OTEC Power Cycles and Auxiliary Uses

*Desalinated water and Ammonia Production*

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Path Forward
Five-Step Commercialization Goals

1. Global displacement of petroleum-based fuels (diesel and fuel oil) for power generation specifically in the island market
2. At-sea production of desalinated water for regions of critical water shortages
3. Displacement of carbon-based production of fertilizer ammonia
4. Hydrogen supply to allow economic processing of heavy crude oils and upgrading oil sands
5. Ammonia-fuel-based distributed energy to displace natural-gas for power generation
Energy-Water Nexus

Energy production and generation require water

Water pumping, treatment, and distribution require energy

- Alternate energy sources (nuclear hydrogen, ethanol, oil sand) have high consumption of fresh water
- Ocean-thermal only energy source that can co-produce power and desalinated water
## Cost of water

<table>
<thead>
<tr>
<th>Plant Utilization</th>
<th>7920 hr/y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>2.64 mgpd</td>
</tr>
<tr>
<td>Electric rate</td>
<td>0.060 $/kWh</td>
</tr>
</tbody>
</table>

| Bidder           | 2005$    |
| Type             | SWRO     |
|                  |          |
| Total Installed Costs (TIC), $ | 13,565,350 |

**Annual Costs**

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depreciation over 10 years, $</td>
<td>1,356,535</td>
</tr>
<tr>
<td>Electric Power, kW</td>
<td>2900</td>
</tr>
<tr>
<td>Costs, $</td>
<td>1,378,080</td>
</tr>
<tr>
<td>Membrane Replacement, $</td>
<td>453,150</td>
</tr>
<tr>
<td>Cartridge Filters, $</td>
<td>68,900</td>
</tr>
<tr>
<td>Chemicals, $</td>
<td>259,700</td>
</tr>
<tr>
<td>Maintenance &amp; Parts, $</td>
<td>265,000</td>
</tr>
<tr>
<td>Operating Labor, $</td>
<td>238,500</td>
</tr>
<tr>
<td>Total Annual Cost, $</td>
<td>4,019,865</td>
</tr>
</tbody>
</table>

| Cost of Water, $/m3                      | 1.22      |
| $/KGPD                                   | 4.61      |
Technology Status
OTECE Desalinated Water Production

Hybrid Cycle

- Land-based plants shown to be competitive to SWRO for the island market
- Possible option - OTEC to operate land-based OTEC desalination plants

On-Board Reverse Osmosis (RO) is an option for at-sea production of desalinated water
OTEC Plantships for Ammonia Production

- Ammonia is being considered as the hydrogen carrier for renewable energy sources – wind, remote PV, and OTEC
- Global impact of OTEC Plantships – Four Strategic Regions
Ammonia Imports to the USA
Ammonia Cost FOB Tampa, FL

![Cost of Imported Ammonia $/Metric](chart)

- **2003**: Cost is approximately $170/metric ton.
- **2004**: Cost is approximately $230/metric ton.
- **2005**: Cost is approximately $270/metric ton.
- **2006**: Cost is approximately $290/metric ton.
- **2007**: Cost is approximately $310/metric ton.

**Notes:**
- Costs are in $/Metric ton for FOB Tampa, FL.
- The cost for imported ammonia has increased over the years from 2003 to 2007.
Displacement of carbon-based feed stocks and energy for production of ammonia as fertilizer

- World ammonia production ~ 140 million metric ton /yr (31,000 cf /MT)
  - Equivalent NG consumption ~ 4,340 billion cubic feet (bcf) /yr
- US ammonia consumption ~ 16 million metric ton /yr (~ 50% imported)
  - Equivalent NG consumption of 496 bcf /yr; (LNG imports of 652 bcf in 2004; projected 1080 bcf in 2010)
- NG-based cost of ammonia:
  - Capital - $1.6 billion for a typical 4,000 MTD (CEP-Aug07, Plant Startup 2010)
  - $109 /MT Capital @ 10% IRR + $174 /MT @NG cost $5.6/kcf (Henry Hub Aug07) = $283 /MT + O&M costs
  - (No credit taken for byproducts CO2, methanol, sulfur)
Ammonia-fueled distributed energy generation to displace natural-gas fueled power generation

Illustration using California (2006):
- Power generation: instate 78%; import 22%
- NG-based power 42% of 78%
- NG (2005) consumption:
  - Instate 873 million cfd (7.5%)
  - Import 10,895 million cfd (92.5%)
- Power generation from NG (2006):
  - 107,000 GWh of 230,000 GWh total
  - 3,000 million cfd of NG at 33% thermal efficiency
- 12,000 MW of OTEC Power
  - Twelve 1,000 MWe OTEC Plantship Systems
- Significant impact on water supply
Technology Status

- Haber-Bosch is commercial ammonia synthesis process hydrocarbon as feedstock

- Innovative solid-state ammonia synthesis process has been proposed with significantly improved energy efficiency