Energy from the Oceans: A New Renewable

Summary:

As oil supplies dwindle and as the carbon footprint of coal and gas becomes unacceptable, developing a diverse and robust portfolio of renewable energy sources for the future is becoming increasingly compelling.

Oceanic sources, largely untapped, can play an important role in such a portfolio.

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Center for Ocean Energy Technology
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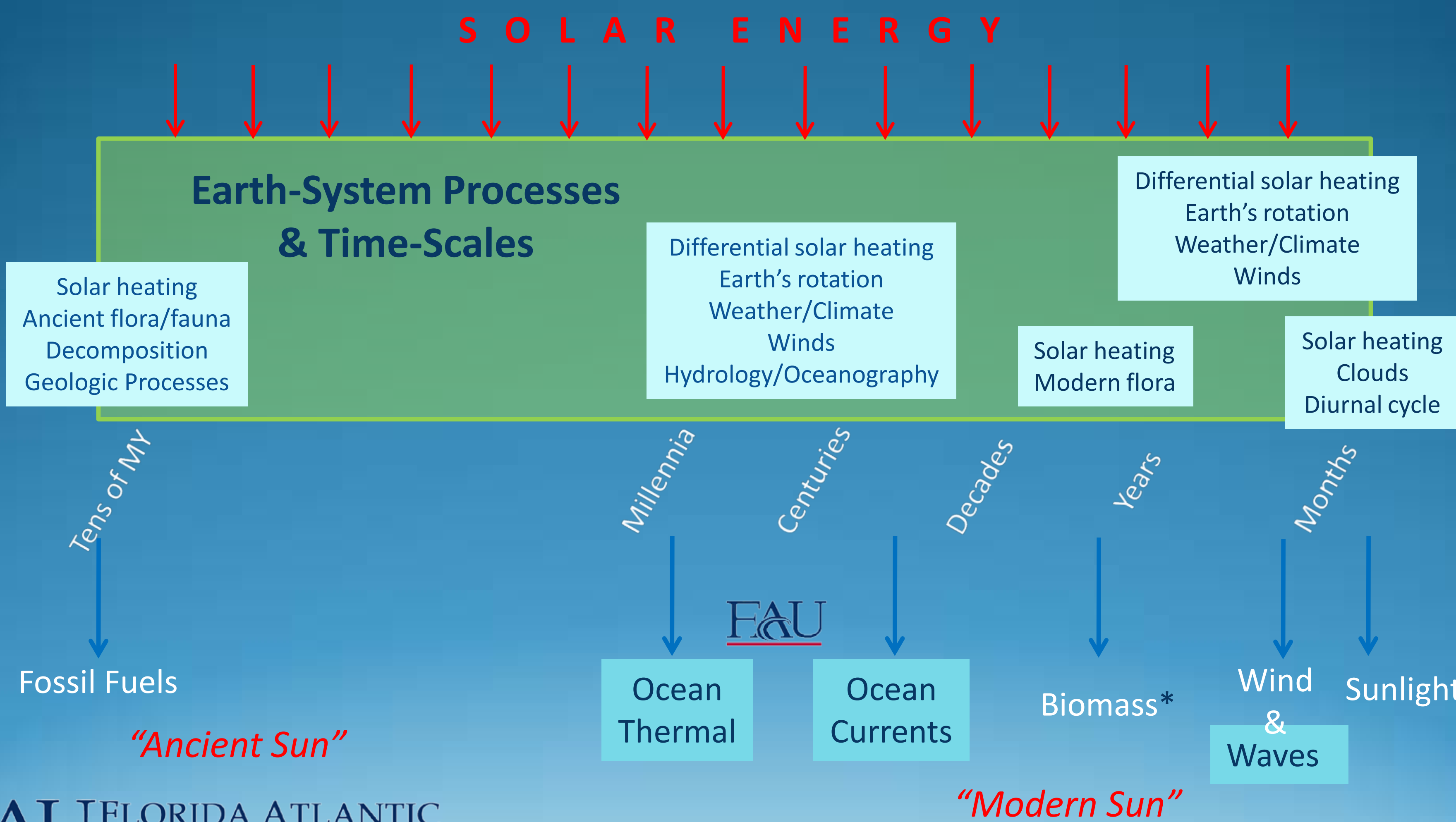
Whence Energy?

Ultimately, all of the energy we use is derived from three basic sources (increasing order):

- gravity (tides) ← Oceanic source
- nuclear fission (geothermal & power plants)
- nuclear fusion (in the Sun, so far)

But where, you ask, are fossil fuels?

Sunlight Conversion



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Oceanic Sources

In terms of Earth's time scales, then, the *physical* oceanic energy sources are:

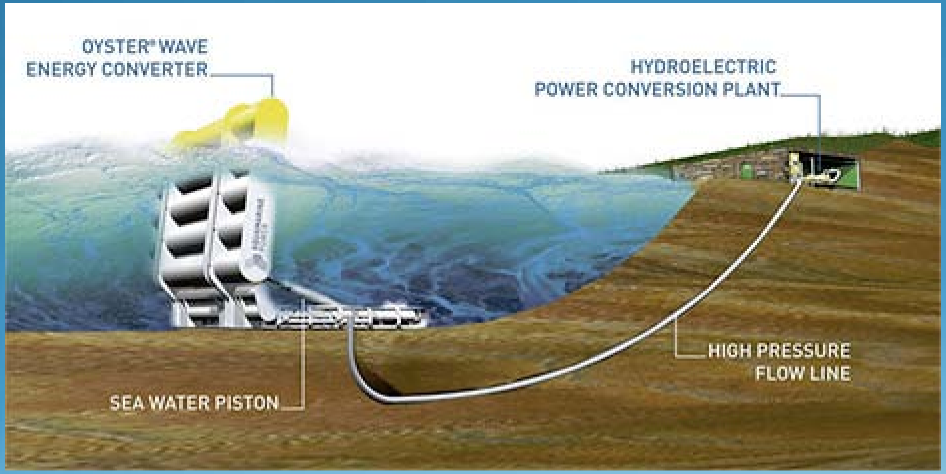
- tides (hours to days)
- waves (days to months)
- currents (months to decades)
- temperature differences (decades to millennia).

COET, in an FAU-wide effort, is focusing on the last two of these. In addition HBOI is investigating algae as a biofuel.

Wave Technologies

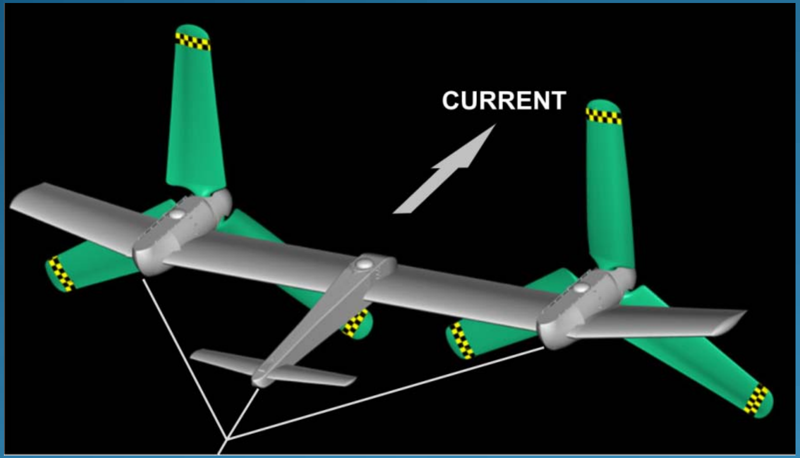
De vices convert wave displacement into another form of energy (e.g., hydraulic);

Production depends on wave height and frequency.



Continental west coasts are best locations.

Current Technologies



Applies to both tidal and open-ocean currents; works like wind turbines underwater.

Tidal channels: shallow, but water changes direction;
Open-ocean: unidirectional, but water is deep.

Thermal Technologies

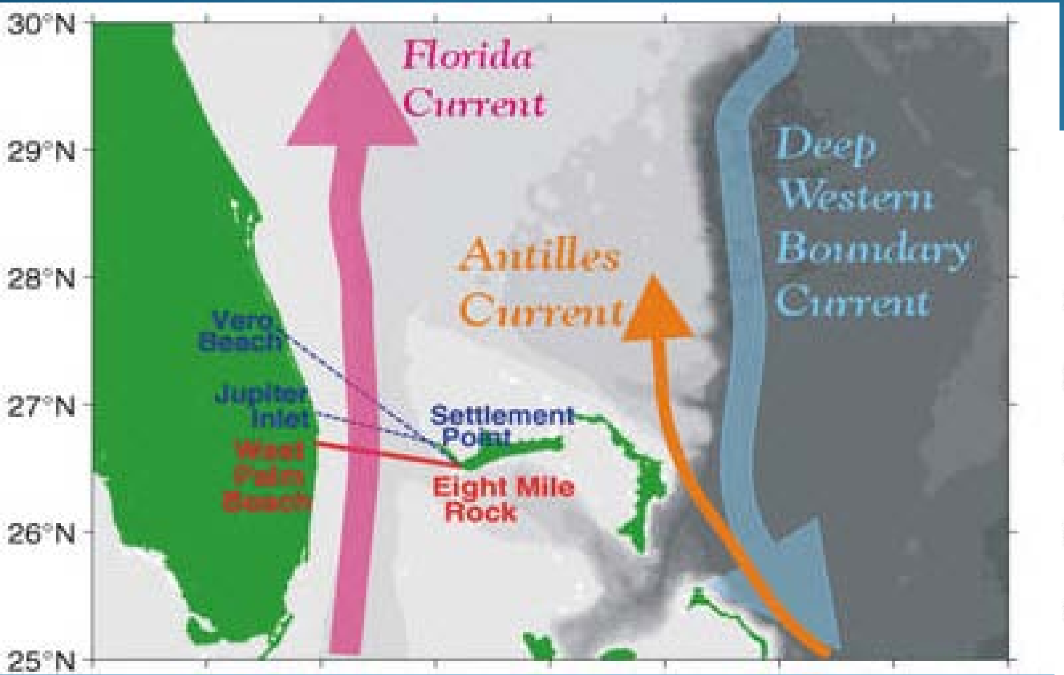
Ocean thermal energy conversion (OTEC) uses temperature differences to drive a *Rankine cycle,* just like a conventional power plant but with a different working fluid such as ammonia.

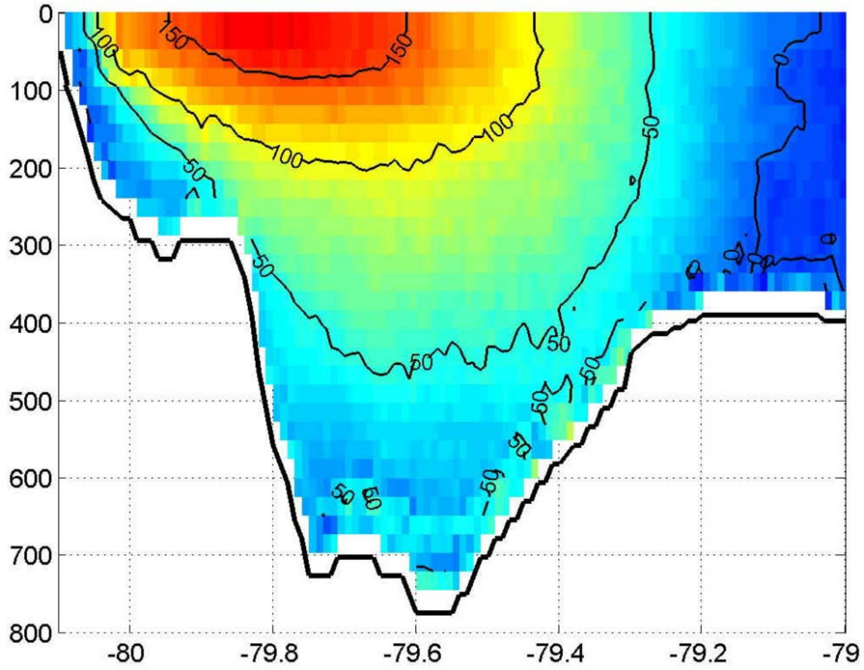
A test facility in Hawaii has been under development for years.

Thermal potential is the largest of all, and Florida is a prime location (water is renewed by Gulf Stream flow).

In Florida...

...the waves are tame;
...the tides are weak;





...but we've sure got current.

Moreover, we have a significant thermal potential as well.

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The Challenge

The fundamental question is:

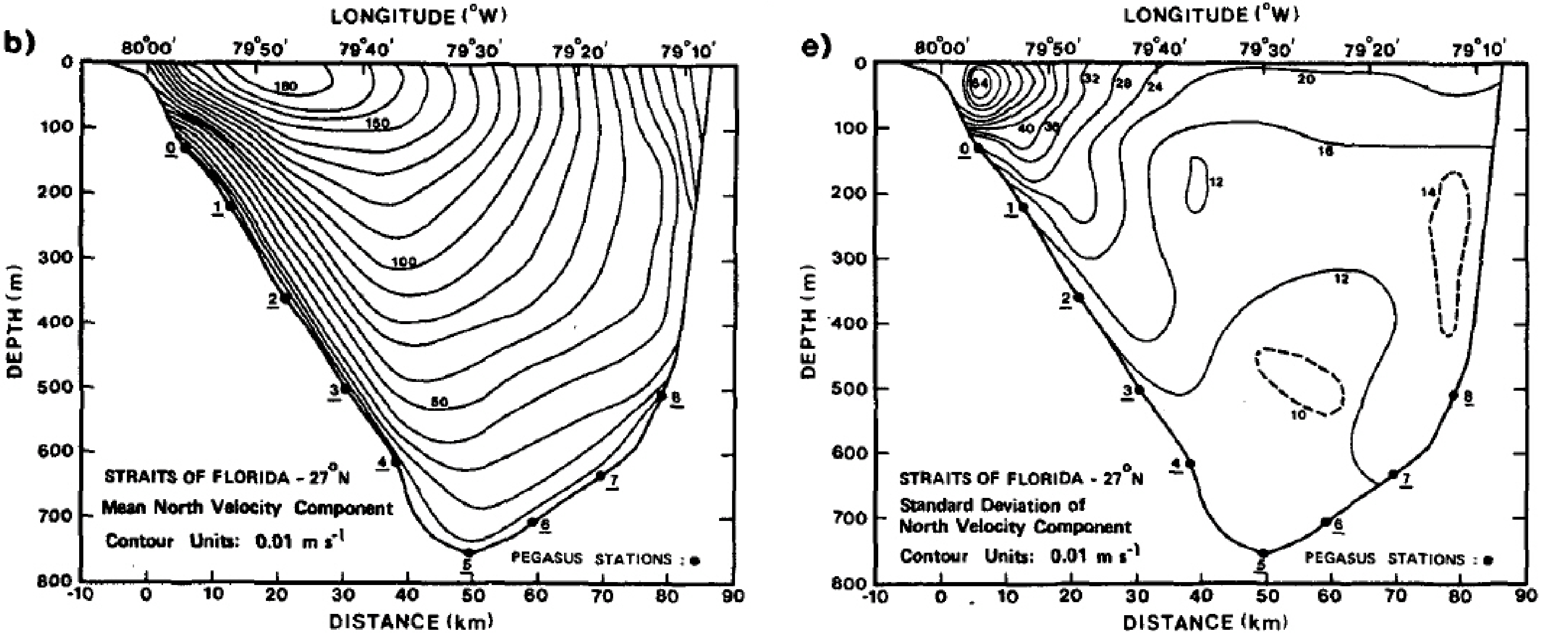
Is there enough power out there to make this economically feasible?

Clearly, the first part of an answer concerns how much power is available and accessible.

Oceanographers have been studying the Florida Straits for decades, but not from the power perspective.

For Example

Northward flow measurements



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From: K.D. Leaman *et al.,* 1987: Structure and Variability of the Florida Current at 27°N: April 1982 – July 1984. *J. Phys. Oceanogr.* **17**, p. 565ff.

Power

The power that can be obtained from a simple turbine can be written as

$$P = \varepsilon \, \mu_B \, A \, \rho \, v^3 / 2$$

where:

- P is power (W)
- ε is the efficiency of the particular unit
- μ_B is the *Betz coefficient* (=0.59)
- A is the area swept by the rotor's blades (m^2)
- ρ is the fluid density (kg/m^3)
- v is the fluid velocity (m/s)

Power & Force

The power for a given device, then, is proportional to the fluid's density times the cube of its speed, i.e.,

$$P \propto \rho\, v^3$$

Consider:

- For the atmosphere, $\rho \approx 1$ and $v \approx 10$;
- For the ocean, $\rho \approx 1000$ and $v \approx 1$;

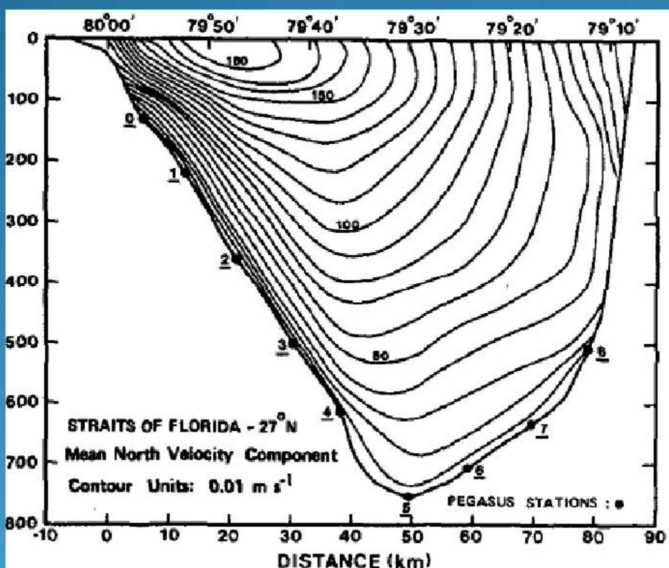
so the power per unit area is about the same.

But force varies as density times the square of the fluid speed.

→ **What does this imply?**

Incentives

Turbines that are able to operate at lower speeds will obviously have an advantage.



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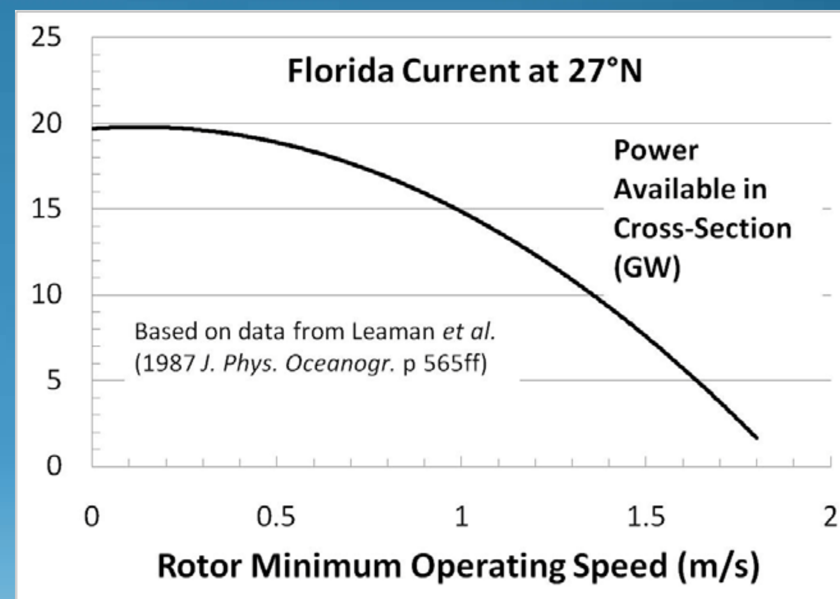
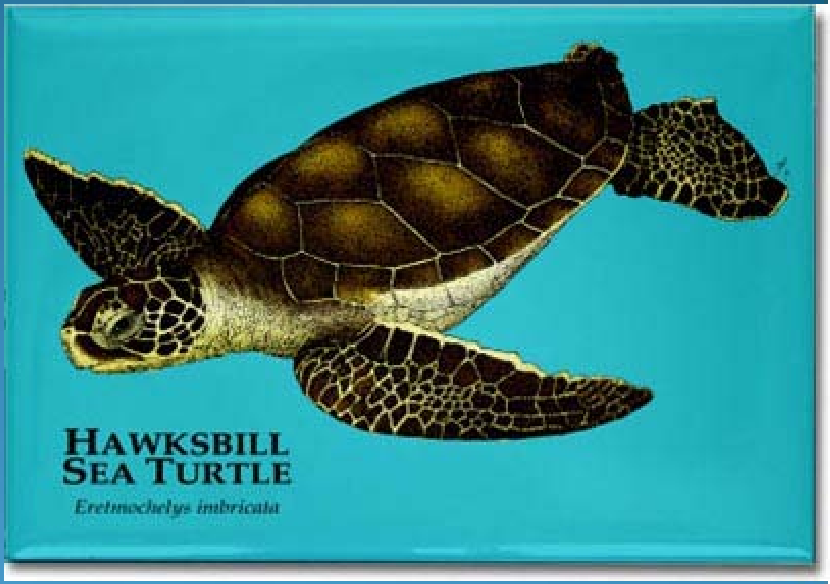


Related R&D

- **Flow Simulation**...to understand how large-scale development will impact the Florida Current;
- **Prognostics & Health Monitoring**...to track system performance and predict failure modes;
- **Rotor Behavior**...to optimize instrumentation and develop better materials for blades;
- **System Dynamics & Stability**...to ensure robust test facility; and
- **Ecosystems Interactions**...to understand environmental effects.

Environment

- Wake effects (alteration of currents and waves);
- Alteration of bottom substrates, sediment transport and deposition;
- Alteration of benthic habitats;
- Noise;
- Electromagnetic fields;
- Chemical toxicity;
- Strikes and entanglement;
- Inadvertent FADs issues;
- Interference with animal movements and migrations;
- User conflicts (shipping; fisheries).



Outlook

- As we move toward prototype testing, we are also tackling many of the R&D issues, largely through student projects (two dozen or so to date).
- By working with regulatory agencies, we are laying the groundwork for future large-scale deployments.
- Our collaborations with industry, government, and academia provide the basis for long-term sustainability and creation of the **National Open-ocean Energy Laboratory**.