, heat and electricity supply, gas turbine and waste heat recovery steam generator. Facilities of demand-side are intact before and after the project and that omitted from project boundary. In DCAP project, a stand-by boiler was not used and neglected for the sake of simple methodology development.

Project boundary covers, following GHG and emission sources:

<table>
<thead>
<tr>
<th>Source of Emission</th>
<th>GHG</th>
<th>Yes/No</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid-Electricity (In case renovation project)</td>
<td>CO₂</td>
<td>Yes</td>
<td>Major Source</td>
</tr>
<tr>
<td></td>
<td>CH₄</td>
<td>No</td>
<td>Excluded for Simplification</td>
</tr>
<tr>
<td></td>
<td>N₂O</td>
<td>No</td>
<td>Excluded for simplification</td>
</tr>
<tr>
<td>Chillers and Generators employed for Project</td>
<td>CO₂</td>
<td>Yes</td>
<td>Major Source</td>
</tr>
<tr>
<td></td>
<td>CH₄</td>
<td>No</td>
<td>Excluded for simplification</td>
</tr>
<tr>
<td></td>
<td>N₂O</td>
<td>No</td>
<td>Excluded for simplification</td>
</tr>
<tr>
<td>Emission from Natural combustion for gas turbine</td>
<td>CO₂</td>
<td>Yes</td>
<td>Major Source</td>
</tr>
<tr>
<td></td>
<td>CH₄</td>
<td>No</td>
<td>Excluded for simplification</td>
</tr>
<tr>
<td></td>
<td>N₂O</td>
<td>No</td>
<td>Excluded for simplification</td>
</tr>
</tbody>
</table>
(7) Monitoring Methods:

DCAP monitors electricity and steam generation and power consumption with automated DCS. Measured data is integrated and stored in data server. Chiller’s performance is also monitored of its power generation, amount of chilled water, flow-rate of chilled water, temperature and amount of steam. This data set is used to calculate sales revenue of electricity with real time basis. The Study team confirmed that DCAP’s operational skills and systems are highly advanced compared with general Thailand’s utility supply practices, however, application of DCS for plant operation is common in case Japanese technology and that team believes proposed monitoring methodology is acceptable.

Monitoring methods and parameters are described in the following table.

<table>
<thead>
<tr>
<th>Items</th>
<th>Method/Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Refrigerant amount by absorption chiller</td>
<td></td>
</tr>
<tr>
<td>Chilled Water Amount</td>
<td>Continuously monitored by each chiller’s measurement instruments. Recorded hourly and monthly accumulate. Annual data is consolidating entire chiller sets.</td>
</tr>
<tr>
<td>Average inlet temperature</td>
<td></td>
</tr>
<tr>
<td>Average outlet temperature</td>
<td></td>
</tr>
<tr>
<td>2. Refrigerant amount by electric chillers</td>
<td></td>
</tr>
<tr>
<td>Chilled Water Amount</td>
<td>Continuously monitored by each chiller’s measurement instruments. Recorded hourly and monthly accumulate. Annual data is consolidating entire chiller sets.</td>
</tr>
<tr>
<td>Average inlet temperature</td>
<td></td>
</tr>
<tr>
<td>Average outlet temperature</td>
<td></td>
</tr>
<tr>
<td>3. Amount of Electricity generation by gas turbine</td>
<td>Continuously monitored by each chiller’s measurement instruments. Recorded daily and monthly accumulated. Annual data is consolidating entire chiller sets.</td>
</tr>
<tr>
<td>4. Amount of electricity generation by WHSG</td>
<td>Monitor and recorded daily with each individual gen-set’s measurement devices. Recorded monthly and accumulate each gen-sets.</td>
</tr>
<tr>
<td>5. Electricity Consumption by gas turbine (either one of following)</td>
<td>Monitor and recorded daily with each individual gen-set’s measurement devices. Recorded monthly and accumulate each gen-sets.</td>
</tr>
<tr>
<td>Electricity Consumption (Direct Measurement) (Op.1,3)</td>
<td></td>
</tr>
<tr>
<td>Operating hours (Op.2,4)</td>
<td></td>
</tr>
<tr>
<td>6. Electricity Consumption by WHSG (either one of following)</td>
<td>Monitor and recorded daily with each individual gen-set’s measurement devices. Recorded monthly and accumulate each gen-sets.</td>
</tr>
<tr>
<td>Electricity Consumption (Direct Measurement) (Op.1,3)</td>
<td></td>
</tr>
<tr>
<td>Operating hours (Op.2,4)</td>
<td></td>
</tr>
</tbody>
</table>
7. Amount of natural gas consumption of each gas-turbine.

Monitor and recorded daily with each individual gen-set’s measurement devices. Recorded monthly and accumulate each gen-sets.

(8) Quantification of GHG Emissions and its Reductions:

Project emission is calculated by measuring natural gas consumption. The amount is a product of natural gas consumption by gas turbine and natural gas’s emission factor announced by TGO.

For renovation project, the reference emission is a product of the replaced amount of electricity from grid to project, and emission factor of grid electricity. The replaced amount of electricity is composed from those consumed in chillers and those in other facilities. The replace amount from electric chiller to absorption chiller is accounted as a product of cooling effect produced by absorption chillers and ex-ante electric chillers’ PCF. The amount of electricity replaced in other than chillers is a residue of an entire project’s electricity generation minus electricity consumption of gas turbine and waste heat recovery steam turbine. Leakage emission is negligible.

By using monitoring results by this Study in DCAP, emission reduction amount is estimated as 55,886 t-CO2/year with the calculation method 1 and 47,364 t-CO2/year with the calculation method 4.

For greenfield project, reference emission is calculated as a product of natural gas consumption amount, natural gas emission factor and a proportion of energy efficiency of project cogeneration system and that of standard cogeneration system.

District cooling supplier including Small Power Producer (SPP) projects located in/near industrial parks are one of the possible targets for application of this methodology. According to the Power Development Plan 2010, SPP project will be developed, of which total capacity increases from 2340MW in 2012 to 6614 in 2019. PTT’s gas pipelines will be expanded, and be able to supply natural gas to such projects.

(9) Verification of GHG Emission Reductions:

Beauro Veritus Thailand was engaged in verification in the Study. Followings are Verifier’s comments for BCOM/JCM.

- Uncertainty of Assurance Level
  Verification protocol is not precise enough. Without flaming verification purpose and a level of assurance expected to verifier, it is difficult for verifiers to make a productive comments and arguments.

- Document Format
  Lack of documentation templates makes the verification work difficult. Required information for verification are described in various parts of submitted documents and record.

- Ambiguous Project’s Eligibility
  Eligibility of the project shall be determined with a different process. It appeared that mechanism process integrated project’s “eligibility” test for BOCM and methodology’s “applicability” test. It shall be segregated and verifier is not supposed to make an assessment.
(10) Ensuring Environmental Integrity:

DCAP facility locates in the area between two main runways of the Bangkok Airport, adjacent buildings and facilities are for the airport operation and have minimal impacts by DCAP’s operations in terms of environment. Emissions of DCAP plant’s operation with NOx and SOx are monitored constantly to satisfy Thailand’s environmental regulations. Chillers for passenger terminal buildings locate in the parking tower buildings’ basement floor to reduce noise level. Future expansion project will also be locates in adjacent land area thus the environmental integrity are kept.

(11) How to Promote the Dissemination of Japanese Technologies:

A cogeneration system consisting of gas turbine, heat recovery steam generation and absorption chiller is more suitable to a group of facilities locating nearby which continuously require combination of electricity and chiller water with certain amount, than to sole and isolated building and/or factory. The cogeneration system is better to be promoting as a packaged system rather than each individual parts. The customer services, including training of O&M, following installation, are highly appreciated by customers and is one of the strong advantages of Japanese. Upheld these features of Japanese companies are imperative to promote Japanese products in this market.

(12) Prospects and Challenges for Similar Project/Activity Implementation:

Following two aspects are recognized through this Study.

① Expansion of Bangkok Airport

Airport operator announced future expansion plan of the Bangkok airport due to traffic congestion and increase of passengers. This expansion goes with addition of new passenger terminal which requires an expansion of DCAP facility to meet increasing utility demand. Application of developed methodology is considered when expansion project apply to BOCM/JCM in future.

② Development of SPP

Thai government promotes SPP project in order to diversify source of electricity. In 2012, SPP provides 2,340MW of electricity in Thailand and this proportion is expected to grow up to 6,614MW in year 2020. More than 30 projects are filed an application for licenses and some has not yet decided plant’s specification. Thai government also reconsiders energy policy with respect to nuclear power development and this change implies more importance on SPP development to satisfy country’s growing energy demand.

Challenges for Japanese vendors and regulators of BOCM/JCM are as follows;

① Japanese vendor’s challenge

As described in “promotion” section, it is critical for vendors to consolidated and packaging proposals from waste heat recovery unit to fun-blower units. When considering SPP, project requires turbine with a capacity of 40~50MW, which is just starting product development by Japanese vendors. To penetrate Thai market, Japanese has to accelerate product development for ideal size turbine and to build installation record.

MRV methodology of this project stipulates an eligibility condition regarding absorption chillers’ maintenance by vendors to promote Japanese product and
services. In general, absorption chiller requires more frequent maintenance than electric chiller. Appropriate maintenance keeps chillers’ performance so that vendors are expected to provide attentive after-maintenance services.

② BOCM/JCM regulators’ challenge

A challenge of the regulators is to develop detail of BOCM/JCM in order to link its mechanism to domestic regulations related to energy saving in Thailand.

In line with “Energy Saving Regulation 1992” there are couple of financing schemes to promote energy saving project by facility owners. It is difficult for such owners to consider to take part in BOCM/JCM if they don’t know differences between the mechanism and existing domestic schemes.

Therefore, the regulators of BOCM/JCM should first examine existing schemes in Thailand and clarify an advantage of its mechanism comparing to the existing scheme.

If Thai government determine to place an emission-cap to designated entities, many large emitters has to consider the usability of BOCM/JCM for compliance. Therefore, paying keen attention to Thailand’s domestic regulation is important to maximize opportunity to develop BOCM/JCM projects.

5. Contribution to Sustainable Development in Host Country

Natural gas sourced cogeneration system has less environmental burden compared with conventional fuels in terms of air pollution. The project further contributes to realize Thailand’s development strategy to achieve “Low-Carbon Environmentally Harmonized Society” by providing higher energy efficiency utility provided to large scale industrial facilities with waste-heat’s cascade utilization.