A Technical and Economic Feasibility Assessment of a Deep Sea Water District Cooling System at Tumon Bay, Guam

Prepared for:
GUAM POWER AUTHORITY

Prepared by:

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and

Market Street Energy, LLC
St. Paul, MN

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October 15, 2005
Sensitive cost data is blanked out intentionally
EXECUTIVE SUMMARY

1.1 PURPOSE OF THIS STUDY.
This document reports the results of a technical and economic assessment of the potential for using deep cold seawater to air condition hotels and other buildings at Tumon Bay, Guam. The purpose of the work is to determine whether or not there is technical and economic merit to proceed with implementing this system in Guam.

In this study, Makai and Market Street Energy have analyzed and sized the major components of the Guam Seawater Air Conditioning (GSWAC) system, determined the operational performance, estimated the probable costs and identified the economic and business advantages of the GSWAC system. The team has also defined the opportunities, risks and potential problems associated with such a cold water system for Tumon Bay.

1.2 BRIEF EXPLANATION OF GSWAC – HOW IT WORKS.
The hotels along Tumon Bay are presently cooled with electric-powered refrigeration systems, or chillers, that cool chilled water which is circulated throughout the building. Seawater air conditioning is a means of bypassing the conventional chiller and using deep seawater and a heat exchanger to directly cool the building’s chilled water. A schematic of a basic SWAC system is shown on the right.

For Tumon Bay, GSWAC would use a deep seawater intake pipeline going three miles offshore to a depth of 2200’ and bringing 42.5º F seawater ashore. This water passes through a heat exchanger and chills a fresh water loop that is delivered to the customers. Each customer is provided cold fresh water at 44º F, the same as within most Tumon Hotels. Operation of the AC system within the hotel is unchanged. The next page shows the general features of the Guam SWAC system.
Cold seawater is drawn from 2300 feet deep at a temperature of 42.5 deg F. It follows a long pipeline that lies along the seabed, represented by the long blue line pointed out to sea. About 1700 feet from shore, the pipeline connects to a pair of underground tunnels, represented by the dashed blue line. The tunnels carry the water under the reef, across the shoreline, and into a pump station located near the Hilton, represented by the green square.

A pair of 600 hp pumps pushes the water into a cold water distribution pipe buried under the beach, represented by the blue line running along shore. The distribution pipeline has smaller branches that run to heat exchangers servicing the hotels along Tumon Bay. The yellow circles represent groups of hotels that may share a single large heat exchanger or single hotels that use a smaller individual heat exchanger. The heat exchangers allow the cold seawater to cool the hotels’ chilled water to 44 deg F or cooler without contaminating it. Exiting the heat exchangers at about 54 deg F, seawater flows into a return water distribution pipeline, represented by the red line running along the shore, buried parallel to the cold water pipeline.

The warmed seawater follows the return distribution pipeline back to the pump station where it enters another tunnel, represented by the dashed red line, which carries it back under the reef. The tunnel takes the water to a return pipeline, represented by the red line pointing out to sea. At the end of the return pipeline, at a depth of 300 feet, the water is returned to the ocean via a 300 foot long diffuser. The diffuser serves to mix the return water with ambient seawater to minimize any environmental impacts.

Seawater air conditioning is particularly attractive on Guam because of the ease of access to the deep water, the concentration and quantity of AC users, the high utilization of AC on Guam, and the relatively high cost of electricity and water.

1.3 SUMMARY OF BENEFITS FOR USERS, OWNERS, GUAM.

The GSWAC system can provide meaningful energy to a portion of Guam using a sustainable, non-polluting natural energy source. Among the benefits of this system are:

- **Energy Savings:** By using the deep ocean for cooling, approximately 8 to 12 MW of power are conserved and the associated electrical power pollution will be reduced. The GSWAC system uses 1/6 the power of conventional AC chilling.

- **A Natural Resource:** Guam’s major natural energy resource is the thermal resource in the ocean. Guam has excellent access to this resource. GSWAC is an important step toward the expanded development of this resource in the future.

- **Economically Viable:** GSWAC makes economic sense; it is an environmentally friendly and sustainable alternate energy that is financially attractive.

- **Environmentally Responsible:** Guam’s natural resource is readily available; it is environmentally responsible to use this renewable resource.
• Environmentally Friendly: GSWAC conserves fossil fuels and reduces air and heat emissions. If properly designed, its local environmental impact during construction will be minimal.

• Financial Independence: A locally available energy resource is substituted for energy from imported oil.

• Greater Independence from Energy Price Escalation: In a world of rapidly increasing energy prices, GSWAC costs (which are capital dominated) are relatively flat compared to that of energy intensive conventional AC systems. Users will have a known and relatively flat future AC cost.

• No Water Consumption by Cooling Towers: A significant cost of conventional AC is the consumption of fresh water by evaporative condensing units; GSWAC does not consume of fresh water.

• Secondary Applications: Cold seawater is available for secondary applications such as production of healthy drinking water.

• Proven Technology: Similar systems have been used at other locations; the technology is simple.

1.4 AC DEMAND.

The likely customers for seawater AC are the large hotels near the beach or San Vitores Road in Tumon Bay. This study identified 19 potential users who currently have a total peak cooling demand of nearly 11,000 tons of refrigeration. The annual average AC load for these users is high due to the nature of their business (hotels) and the uniformly warm temperature and high humidity on Guam; the utilization factor is at least 70%, with an average demand of 7,700 tons.

<table>
<thead>
<tr>
<th>Hotel/Location</th>
<th>Capacity (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hilton Guam Resort &amp; Spa</td>
<td>1035</td>
</tr>
<tr>
<td>Pacific Island Club</td>
<td>1030</td>
</tr>
<tr>
<td>Royal Orchid</td>
<td>326</td>
</tr>
<tr>
<td>Guam International Market</td>
<td>332</td>
</tr>
<tr>
<td>Marriott Resort &amp; Spa</td>
<td>729</td>
</tr>
<tr>
<td>Dal Ichl</td>
<td>539</td>
</tr>
<tr>
<td>Holiday Resort</td>
<td>402</td>
</tr>
<tr>
<td>Fujita</td>
<td>352</td>
</tr>
<tr>
<td>Holiday Plaza</td>
<td>206</td>
</tr>
<tr>
<td>Grand Plaza</td>
<td>169</td>
</tr>
<tr>
<td>Total</td>
<td>10782</td>
</tr>
</tbody>
</table>

The customers include hotels and businesses located near the beach or San Vitores Road in Tumon Bay.
1.5 GSWAC SCENARIOS ANALYZED

The team analyzed five GSWAC configurations for Tumon Bay. The baseline system is termed Scenario I. Primary variables considered within the four other scenarios involved changes to the onshore pipe routing, ocean pipe path, and the total size of the system. More specifically, the following designs were considered:

- Onshore Distribution Loop along San Vitores Road or Along the Beach: Seawater distribution systems along the beach and fresh water distributions at higher elevations were modeled.
- Offshore Pipe Route and Shoreline Landing: At the southwest end of the Tumon Bay shoreline near the Hilton (Route A), and in the middle of Tumon Bay (Route B)
- Overall size: 16,000 tons and 11,000 tons.

The following table summarizes these five scenarios.

<table>
<thead>
<tr>
<th>GSWAC Scenarios:</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max AC Load (Tons)</td>
<td>16,000</td>
<td>16,000</td>
<td>16,000</td>
<td>16,000</td>
<td>11,000</td>
</tr>
<tr>
<td>Initial Load</td>
<td>11,000</td>
<td>11,000</td>
<td>11,000</td>
<td>11,000</td>
<td>11,000</td>
</tr>
<tr>
<td>User supply Temperature (Deg F.)</td>
<td>44</td>
<td>44</td>
<td>44</td>
<td>44</td>
<td>44</td>
</tr>
<tr>
<td>Seawater Supply</td>
<td>Route A</td>
<td>Route B</td>
<td>Route A</td>
<td>Route B</td>
<td>Route A</td>
</tr>
<tr>
<td>Seawater Distribution</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Fresh Chilled water Distribution</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Pump Location</td>
<td>Hilton end</td>
<td>Mid Bay</td>
<td>Hilton End</td>
<td>Mid Bay</td>
<td>Hilton end</td>
</tr>
<tr>
<td>Main Distribution</td>
<td>Beach</td>
<td>Beach</td>
<td>San Vitores</td>
<td>San Vitores</td>
<td>Beach</td>
</tr>
</tbody>
</table>

1.6 GSWAC COMPONENTS, SCENARIO I

The overall layout of the piping for Scenario I is shown below. The deep water pipeline is a 63” diameter polyethylene pipe that is three miles long and brings in 42º F water from 2300’ depth. The pipeline lays on the seafloor.
The shoreline pipe crossing is tunneled below the reef to both protect the shoreline from construction damage and to protect the pipe from severe storms. The pipeline crosses the Tumon Bay Marine Preserve in this region, and the 1700’ long tunnel goes below the shallow portion of the preserve. The tunnel terminates at a seawater pump station located at the Hilton end of the beach. The pump station should include backup generators capable of maintaining the system at 2/3 of full capacity.

The more detailed view of the distribution system is shown below. The red line is a seawater distribution system buried below the beach. Several users are cooled through single-user heat exchangers along this route. Three chilled fresh water loops, cooled by a single heat exchanger, feed larger groups of clustered users. All users are provided with chilled fresh water that is colder than 44º F.
1.7 TOTAL SYSTEM COSTS

The total construction cost of each of the five scenarios was estimated. Capital costs range from $73 million for Scenario V to slightly over $100 million for Scenario IV as shown below. Scenarios III and IV costs are high because of the high cost of the San Vitores Road pipe installation. Scenarios II and IV have higher offshore costs associated with longer pipes and tunnels needed to land the offshore pipes at the middle of the bay. Overall, Scenario I is the most financially attractive of the four 16,000 ton systems. Scenario V is a smaller, 11,000 ton version of Scenario I that has the lowest cost.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Capital Cost, million $</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>CW Distribution</td>
</tr>
<tr>
<td>II</td>
<td>FW Pumps</td>
</tr>
<tr>
<td>III</td>
<td>SW Distribution</td>
</tr>
<tr>
<td>IV</td>
<td>SW Pumps</td>
</tr>
<tr>
<td>V</td>
<td>Offshore Pipes</td>
</tr>
</tbody>
</table>
1.8 ECONOMIC FEASIBILITY ANALYSIS

The economic merit of the GSWAC was evaluated by using simple payback, a levelized cost comparison with conventional AC, and finally, a brief business plan was prepared for the most attractive GSWAC scenario.

1.8.1. Simple Payback

Simple payback was computed for the five scenarios based on the capital costs given above and net revenue. When fully loaded, the simple payback is between 5.1 and 6.7 years. If the system is partially loaded at only 2/3 capacity, the simple payback is between 8.5 and 11.4 years. Scenario I is the most financially attractive. The actual payback period is likely to be somewhere between these two ranges as the system starts out partially loaded and will expand its capacity over time. It should be noted that full load for Scenario V represents 11,000 tons, which is comparable to the other four scenarios’ 2/3 load. Therefore, Scenario V has a shorter simple payback period for an 11,000 ton load than any other scenario.

1.8.2. Levelized Cost Comparison

A more rigorous financial comparison was performed between the five GSWAC scenarios and the conventional AC systems currently used at Tumon Bay. A Guam SWAC system will have a large capital cost and low operating costs. Conventional AC systems are already installed and have no installation cost but high operating and replacement costs. Considering a financing rate of 8% for payments during the 20-year book life of the system, Scenario I yields a 45% cost saving compared to conventional air conditioning.

The graph below shows the levelized cost difference between conventional AC and each of the five scenarios at full load. This analysis shows that GSWAC has a levelized cost ranging from $1,100/ton/year to $1,300/ton/year and conventional air conditioning’s levelized cost is $2,020/ton/year. The wide difference between these costs suggests that GSWAC presents a viable business opportunity. Scenario I shows the widest gap between costs.
GSWAC and Conventional AC and is therefore the most financially attractive system if fully loaded. However, all GSWAC scenarios cost less than conventional AC at full load.

1.8.3. Business plan

An example conservative business plan was constructed using Scenario I. As opposed to the parametric analysis methods used in the bulk of this report, the business plan calculations focused on a cash flow analysis which yielded slightly different values. The following is a summary of the assumptions and results of the business model.

In addition to the $83 million in construction costs, the business plan allows for $15 million for incidental project initiation costs. Thus, the total cost to begin service is $98 million. It was assumed that 80% of this cost is financed with 6% bonds, and that GPA (or others) invests the remaining 20% with a minimum expected return of 10%.

In order to determine the current value of air conditioning, the avoided cost of using conventional air conditioning was determined. Included in the calculation is the conservative assumption that crude oil costs $50/barrel, which is 83% of the current value of $60/barrel. Given this assumption, the avoided cost of air conditioning is $0.202/ton-hr.

The business model showed that a minimum of 9000 tons of peak customer load is needed for the project to meet its financing commitments. It is conservatively assumed that only 9000 tons of peak AC is provided for the first 20 years; this is 9000 tons out of a total system has a capacity of 16,000 tons.
With this customer base, the project’s first year revenue is $10.9 million, which approximately matches that of conventional air conditioning. However, since SWAC is less sensitive to increases in variable costs, the project’s savings over conventional air conditioning increases with time. The model shows a positive cash flow for all but the first year, and yields a net savings over conventional air conditioning of $52 million.

Under this worst-case scenario, there is still a 10% return on equity. There are an additional 7000 tons of AC capacity to be sold with minimal additional cost. After 20 years when the capital loans are paid, revenue is high and expenses are very low.

A similar analysis was performed using a smaller 11,000 ton SWAC system, represented by Scenario V. The smaller system needed 8100 tons of peak customer load to meet its financing commitments.

1.9 ENVIRONMENTAL AND COMMUNITY ISSUES

GSWAC will be an environmentally responsible system that will reduce air pollution caused by burning fossil fuels and will cut greenhouse gas emissions. It is visually unobtrusive and uses little land, unlike other renewable technologies such as wind power or solar panels. However, the recently designated Tumon Bay Marine Preserve presents a regulatory challenge because the necessary GSWAC system pipelines will cross the Preserve; this will likely be a sensitive community issue.

To minimize impact on the preserve, the pipelines could be located along the southern side of the preserve, the pipelines would be tunneled below the more delicate coral regions, and the return seawater would be released deeper than 300’ as suggested by Guam EPA representatives.

On land, the cold seawater is distributed via buried pipelines. Building the distribution pipelines will create some temporary disturbance. Three scenarios route the distribution pipes under the landward edge of the beach, which is within the Marine Preserve. An alternate, more expensive, route along San Vitores Road avoids the beach. More feedback is needed from the community on these potential routes.

1.10 OTHER WATER USES

Deep ocean seawater has potential applications other than air conditioning. Cold seawater applications include: improved power plant or cooling system efficiency, aquaculture, agriculture, desalination, health (drinking and bathing), and electrical power production. These side benefits of deep seawater have not been included in the economic assessment of a SWAC system.

The direct desalination of deep seawater for premium health-food drinking water has been rapidly expanding in Northeast Asia. Guam would have a ready market for its bottled water given its close proximity to Japanese and Taiwanese markets.

Cost estimates for deep water power plant cooling at Cabras and Tanguisson have been provided for further analysis by GPA.
Also, analysis has been presented for Ocean Thermal Energy Conversion (OTEC) and desalination at Cabras. OTEC and desalination are not cost effective today, but may be important to Guam in the future.

1.11 CONCLUSIONS

- GSWAC is a technically feasible means of providing up to 16,000 tons of air conditioning to the Tumon Bay area.
- GSWAC is financially feasible for loads that exceed 8100 tons of cooling. Simple payback periods are in the range of 5 to 8.5 years depending upon initial loading.
- Makai has performed similar SWAC studies at other locations in the Pacific Ocean and the Caribbean Sea. Comparison with these earlier studies indicates that Guam has a uniquely high potential for energy savings and profitability.
- 44 deg F chilled water can be provided to users without auxiliary chillers. If water below 44 deg F is required, auxiliary chillers would be more cost-effective.
- At full load, all five scenarios are cost-competitive with conventional air conditioning. Scenario V is the most cost-effective scenario to meet existing load. Scenario I is the most cost-effective scenario to meet the near-future expected load.
- A distribution system along San Vitores Boulevard is more costly than one along the beach.
- Energy usage would be reduced by 8.4 MW, and CO₂ emissions would be reduced by 45,000 tons per year.
- Potable water usage would be reduced by 184 million gallons per year.
- SWAC is a renewable and sustainable energy technology.
- All five scenarios involve construction within the Tumon Bay Marine Preserve.

1.12 RECOMMENDATIONS

- If GPA expects a final system load between 8000 tons and 11000 tons, Scenario V is recommended.
- If GPA expects a final system load between 13,500 tons and 16,000 tons, Scenario I is recommended.
- Based on this feasibility study, a GSWAC project should be conducted.
- GPA should hire a multi-disciplinary team to perform a conceptual design. In addition to Makai and Market Street, this team should consist of a civil engineer, geotechnical engineer and electrical engineer, an architect and a firm specializing in environmental permitting.