

*Alternative Energy From The Sea:
A New Paradigm,
A Call To Action*

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The opinions expressed herein are those of the author and are not to be construed as representing official policy of the U.S. Coast Guard.

1

Thanks for coming.

As Alan Rowen told me, this paper is mainly about old friends, stuff we already have studied, and that's true.

I'm not sure I have anything new to add, but my goal is mainly a call to action, as if driving by the Citgo gas station on your way here wasn't enough.

What we're looking at here is a possible paradigm shift, and my Nova Scotia Duck Tolling Retriever tells a story about paradigm shifts.

Paradigm Shifts: Ducks, Dogs, and Dinner



The Nova Scotia Duck Tolling Retriever lures (tolls) ducks by running and playing on the shore.

For some reason this attracts ducks into the range of the hunter, who is concealed in a blind.

The hunter then shoots the ducks, and the “Toller” retrieves them.

- Tolling ducks is an old paradigm in Nova Scotia
- This paradigm is good for the dog and the hunter.
- **But not so good for the ducks !**

2

A Toller is a relatively unusual breed of dog, the smallest of the retrievers at about 50 pounds.

They are called a Toller because they instinctively dance along the shoreline. This lures ducks for some unknown reason.

So one day a Toller went out to the shore to practice, without his owner.

Sure enough, a duck flew in – and the dog figured, this was his chance.

The dog asked the duck, “Why do you come when I toll?”

The duck replied “It is an old tradition, the way we have always done. But why do you toll?”

The dog said, “This is also an old Canadian tradition, but if my master were here, he would shoot you and we would both have a duck dinner.”

The duck, having read a lot of recent business books said “Well, maybe I should think about a paradigm shift.”

Right now, it looks like unless we can come up with a new paradigm for energy, we will be dead ducks too.

Overview

- America Is Addicted To Oil
- Alternative Energy From The Ocean
 - Wind, Wave, Tide, Current, OTEC, Salinity
 - Biofuels
- Conservation
 - By Mode Switch
 - Short Sea Shipping
 - Ferries Vs. Cars/Planes
 - Fast Sea Shipping
 - Conservation Aboard Ships
- Where Do We Go From Here?

3

There is pretty universal agreement that we have an issue we need to address, though folks differ in the details.

However, I've heard that the kanji for "danger" and "opportunity" use the same basic character. I don't know if this is true, but in this danger there is definitely opportunities.

I see the opportunities here mostly in reviving concepts we have done before, combining it in new ways, and most important in bringing our special expertise in the marine environment to people from other fields looking at alternative energy.

I would like to talk about three basic opportunities for oceanic sources of energy, making new energy, saving energy by traveling by sea instead of by land or air, and by conserving energy at sea.

Then I would like to open the flow up to a couple of other presentations, and to your ideas about what we as a technical society and as citizens can to do.

"America Is Addicted To Oil..."

- Oil Prices High (\$70 + / Barrel)
And Unlikely To Come Down A Lot Soon
- International Oil Demand
 - US Imports ~ 20 M Bbls / Day
 - China Imports ~ 6 M Bbls / Day
- Global Warming (Limit For Coal)
- Hubbert's Peak
- 1978: Moral Equivalent Of War - What Happened?
1978 - \$20+/Bbl, *But By 1985 – \$8-9 / Bbl*
"Stay Alive Through '85"
 - This Time We Have Low Interest Rates
And Relatively High Oil Prices Are Probably Permanent

4

We saw this in '78, and I don't think having MEOW as the acronym was the only reason Carter's initiatives died.

In the words of Yogi Berra, this may be déjà vu all over again, but maybe this time it's different.

However, one of the most important changes is low interest rates. In 1978, I was lucky to get a 12% mortgage. Paying a lot of money up front to get free energy just didn't make sense, especially when OPEC was artificially holding down production and could – and did – open the taps any time.

Alternative Energy Goals

- US Fossil Fuel Use, 2004 (Coal, Oil, Natural Gas) = 88.5×10^{15} BTU/Year
- Solar Energy ~ 700,000 BTU/Ft²/Year
 - 4300 Square Miles At 100% Efficiency
 - Equivalent to Just Fort Dix and White Sands, NM
- Economics - Competition:
 - Oil, 2004 = 80,000 BTU/\$ (Maybe 40,000 Now)
 - Coal, 2004 = 720,000 BTU/\$
 - Natural Gas, 2004 = 130,000 BTU/\$
- Economics – External Effects:
 - Greenhouse Gas Credits Could Shift Economics
 - Third World Applications Have Different Economics (And We Can Use The Oil They Don't)

5

This is where we are, and at a first glance, it is pretty scary. In 2004 the US used almost 89 quads of fossil fuel derived energy, that's 88.5 quadrillion BTU.

This seems like an enormous number, but compared to the solar resource, it is doable.

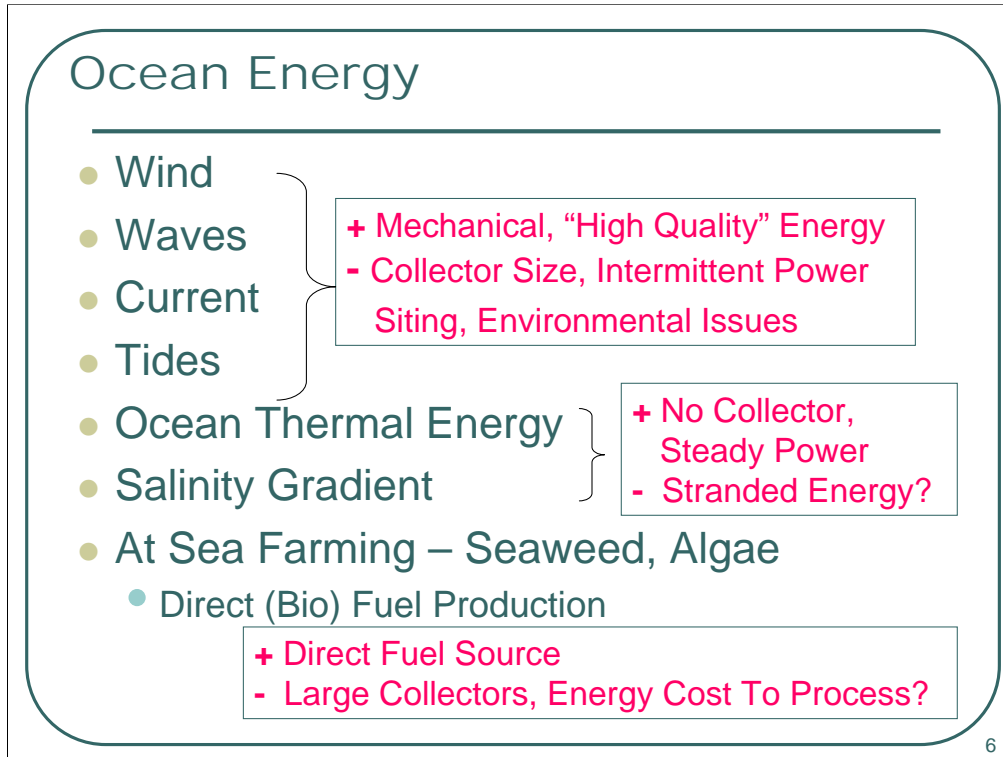
The key is economics, and it's worth looking at the comparison, again based on 2004 data.

These are our goals to get alternatives competitive, but this what engineers do. It's said an engineer is someone who can do for one dollar what any fool can do for two.

As regards economics though it's important to note that there are a couple of other boosters.

First, if carbon trading becomes a real market, alternatives have a secondary source of income that might balance higher costs.

Second, we can look at economics anywhere, because energy is fungible. If we can come up with a solution that works in a third world country with low cost labor and lots of sun, giving it to them benefits us, because we can use the energy they save – and sell them stuff that low local energy costs allow them to afford.



Why ocean energy?

The simple answer is real estate – most of the earth’s surface is ocean, so most of the earth’s solar energy falls on the ocean. The ocean also provides, naturally, various mechanisms to collect, concentrate and transform that energy into something that might be more useful.

The oceans are a heat engine that transforms solar energy into the kinetic energy of wind, waves and current. (Tides of course are gravitational energy, not heat, but still energy.) This high quality energy is very useful, but it’s intermittent, it requires more or less large collectors, and has siting and environmental issues.

OTEC and salinity eliminate the heat collector, but they tend to be in distant locations.

One of my favorites is various farming schemes, because biological systems make fuel directly and manufacture themselves.

Wind

- Well Established Technology
Fully Competitive – But:
 - Landside Impacts: Noise, Bird/Bat Kills, Visual Impact, Only So Many Good Sites
Land Sites: Funneling - Larger Variation
 - Offshore: Visual Impact, Vessel Navigation
- Most Systems Are Bottom Founded
 - Cost Of Ocean Platform = Depth³
 - Solutions From Offshore Oil – Floaters?
 - Spar Platforms
 - Tension Leg Platforms
 - ***Jobs For Shipyards?***

7

Wind is well established and even cost competitive now. There are existing ocean wind farms off Europe and some proposed for the coast off the US.

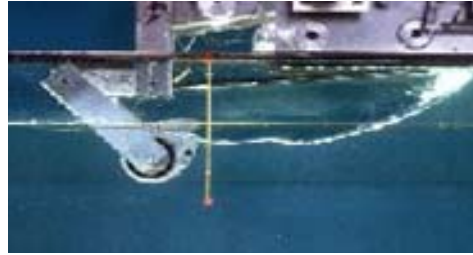
This is an example of who marine people can help right away. First, we know how to install ocean platforms and have a lot of experience that wind farmers might draw on.

Also many of the issues of coastal wind farms can be fixed by moving them farther offshore, but the cost of a bottom founded platform goes up with the cube of water depth.

Well, this is a problem the offshore industry faced twenty years ago, and I would suggest that the solutions, Tension Leg Platforms, Spar platforms and other systems well proven in ocean engineering might be useful, might address costs, and might provide jobs for naval architects and shipyards.

Wave Power

- $E = \frac{1}{2} \rho g \lambda_a^2$ (/Area)
- $E = \frac{1}{2} \rho g \lambda_a^2 L_w$ (/Breadth)
- 40 – 70 Watt/m² (Annual)
1.2 Million BTU/m²/Year
- Energy is Half In Height
Half In Orbital Velocity
- Pick Up Orbital Velocity Energy And Height
- *Salter's Duck* – 70% – 80% of Wave Energy
- Size Matched To Wave Frequency ~ 8 Meters
Hence Each Duck = 2 – 3 KW+
- Alternative Roles: Breakwaters, Auxiliary Power,
Mitigating Water Pollution / Sequestering CO₂



8

One of my favorites from the 70's, and earlier is wave power, because again it is mechanical, it is easy to harvest, and it is another place where proven offshore techniques for providing platforms and for anchoring them. In addition I would suggest that naval architects, if anyone, are experts in waves and their effects on floating bodies.

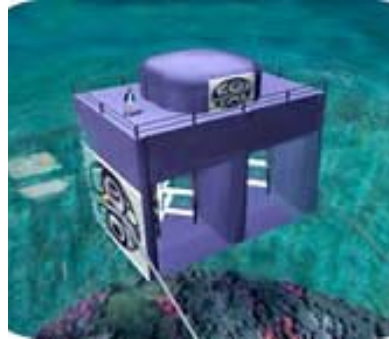
Salter's duck is one of my favorites, because it is efficient and harvests both the kinetic and height energy.

I mentioned thinking about combining technologies, and here again there are opportunities. Though Salter's ducks or other systems may not be useful for direct production of power in some cases, they may have other related roles. One favorite is a floating breakwater – how cool would it be to install a marina breakwater that was not only cheaper, but provided the parking lot lighting too.

Another role might be mitigating pollution by pumping air into deep water. This would address increase nutrient runoff from land farming of energy crops and might even help sequester CO₂. The CO₂ cycle includes vast amounts of carbon removed as calcium carbonate sediment from species that have shells. This is cycled into the earth as limestone to remerge in millions of years through vulcanism.

Current

- Denser Medium:
More Power/Unit Area
- Slower Speeds:
3 – 8 Knots vs. 12 – 30
- Power = $800 * (6 / 20)^2$
= **72 X Wind**
- Possibly Limited Sites?
- Environmental Impacts?
- Similar Platform Issues As Wind



Blue Energy Canada Inc.

Current is another energy source.

Tides

- Well Understood Technology
 - Two Way Dams – Conventional Hydropower
 - Tidal Currents
- Predictable Power Flow
- Limited Sites
- Major Civil Engineering Works
 - Very Expensive
 - On Limited Shoreline
 - Impact On Species
 - Impact On Silt, Etc.

10

There have been many schemes to harvest tidal energy.

Ocean Thermal Energy

- **Strengths** Exploits Thermal Difference Between Cold Deep Water & Warm Surface Water
 - Steady Power
 - Energy Collector Is The Ocean Itself
- **Weaknesses** *Can We add Solar Collectors?*
 - Small Thermal Difference = Poor Efficiency
 - Enough Power To Carry Overhead?
 - Need Very Deep Water, In Tropics
 - Limited Sites, Far From Shore
 - Anchoring, Using The Power (Na *Powerballs*™?)
 - Cold Water Pipe Is A **Big Challenge**
 - Environmental Impacts (Good Or Bad?)

11

I worked on OTEC myself, in 1978, and there have been ongoing efforts ever since. We will have a couple of presentations on OTEC as well, so I'll leave it to them, except to note that I see a big opportunity in figuring out how to use the "stranded energy".

I personally like *Powerballs*™, which are little coated balls of sodium, made from seawater by electrolysis. When they are placed in water they evolve hydrogen, so they are a scheme to store hydrogen in a relatively dense medium – eleven pounds of sodium produces a pound of hydrogen, and the density of sodium is about the same as water. Since hydrogen has about six times as much energy per pound as gasoline, this might be a feasible solution for hydrogen storage.

There is some concern about the environmental impact of OTEC, but it might be beneficial, bringing nutrients to the surface and increasing the take up of CO₂ by the deeper oceans. (This is also part of the CO₂ cycle but natural deep ocean sequestering is too slow to help much with climate change.)

Salinity Gradient

- Osmotic Pressure Difference Between Salt and Fresh, and Salt and Saltier
- High Quality, Concentrated Power
Equivalent To 780' of Hydraulic Head (SW / FW)
Extracted By Vapor Turbines, Hydraulic Turbines, or Dielectric Batteries
- Three Sources:
 - Fresh Water Runoff From Shore
 - Salt Domes (Much More Head – SW / Brine)
 - Solar Desalination (SW / FW **or SW / Residual Brine**)
- Membranes, Environmental Impact Are Challenges

12

Salinity gradient provides and enormous amount of energy, and in useful forms.

One interesting idea is to combine solar desalinization with salinity gradient. Fresh water would be made by evaporating water out of floating rafts, using sunlight, and the gradient between the residual brine and the sea would be used for energy.

At Sea Farming – Seaweed

- Farming Giant Kelp (*Macrocystis*) At Sea
 - Kelp Growth Mainly Limited By Anchor Points
Provide Floating Frame With Artificial Anchors
 - Crop Every Six Months
 - Yield (*Ocean Food And Energy Farm Project*):
200-400 Tons/Acre = 200-400 MBtu/Acre/Year
- Main Challenge: Conversion To Fuel
 - 70% Water (*Energy Costs To Dry*)
 - 40-50% Remainder Long Chain Carbohydrates
Must Be Digested To Sugars, Converted To
Methane Or Alcohol (*Energy Costs To Distill*)

13

Ocean farming of kelp has been proposed

At Sea Farming – Algae

- Where Oil Came From In The First Place
 - Why? Algae Need To **Float**, And **Store Energy**
One Strategy Is To Make Hydrocarbons
- *Botryococcus Braunii*:
 - Blue Green Denitrifying Algae, Found In Oil Shale, Up To 40% Dry Weight
 - C30-C37 Triterpenes 
 - Theoretically 10% Efficiency, Sun To Fuel - \$1.50/Gal
 - Could Use Agricultural Waste, Sewage
- Why Ocean Farming?
 - Real Estate Required: 20 MBbls/Day = **Half Of Nebraska**
 - Fresh Water Is Limited – Use Salt Water Species
 - Agitation Increases Yield – Use Wave Power
- How: Floating Trays? Floating Flexible Tubes?

14

Another one of my favorites is ocean farming of the critters responsible for making oil in the first place.

This is an impressive potential resource, since it is very efficient as biological process go, since the critters in question spend a great deal of their efforts in making hydrocarbons.

It is interesting for a naval architect to look at these algae, because it is another example of nature anticipating a human invention, in this case the bathyscaph.

Conservation

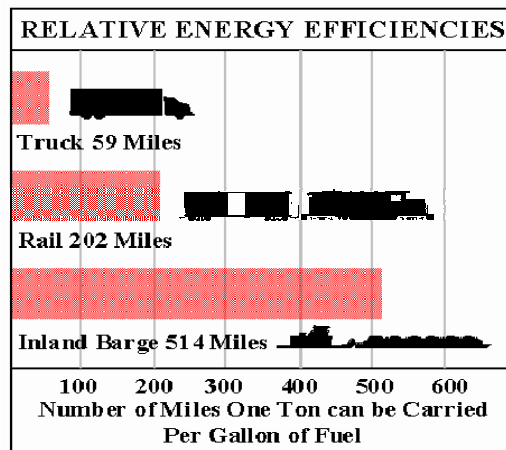
- Energy Is Fungible –
Save It Here, Spend It There
- Often The Cheapest “Source”
 - Off The Bottom Line – After Efficiency Losses
- Conservation By Mode Switch:
Move Transport To Marine Modes
 - Short Sea Shipping
 - Passenger Ferries
 - Fast Sea Freight
- Conservation Aboard Ships

15

Many environmentalists like to point out that conservation is a source of energy as well, and a good one, because it is off the bottom line – saving an additional dollar out of your paycheck is always better than making a dollar up front before taxes.

Short Sea Shipping

- **Strengths**
 - Saves Energy
 - Reduces Highway Congestion
 - Reduces Personnel Costs
 - Truck: 2 TEU
 - Barge: 1000 TEU
- **Weaknesses**
 - Stevedoring Costs
 - Intermodal Logistics (Business) Issues



16

Short sea shipping is another opportunity for naval architects and ship builders.

Short Sea Shipping Opportunities

- **Integrated Sea/Land Logistics Businesses**
 - Shippers Need A Single Solution Offering Door-to-Door Service
- **Innovative Loading Systems**
 - Truck Trailer RO/RO?
- **Current Proposals**
 - California: Conventional Small Boxships:
 - Containers Outbound From Long Beach, Oakland
 - East Coast, "W 95" (Mainly To Reduce Congestion)
 - Box On Barge From NJ
- **Challenge: Terminal Facilities**

17

The opportunities in short sea shipping are mainly business innovations, though innovative loading is another key.

There are a number of current proposals for new short sea shipping enterprises.

The big challenge I see is getting access to terminal facilities.

Passenger Ferries

- Urban Ferry Systems
 - Reduce Congestion, Pollution, Save Energy?
 - Current WTA (San Francisco):
Energy Use, Car vs. Ferry is About Equal – Now
But – Slow Down, Increase Ridership
 - Single Occupancy Car: 7,000 BTU/Pax-Mile
 - *Peralta* (26 Knots, 331 Pax), 50% Load: 4,560 BTU/Pax-Mile
 - *Bay Breeze* (26 Knots, 250 Pax), 50%: 2,420 BTU/Pax-Mile
 - 18 Knot Berkeley Ferry, 50%: 1,030 BTU/Pax-Mile
- Can Fast Marine Transport Compete With Air?
 - PAR/WIG – Reduce Fuel, Reduce Airport Congestion
AVOID FAA REGS ! (Especially For Island Hops)

18

Passenger ferries have possibilities for energy saving too.

Aircraft are always going to be energy intensive, at least compared to anything running on the sea. There may be some opportunities here especially with passenger carrying Wing In Ground craft.

The other advantage of WIGs is that they are not regulated by the FAA. This is enough to make huge operating cost differences.

Fast Sea Freight

- Fast Sealift To **Save Energy?**
- Shift The Paradigm:
Not High Cost Sea Transport,
Low Cost Competition For Air Transport
- Use Advanced Hull Forms
 - Trimarans
 - Partial Hydrofoil Support
 - Very Slender Hulls
 - SES, SWATH, Etc.
- Nuclear Propulsion (McKesson, *Fast '99*)

19

Likewise fast sea freight is another opportunity. This seems strange, since fast ships are energy hogs of the worst sort ... but not compared to aircraft.

There are also a lot of systems to go fast with less power.

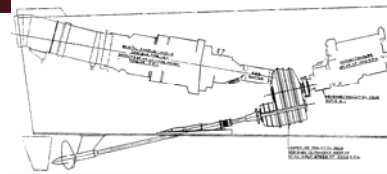
Conservation Aboard Ships

For who hath despised the day of small things?

Zechariah 4:10

- **Many Proven Answers**

- Stern Flaps: 8-15%
- Combined Propulsion
- Combined Cycles
 - Steam Bottoming
 - Steam Injected Gas Turbine
 - Waste Heat Use (*Servel AC*)
- Better Hull Forms
CFD Optimization,
- Advanced HS Craft (Hybrid Hydrofoils, Etc.)
- Longer, (Steel Is Cheap) Narrower, Slower
- The Return Of Steam? (Alternative/Low Quality Fuels)
- Sail Assist
- Many, Many Other Ideas



20

We all know or may even have studied ways to reduce energy on shipboard. In each case we know how to do it, and it's just a matter of wanting to.

Where Do We Go From Here?

- Be Mindful Of Conservation Aboard
Walk the Talk
- Contribute To The Dialog
 - SNAME Alternative Energy Panel
- Be Prepared For “Incoming” Roles
 - Coast Guard Regulation
 - ABS Certification – *Not Only For Offshore*
 - Certification Of Landside Systems
 - Carbon Credit Auditing
 - Service Vessels
 - Landside Engineering Opportunities
- Your Ideas - Please

21

So what do we do now?

Thank You

Chris Barry