OTEC Power Cycles and Auxiliary Uses

Desalinated water and Ammonia Production

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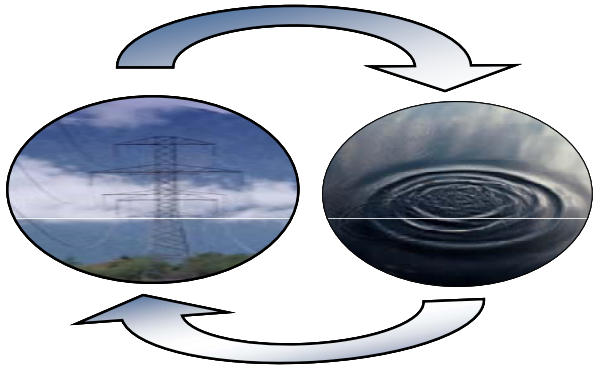
Path Forward

Five-Step Commercialization Goals

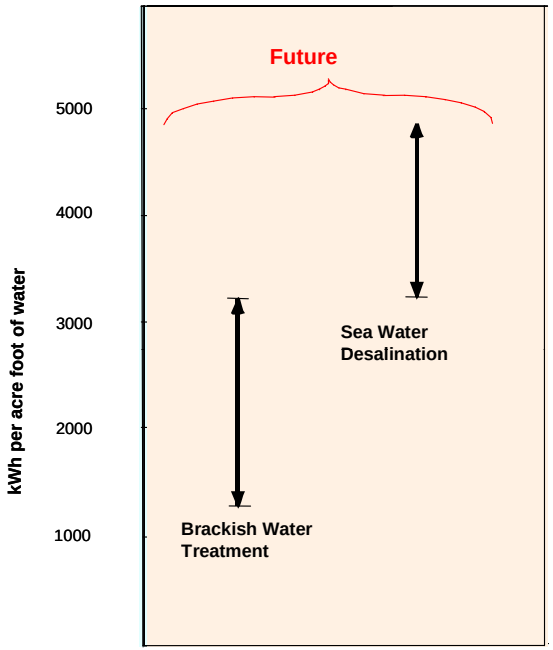
1. Global displacement of petroleum-based fuels (diesel and fuel oil) for power generation specifically in the island market
2. At-sea production of desalinated water for regions of critical water shortages
3. Displacement of carbon-based production of fertilizer ammonia
4. Hydrogen supply to allow economic 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

Plant Utilization	7920	hr/y
Production	2.64	mgpd
Electric rate	0.060	$/kWh

Bidder	2005$
Type	SWRO
Total Installed Costs (TIC), $	13,565,350
Annual Costs	
Depreciation over 10 years, $	1,356,535
Electric Power, kW	2900
Costs, $	1,378,080
Membrane Replacement, $	453,150
Catridge Filters, $	68,900
Chemicals, $	259,700
Maintenance & Parts, $	265,000
Operating Labor, $	238,500
Total Annual Cost, $	4,019,865
Cost of Water, $/m3	**1.22**
$/KGPD	**4.61**

Technology Status
OTEC Desalinated Water Production

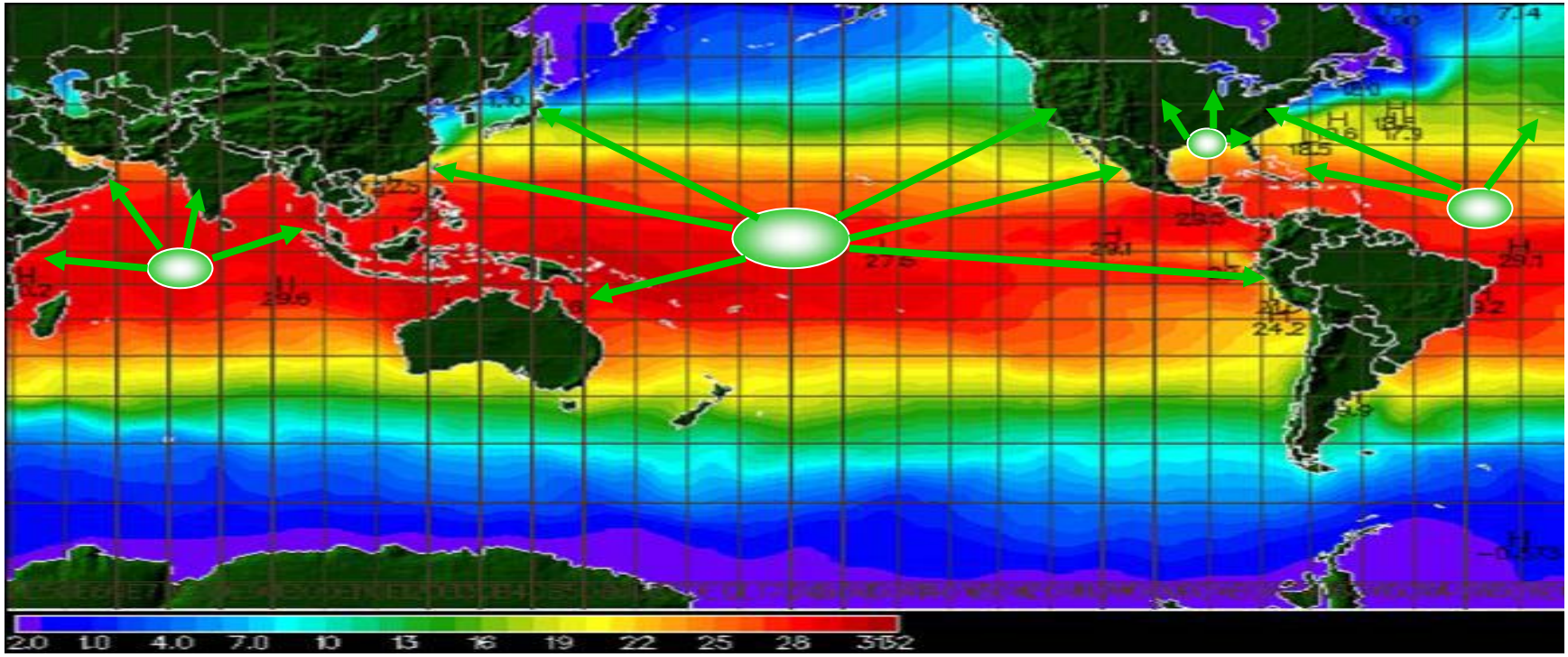
Hybrid Cycle

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

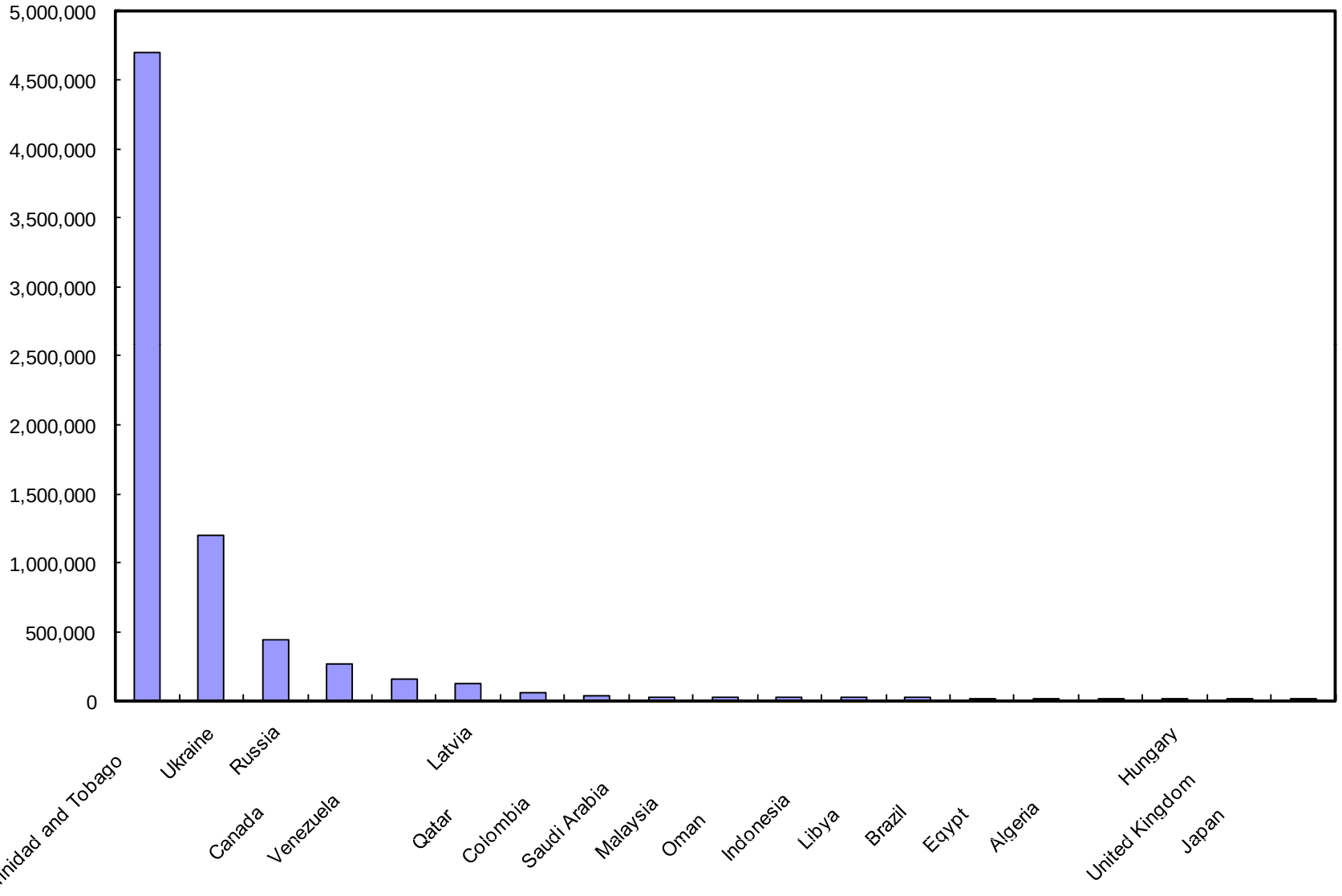
On-Board Reverse Osmosis (RO) is an option for at-sea production of desalinated water

OTEC Plantships for Ammonia Production

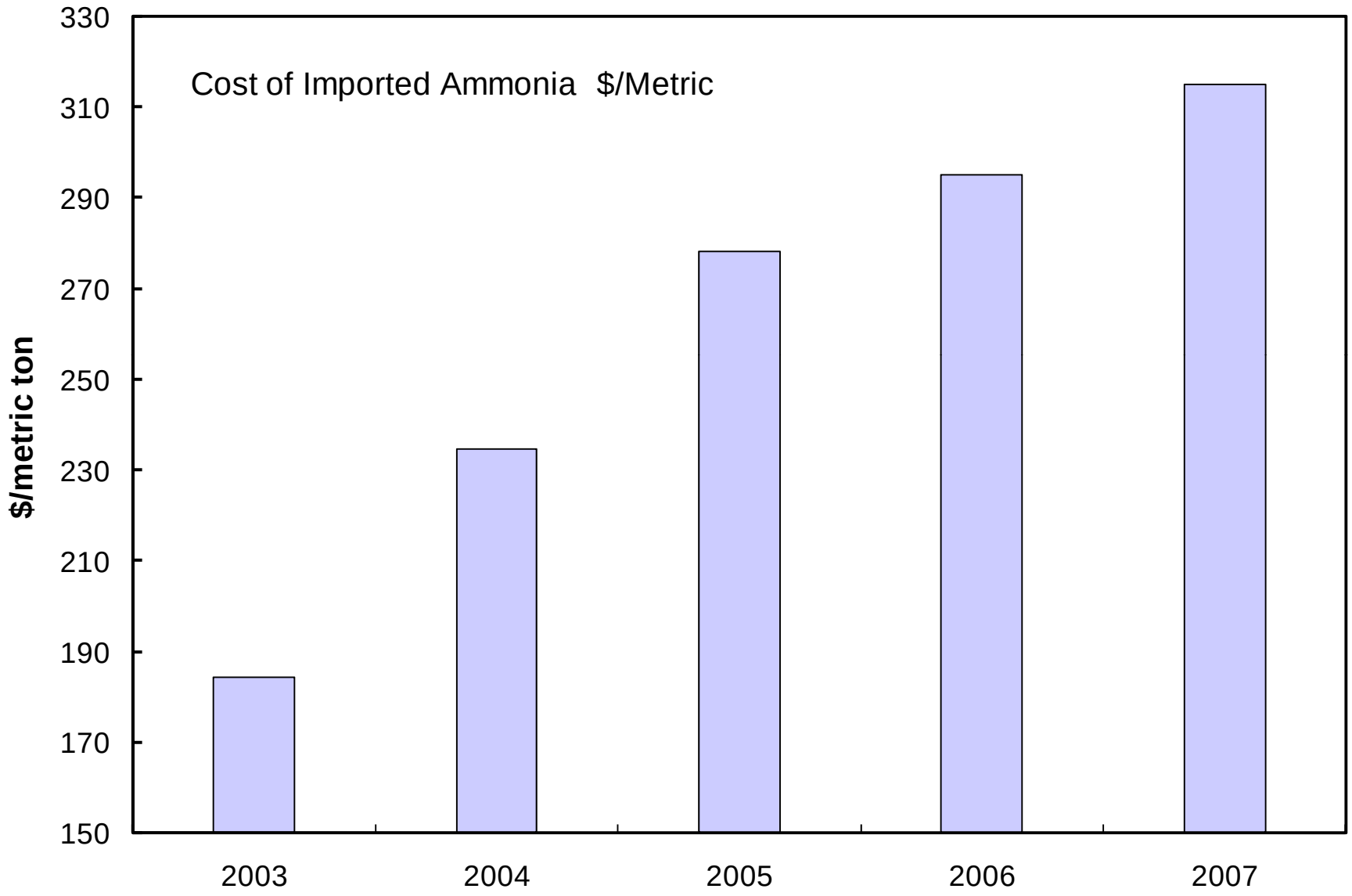
- **Ammonia is being considered as the hydrogen carrier for renewable energy sources – wind, remote PV, and OTEC**
- **Global impact of OTEC Plantships – Four Strategic Regions**



Ammonia Imports to the USA



Ammonia Cost FOB Tampa, FL



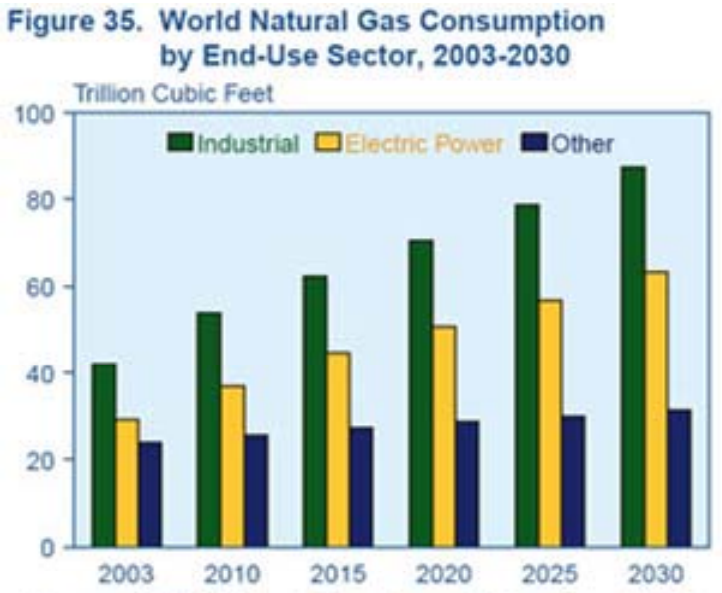
Displacement of carbon-based feed stocks and energy for production of ammonia as fertilizer

- 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