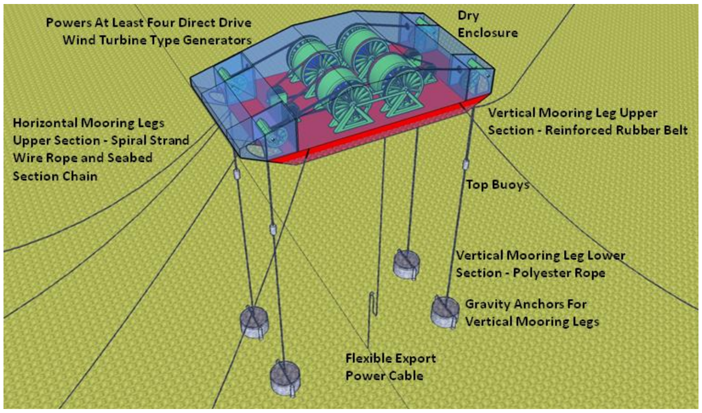
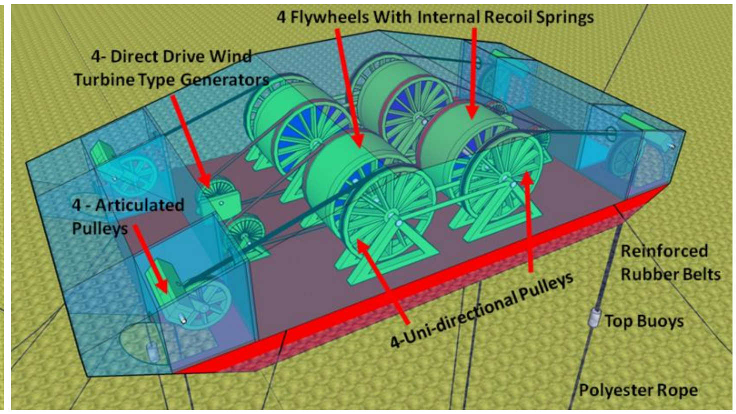
Super Watt Wave Catcher Barges

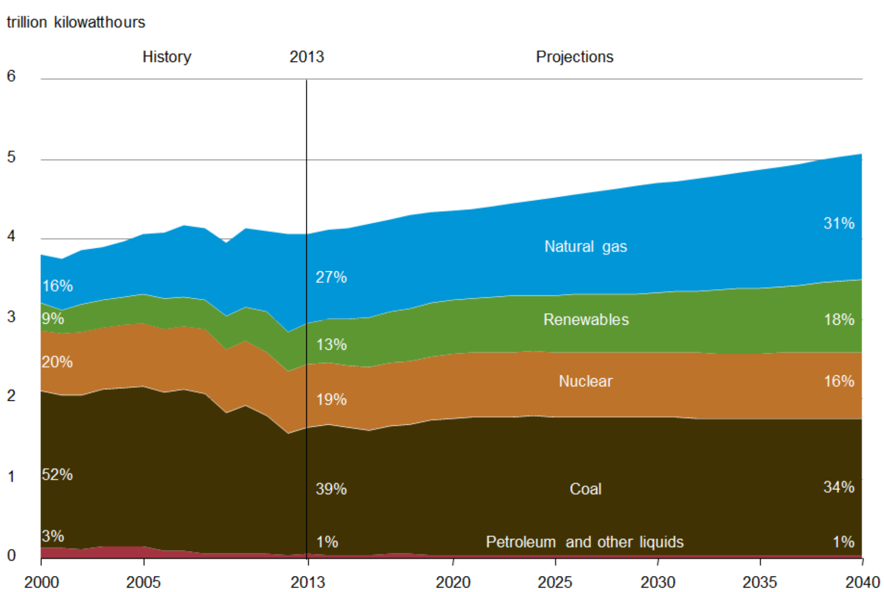




Super Watt Wave Catcher Barges (SWWCBs) are Wave Energy Convertors designed to harness ocean wave energy at the lowest "Levelized Cost Of Electricity" (LCOE) of all new power plant options and to do it safely for maintenance personnel and the environment and to do it reliably for decades.

Note US DOE power generation projections below: (Source http://www.eia.gov/forecasts/aeo/section_elecgeneration.cfm)

Figure 31. Electricity generation by fuel in the Reference case, 2000-2040



which indicates that renewables and natural gas are expected to grow and all other forms of power are expected to decline in the next 24 years. Table 1 below (**http://www.eia.gov/forecasts/aeo/electricity_generation.cfm)** considers Capacity Factors, Levelized Capital Costs, Fixed O&M, Variable O&M (including fuel), Transmission Investment, and Subsidies and is based on U.S. average levelized costs (2013 $/MWh) for plants entering service in 2020.

Table 1 Below Orders The New Power Generation Plant Options From Lowest to Highest LCOE

1.	Geothermal	47.8
2.	Advanced Combined Cycle Gas	72.6
3.	Land Based Wind	73.6
4.	Conventional Combined Cycle Gas	75.2
5.	Hydroelectric	83.5
6.	Conventional Coal	95.1
7.	Advanced Nuclear	95.2
8.	Biomass	100.5
9.	Solar PV[3]	125.3
10.	Wind – Offshore	196.9
11.	Solar Thermal	239.7

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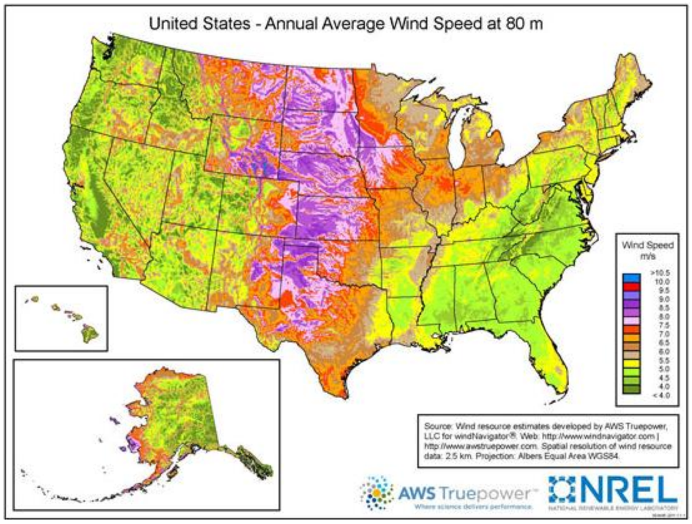
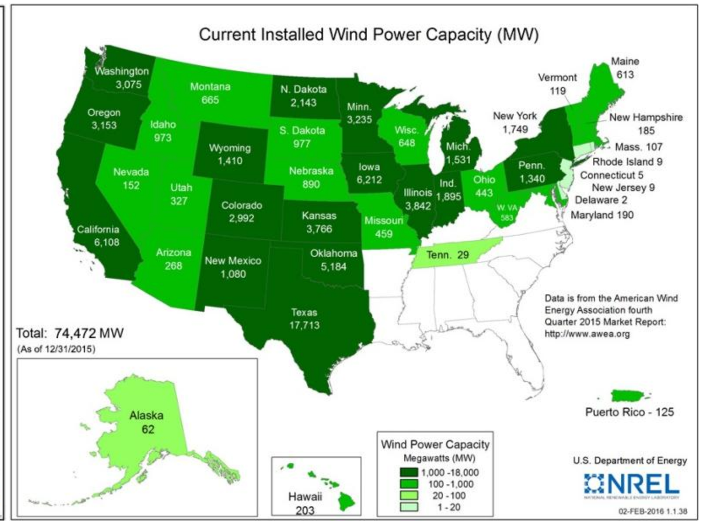
Geothermal opportunities are rare. New gas power plants have the current advantage of lowest fuel gas costs in recent times and are especially attractive in areas of low wind resources, but they still produce significant emissions. Land based wind has a similar low LCOE to gas in areas of significant wind resources like the central portion of the USA where the wind resources are high, they do not produce harmful emissions and are not subject to future rising gas prices.





Note that there have been very few wind turbines installed along the East Coast of the USA where the wind resources are the lowest. Ideal land based wind power resource opportunities are also few on the West Coast. Conclusion: The US East and West Coasts provide good wave power plant opportunities if they have low LCOEs.

The Super Watt Wave Catcher Barge patent was filed in the US on April 10, 2014 and received notice of approval approximately 3 months later with no questions or changes. It subsequently has received approval in Korea, Taiwan, Japan and soon China.

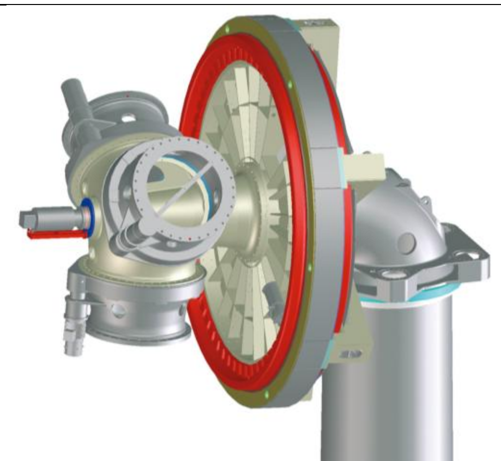
We call it the "**Super Watt** Wave Catcher Barge" (SWWCB) because it provides the highest power output per floating unit of all Wave Energy Convertors (WECs) minimizing all costs associated with installing numerous smaller output individual WECs. Like wind power plants, SWWCBs will be sized for the environmental resource and equipped with generators that match the expected power output of the resource. Higher and higher output wind turbine generators keep being developed, currently today as high as 15 megawatts / generator. SWWCB design efforts to date have been based on the use of four 6 Megawatt direct drive generators for installation off the Oregon and Washington West Coasts. SWWCBs can be designed to handle these new very large generators for installation in even higher wave resource locations than the US West Coast.

SWWCBs are structurally designed for 100 year return period storms and to return to full operation immediately after these major storms. SWWCBs are designed to: the latest codes, guides and standards; to provide decades of reliable service; to cause no pollution; to be friendly to the environment and marine life; to be accessed quickly by helicopter or boat; to use proven technology and to use proven components like proven direct drive wind turbine generators.

Direct Drive Generators:

Super Watt Wave Catcher Barges (SWWCBs) use direct drive generators, like those used in the latest wind turbine power plants. Direct drive generators are very efficient, are readily available, do not require gearboxes, do not have the mechanical losses associated with gearboxes and they are able to generate their maximum power output at low RPM. Direct drive wind turbine generators are turned directly by their rotors. Direct drive SWWCB generators are turned by the SWWCB vertical mooring lines. The SWWCB vertical mooring lines turn 12 meter OD uni-directional pulleys, that wind large recoils springs located inside 12 meter OD flywheels which turn the approximate 6 meter OD direct drive wind turbine type generators.

Enercon E-126 – 7.58 MW Direct Drive Wind Turbine Annular Generator



Rotors and Flywheels:

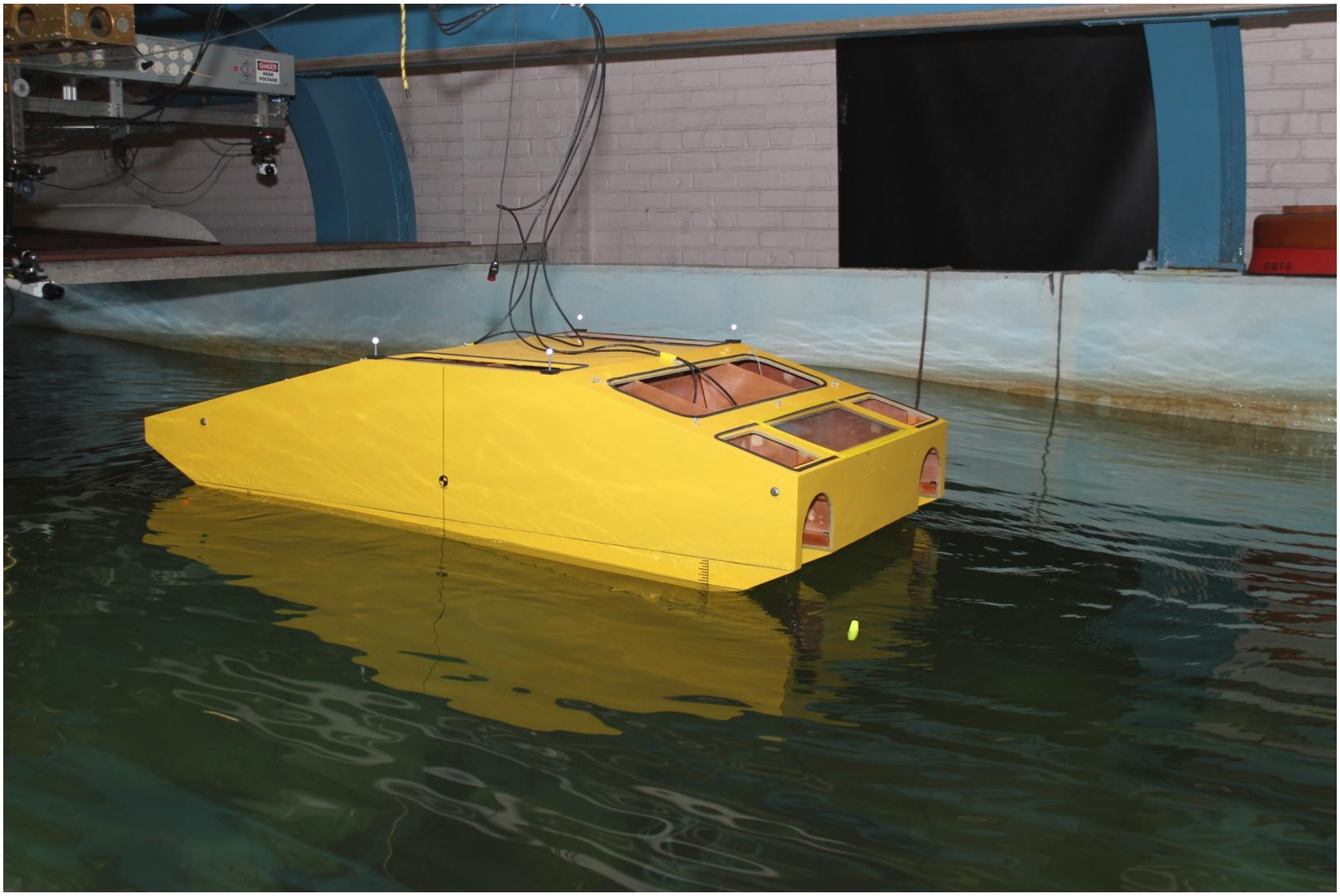
The wind turns wind turbines' rotors and almost always present long period swell waves lift up the SWWCBs causing their vertical mooring lines to turn the SWWCB's generators. Swell wave pressure loads imposed on the large flat bottom area of the SWWCBs cause very high loads in the vertical mooring lines on the order of 500 to 1000 metric tonnes. The high mooring loads pull on the perimeter of the 12 meter OD uni-directional pulleys and temporarily store very high torque with very low looses in the recoil springs located inside the 12 meter OD flywheels. These recoil springs continuously releasing their stored torque very efficiently to 12 meter OD flywheels that store the torque efficiently in the form of momentum in the same way that the wind turbine rotors store torque. The flywheels turned at a fairly constant RPM delivering their stored torque to their direct drive generators in a fairly uniformly manner. When the waves lift up the SWWCBs they also move the SWWCBs horizontally resulting in even higher loads in the vertical mooring lines and longer strokes. Thus the SWWCBs capture both vertical and horizontal wave energy very efficiently and the form of vertical mooring line load and translate that load into very high stored torque that is many times the torque needed by the direct drive generators at their maximum power output. Since the torque is only introduced to the system from the wave trough to wave crest, this high excess torque is temporarily stored in the recoil springs and flywheels for fairly uniform delivery to the generators.

Enclosures:

Wind turbine direct drive generators are protect inside Nacelle enclosures at the top of their towers. The Nacelle are sometimes as high as 150 meters above the ground and require mountain climber type maintenance personnel. SWWCBs also protect their direct drive generators inside a dry water tight enclosures, which are safe and spacious working environments to the highest offshore standards. SWWCB workers do not need to be mountain climbers. One wind turbine tower, its Nacelle and all of its support equipment only supports one generator. One SWWCB with its enclosure supports 4 or more direct drive generators and their support equipment.

US Department of Energy Sponsored Model Testing At Stevens Institute

US Department of Energy Sponsored_1/50th scale model testing took place at Stevens Institute in December 2015 and confirmed the time domain analysis predicted high mooring loads expected for the 31 operational load cases carried out. The mooring leg loads confirmed the high torque that normal operational waves place on the uni-directional pulleys, store in the recoil springs and flywheels and transfer to the direct drive generators in a fairly uniform manner. The following is an SWWCB model test photo.



The Benefits of Using Readily Available Existing Components:

SWWCBs benefit from economies of scale by using readily available existing components including: the direct drive generators, the barge structure, the mooring chain, the mooring ropes, etc., allowing the SWWCBs to be built and maintained at the lowest possible cost, which is usually not possible with most other unique marine energy generating devices.

Designed For Low Mechanical Losses

The SWWCB's are designed for low mechanical losses. Direct drive generators eliminate gear boxes and their friction losses. Large diameter pulleys and flywheels and low friction roller bearings minimize bearing losses. Future developments will include the use of a CVT type viable pulley diameter arrangement between the flywheel and the direct drive generators to insure peak operating performance under the varying range of wave conditions.

Capacity Factors:

Land based wind turbine generators operate roughly at 30% of their capacity in ideal locations like the middle of the USA, but at a much lower capacity factor in the East or the West Coast States of the USA resulting in their low power contributions in these States. Wave generators, on the other hand, should operate at 60% of their capacity off both coasts and possibly higher the further offshore. Like in many parts of the world, the population density is often the highest along the coastal zones increasing the power demand where wind power is the lowest and wave power potential is high. Normal operational wave conditions on the US East and the West coasts are large enough to generate the maximum power capacity of four 6 megawatt direct drive wind turbine type generators.

Some WECs have LCOEs:

Some Wave Energy Convertors (WECs) have already been developed and tested at full scale that have promise to have LCOEs as low as onshore wind power. However, large farm installations, associated grid connections and power agreements are slow in most parts of the world, especially in areas with high environmental concerns like in the USA. Environmental concerns include the impact the WECs will have on: marine mammal migration routes; sounds affecting marine life, fishing ground losses, etc.

SWWCBs have the following advantages over other WECs:

- Estimated to have lower CAPEX costs than land based wind power and similar OPEX costs to land based wind power.
- Should operate at about 60% of their nameplate capacity, which is a much higher capacity factor than the 10% capacity factor of land based wind within about 500 miles of the East and West Coast of the USA. Land based wind in the best locations in the USA, like the middle of the USA, has capacity factors as high as 35%.
- With low CAPEX, low OPEX and a high capacity factor (6 times that of coastal states land based wind), SWWCBs should be the new power generation power plant of choice for the US East and the West coastal zones and further inland with new low loss long distance transmission lines.
- SWWCBs can be designed to last for over 30 years and designed to survive the worst 100 year return period offshore conditions resulting in high long term power reliability.
- SWWCBs use flat plate barge construction which is available all over the world providing the simplest and lowest cost form of floating marine structure.
- SWWCB's large flat surface areas with high drag coefficients capture the maximum possible vertical and horizontal wave energy. Higher drag coefficients are feasible for small extra costs.
- Barges are proven marine structures that have been used for centuries.
- Barges have transported cargo across the oceans of the world for almost a century in extremely high storm environments.
- Waves lift up the SWWCBs causing their vertical mooring lines to wind recoil springs inside large flywheels. The recoil springs and the flywheels temporarily store wave power in the form of spring loading and momentum in the same way that rotors store wind energy in the form of momentum for wind turbine generators.
- SWWCBs can be anchored in shallow water to ultra deep water allowing large portions of the ocean's wave energy to be harvested.
- SWWCBs can be anchored with a fixed heading mooring or a weathervaning mooring for maximum power output at all times.
- SWWCBs capture both horizontal and vertical wave energy for maximum power output.
- SWWCB's have two mooring systems, a vertical mooring system for power generation and a horizontal mooring system for storm survival.
- The vertical mooring system's pretension will either be remotely reduced or slacked off prior to storm conditions to prevent vertical mooring line overloading. The vertical mooring system will also be protected from overload by limiting the weight of its gravity anchors to less than the vertical mooring line load capacity. Gravity anchors are low costs, can be installed quickly and can be used for most seabed conditions.
- The horizontal mooring system can used the widest variety of anchoring systems successfully used by the offshore industry for decades. The loads on the SWWCB's horizontal mooring lines will be well under the high loads required of the offshore industry's mooring systems.
- The horizontal mooring system can also be slacked off remotely during operating conditions to maximize the SWWCBs power generation capacity. The horizontal mooring system can also be remotely pre-tensioned prior to storms for optimum performance and allowing its length to be minimized to reduce costs.
- Power will be exported via flexible power cables that have been used in a similar manner by the offshore industry for decades. These flexible power cables drape configurations developed by the offshore industry minimize loading and fatigue on the export power cables and allow the vessel to move freely during storm conditions.

Conclusion:

Some Wave Energy Convertors (WECs) have already been developed and tested at full scale that should have LCOEs as low as onshore wind power. SWWCBs should have the potential of having lower LCOEs than all full scale WECs tested to date due to the many factors presented in this paper.

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