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Testimony before the

Before the Committee on Natural Resources joint oversight hearing
of the
Subcommittee on Energy and Mineral Resources
and
Subcommittee on Fisheries, Wildlife and Oceans

Unites States House of Representatives

"Renewable Energy Opportunities and Issues on the Outer Continental Shelf"

April 24, 2007

The following comments do not represent the position of Virginia Tech but represent my views as a citizen of Virginia and a research engineer with over 25 years experience in the field of renewable ocean energy conversion. This experience is summarized briefly, below, and my resume is included as an attachment to this testimony.

From 1980 to 1985, I worked as a project engineer for Gibbs & Cox, Inc., a naval architecture firm in Arlington, Virginia, in support of the U.S. Department of Energy's ocean energy program, which at that time was focused primarily on ocean thermal energy conversion (OTEC).

In 1986, I formed SEASUN Power Systems in Alexandria, Virginia, where I conducted regional wave energy resource and technology assessments for private utilities and state government organizations in California, Hawaii, Virginia, and North Carolina. With financial support from the U.S. National Science Foundation, Virginia's Center for Innovative Technology, and limited private funding, I also carried out extensive numerical and physical modeling of wave-powered desalination systems.

In 1996-97, I was again hired by Gibbs & Cox, Inc. to manage a fully integrated feasibility study of a land-based OTEC plant for a commercial client in Puerto Rico, where I was responsible for direction of seven junior engineers and coordination of sub-contractor activities.

In 1999, I was hired by Virginia Tech, where I am now a Senior Research Associate at the Advanced Research Institute in Arlington, Virginia. Recent ocean energy projects include evaluation of coastal wind data to estimate turbine output for a proposed wind energy project on Virginia's Eastern Shore, a preliminary assessment of the wave energy resource potential off southern New England, and potential project site characterizations for the U.S. Electric Power Research Institute's (EPRI's) offshore wave energy feasibility study for Hawaii, Oregon, Washington, Massachusetts, and Maine. Last spring EPRI completed a similar feasibility study of tidal in-stream energy conversion, with participation by and co-funding from Nova Scotia, New Brunswick, Maine, Massachusetts, Alaska, San Francisco, and utilities in the Puget Sound area of Washington. As with EPRI's offshore wave energy study, I was responsible for energy resource assessment and site characterization.

The EPRI wave energy feasibility study was completed in 2004, and its tidal in-stream energy conversion study was completed in 2006. A comprehensive set of reports is freely available for public download at the EPRI ocean energy web site: http://www.epri.com/oceanenergy/.

During the past eighteen months, I have been working closely with colleagues at four other state universities, as well as Virginia's maritime industry, to help launch the Virginia Coastal Energy Research Consortium (VCERC), which was created in the 2006 legislative session of the General Assembly and funded by budget amendment in the 2007 legislative session. The Virginia Tech Advanced Research Institute was named as one of five founding members, in addition to Old Dominion University, the Virginia Institute of Marine Science, Norfolk State University, and James Madison University.

VCERC was established to serve as an interdisciplinary research, study, and information resource for the Commonwealth of Virginia onits coastal energy resources, including offshore winds, offshore waves, marine biofuels, and seafloor methane hydrates. My main research activities for VCERC to date have been estimating the potential energy and economic benefits of offshore wind energy development on the Outer Continental Shelf (OCS) off Virginia, and I will present some preliminary results of this work today.

OCS Offshore Wind Energy Potential

Much of the information presented here was developed by federal researchers at the National Renewable Energy Laboratory (NREL) in Golden, Colorado, under the leadership of Walt Musial. Their preliminary estimate of the offshore wind energy resource distribution of the mainland United States are presented in Figure 1, below.

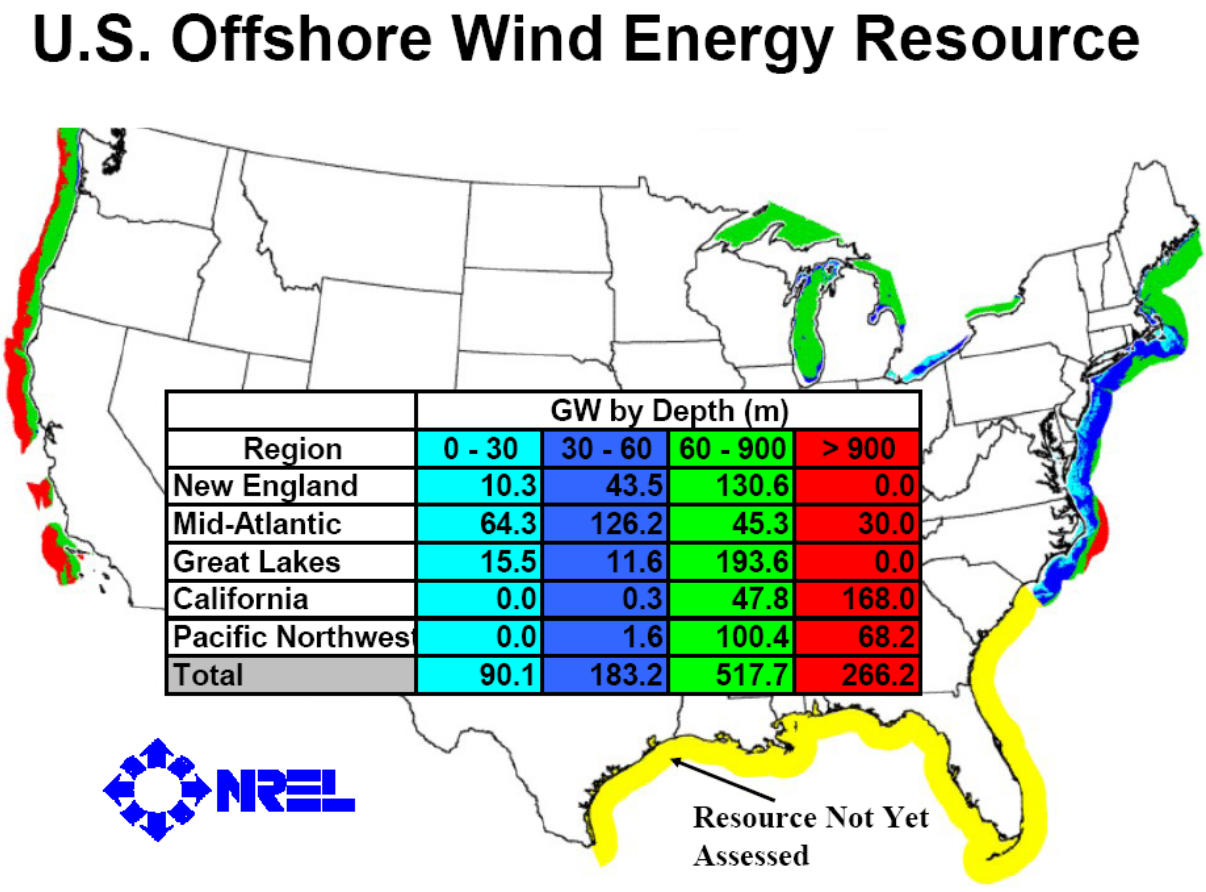

Figure 1. Regional distribution of U.S. offshore wind energy resources out to 50 nautical miles (n.mi) offshore. Numbers are potential installed capacity (in gigawatts), assuming a wind turbine spacing density of 5 megawatts per square kilometer. To account for exclusions due to other uses of sea space (e.g., military exercise areas, shipping lanes, and commercial fishing grounds), NREL researchers assumed there would be no offshore wind energy development within 5 n.mi of shore (100% exclusion), and that only one-third of the available resource could be developed between 5 and 20 n.mi. offshore (67% exclusion), while two-thirds of the available resource could be developed between 20 and 50 m.mi offshore (33% exclusion).

For the "Lower 48" states mapped in Figure 1, the total potential offshore wind capacity in the federal OCS across all regions and all depths is 908 gigawatts (GW). Assuming a 35% annual capacity factor (due to wind speed variability), this represents an electric generation potential of 2,780 terawatt-hours (TWh).

The most immediately developable resource, using monopile foundations that have been commercially proven in European waters is in depths of 30 meters or less. As shown in Figure 2, below, such depths are most abundant in the mid-Atlantic region. The next most developable resource would be in depths of 30 to 60 meters, using trusswork foundations, which are now being demonstrated by the Talisman Project in the Beatrice Field of the North Sea. Again the mid-Atlantic leads the regions in having vast OCS areas in this depth range.

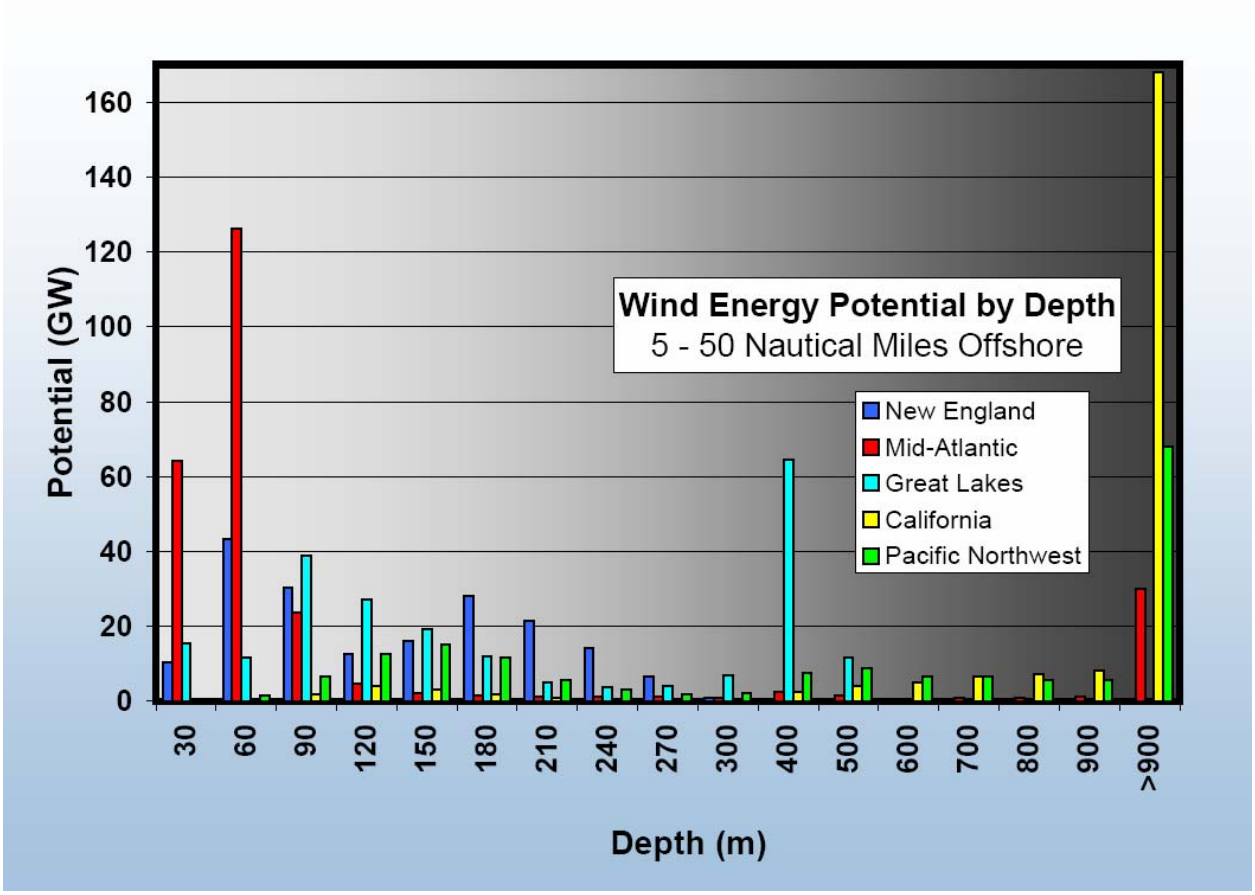

Figure 2. Depth distribution of U.S. offshore wind energy resources out to 50 nautical miles (n.mi) offshore. Note large near-term potential in Mid-Atlantic region.

A significant concern for coastal utility grids interconnected with large amounts of offshore wind energy is the hour-to-hour variability of the resource, as well as its seasonal variability. Rather than relying on back-up fossil fuel power plants onshore, however, utilities may derive more benefits from deploying distributed solar-electric (photovoltaic) systems on commercial and institutional buildings on shore, which particularly addresses the seasonal variability question.

Hourly variability may be addressed by on-shore batter y storage in plug-in hybrid electric vehicles, and/or storage of compressed hydrogen in the offshore tower structure. We are just starting to look at these options in Virginia.

Hybrid offshore wind and offshore gas combustion turbine projects represent another promising alternative, which has many advantages. These include increased revenues derived from having a completely dispatchable baseload power supply, and the much lower environmental impact and greater security of submarine power cable vs. pipeline energy transmission to shore. Eclipse Energy's Ormonde project is an example of such a hybrid, combining 108 MW of offshore wind power capacity with 98 MW of natural gas generation. It is expected to be operating in 2008.

Another renewable ocean energy resource that deserves consideration is marine biomass, which represents a sustainable source of offshore methane that can replace offshore fossil gas in hybrid wind-gas generation projects as described above, once the offshore fossil reserves are depleted.

OCS Offshore Wave Energy Potential

One preliminary finding of the EPRI wave energy feasibility study is that extracting just 15% of the offshore wave energy flux into the federal OCS would yield 252 TWh annually. Although this is an order of magnitude smaller than the offshore wind generation potential estimated above, it is nevertheless comparable to all conventional hydro-electric generation in the U.S. (which was 258 TWh in 2004). Wave energy in the OCS is thus a substantial resource.

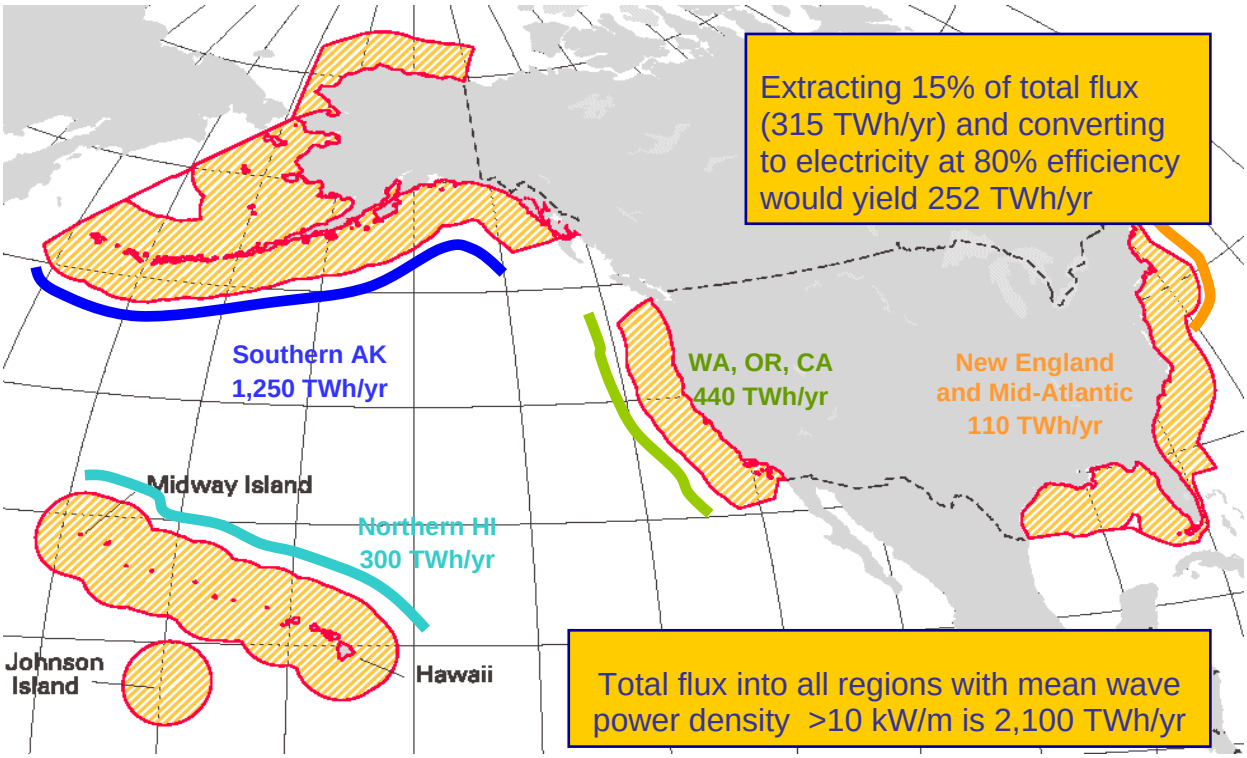

Figure 3. Geographical distribution of offshore wave energy resources having an annual average incident wave power density of more than 10 kilowatts per meter.

Wave energy's contribution could be even greater if hybridized with deep-water wind turbines in a single floating system that would share common mooring hardware and electrical interconnection cables, thus improving system economics. The output of such a floating hybrid wind-wave system would also be more continuous, since "yesterday's winds are today's waves."

Thank you for this opportunity to testify, and I would be happy to answer any questions or provide additional information.

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Attachments:

Resume

George Hagerman – Resume

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EDUCATION:

M.S., Marine Sciences, University of North Carolina at Chapel Hill, 1980
(National Science Foundation Graduate Fellow)

B.S., Zoology, University of North Carolina at Chapel Hill, 1977.

EXPERIENCE:

Academic

1. Senior Research Associate (full-time research), Center for Energy and the Global Environment, Alexandria Research Institute, Virginia Tech, August 2004 to present.
2. Program and Grants Manager (half-time administrative, half-time research), Alexandria Research Institute, Virginia Tech, January 1999 to August 2004.

Industry/Government

1. President and Owner, SEASUN Power Systems, Alexandria, Virginia, September 1997 to April 2000.
2. Senior Ocean Engineer, Gibbs & Cox, Inc., Arlington, Virginia, September 1996 to August 1997.
3. President and Owner, SEASUN Power Systems, Alexandria, Virginia, December 1986 to August 1996.
4. Consultant, Sea Energy Corporation, New Orleans, Louisiana, December 1985 to November 1986.
5. Project Engineer, Gibbs & Cox, Inc., Arlington, Virginia, November 1980 to November 1985.

Sponsored Research Projects at Virginia Tech

1. Sponsor: Electric Power Research Institute
   Project Title: *EPRI Tidal In-Stream Energy Conversion Project, Phase I*
   Performance Period: 01-Apr-2005 to 31-May-2006.
   Description: Provide oceanographic and ocean engineering support for a feasibility study of tidal in-stream energy conversion, potentially leading to the first utility-scale demonstration projects in North America. Characterize potential project sites in five U.S. states and two

Canadian provinces, evaluating tidal current speeds, seafloor bathymetry and geology, utility grid interconnection, and availability of a nearby harbor with marine equipment and services for operational support.

2. Sponsor: Neptune Sciences Division of Planning Systems, Inc., (Virginia Tech as subcontractor on Phase I award for U.S. Navy SBIR Topic N05-076)
   Project Title: *SEA-LOG: A Sustainably Energized Adaptive Littoral Ocean Grid, Phase I*
   Performance Period: 01-Jun-2005 to 31-Jan-2006.
   Description: Develop a distributed underwater environmental sensor grid for covert and persistent monitoring and characterization of ocean physical properties, ambient noise, and the seabed in littoral regions. Each node consists of a single-point, slack-moored sub-surface float that harvests wave energy, providing power for sensors, data processing, communication, and horizontal and vertical propulsion systems that enable the float to avoid hazards and accidental detection.

3. Sponsor: NASA Institute for Advanced Concepts
   Project Title: *A Self-Sustaining Boundary-Layer-Adapted System for Terrain Exploration and Environmental Sampling, Phase I*
   Performance Period: 01-Oct-2004 to 31-Mar-2005.
   Description: Develop and evaluate a novel, autonomous, glider-based architecture for space exploration, which harvests wind energy from the atmospheric boundary layer to enable a persistent science presence on bodies with dense atmospheres such as Venus and Saturn's moon, Titan.

4. Sponsor: Electric Power Research Institute
   Project Title: *EPRI Offshore Wave Energy Conversion Project, Phase I*
   Performance Period: 01-Mar-2004 to 31-Dec-2004.
   Description: Provide oceanographic and ocean engineering support for a feasibility study of offshore wave energy conversion, potentially leading to the first utility-scale demonstration projects in the United States. Characterize potential project sites in five coastal states, evaluating the offshore wave climate, seafloor bathymetry and geology, utility grid interconnection, and the nearest coastal harbor with marine equipment and services for operational support. Also identify and characterize potential environmental impacts.

5. Sponsor: U.S. Department of Energy – Hydrogen Program
   Project Title: *An Interactive Hydrogen Knowledge Base*
   Performance Period: 01-Feb-2004 to 31-Dec-2005.
   Description: Prepare an interactive knowledge base and associated fact sheets about hydrogen production, storage, and utilization, as well as infrastructure elements required for a hydrogen energy economy.

6. Sponsor: U.S. Department of Energy – Wind Powering America Program; cost-shared and managed by the Virginia Department of Mines, Minerals, and Energy
   Project Title: *Wind Powering America – Virginia Initiative*
   Performance Period: 01-Jan-2003 to 31-Dec-2005.
   Description: An outreach effort in partnership with James Madison University, Environmental Resources Trust, and George Washington University Law School to facilitate wind power development in Virginia.

7. Sponsor: U.S. Department of Energy – Million Solar Roofs Initiative; cost-shared and managed by the Virginia Department of Mines, Minerals, and Energy
   Project Title: *Million Solar Roofs and PV4VA: Combining Resources for Solar Energy Education, Research, and Outreach*
   Performance Period: 01-Sep-2000 to 31-Dec-2004.
   Description: An outreach effort to inform residential and commercial building owners in Virginia about the costs and benefits of owner-installed solar energy systems.
8. Sponsor: U.S. Department of Energy – State Energy Program; Special Energy Project managed by the Virginia Department of Mines, Minerals, and Energy
   Project Title: *Geothermal Heat Pumps for EnergySmart Schools in Virginia*
   Performance Period: 01-May-2000 to 31-Aug-2003.
   Description: An outreach effort to inform and promote collaboration among stakeholders to encourage the use of ground source heat pump systems for heating and cooling K-12 schools in Virginia (www.geo4va.vt.edu).

SELECTED PRESENTATIONS:

1. "Energy from Waves, Tides, Ocean Currents, and Free-Flowing Rivers: An Overview of Resource, Technology, and Business Issues." Briefing to the Federal Energy Regulatory Commission, Washington, DC, 06 Dec 2006. Posted at http://www.ferc.gov/EventCalendar/Files/20061206144646-Hagerman.pdf.
2. "Exploring Offshore Wind Power For Virginia." Pre-Conference Workshop, *Energy Virginia 2006*, Lexington, Virginia, 16 October 2006. Two PDFs, "Potential Energy and Economic Benefits for Virginia" and "Potential Environmental Effects" posted at http://www.energyvacon.org/Program/exploring_offshore_wind_power.htm.
3. "Tidal Stream Energy in the Bay of Fundy." *Nova Scotia's Energy Research and Development Forum 2006*, Antigonish, Nova Scotia, 25 May 2006. Posted at http://ns.energyresearch.ca/files/George_Hagerman.pdf.
4. "Wave and Tidal Power: Projects and Prospects." *Northeast Coastal Zone Management Partners Workshop -- Future Energy Needs and Impacts on the Coastal Zone*, Virginia Beach, Virginia, 07 October 2005. Posted at http://www.deq.virginia.gov/coastal/neczmpps.htm#renewable.
5. "Overview of U.S. Ocean Wave Energy Resources." Briefing to legislators and staff at the U.S. Senate Russell Building, organized by the Global Environment and Technology Foundation, Washington, DC, 15 June 2003. Posted at http://www.getf.org/ewebeditpro/items/O70F4076.pdf.
6. "Costs and Benefits of Public Support for Energy Efficiency and Renewable Energy Programs in Virginia." Testimony presented to the Legislative Transition Task Force (Virginia Electric Utility Restructuring Act), Richmond, Virginia, 16 August 1999. Posted at http://dls.state.va.us/groups/elecutil/08_16_99/EECEGE.HTM.

SELECTED PUBLICATIONS:

Sole Author

1. "Wave Energy Systems for Recharging AUV Power Supplies." *Proceedings of Autonomous Underwater Vehicles 2002*, pp 75-84. IEEE Oceanic Society workshop held at the Southwest Research Institute in San Antonio, Texas, June 2002. Paper posted at http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1177207.
2. "Southern New England Wave Energy Resource Potential." *Building Energy 2001*. Greenfield,
   Massachusetts: Northeast Sustainable Energy Association. March 2001. Paper posted at http://www.ctinnovations.com/pdfs/S_New_Engl_Wave_Energy_Resource_Potential.pdf.
3. "Tidal Energy." *Grolier Multimedia Encyclopedia CD-ROM*. Grolier Electronic Publishing, 1996.
4. "Wave power: an overview of recent international developments and potential U.S. projects." *Proceedings of SOLAR '96* (edited by R. Campbell-Howe and B. Wilkins-Crowder), pp. 195-200. Boulder, Colorado: American Solar Energy Society, 1996.
5. "Wave power." *Encyclopedia of Energy Technology and the Environment* (edited by A. Bisio and S.G. Boots), pp. 2859-2907. New York: John Wiley & Sons, Inc, 1995.
6. "Wave energy activities in the United States." *Proceedings of the 1993 European Wave Energy Symposium* (edited by G. Elliot and G. Caratti), pp. 21-28. East Kilbride, Scotland: National Engineering Laboratory, 1993.
7. "Exploration - Power from Ocean Waves," a classroom learning activity developed for National Engineers Week, 16-22 February, 1992 published by the Junior Engineering Technical Society, in cooperation with the National Talent Network, the Challenger Center, and the Total Learning Research Institute. Paper posted at http://www.eweek.org/site/DiscoverE/PDFs/high/Exploration-Power%20from%20Ocean%20Waves.pdf.
8. "Teaching kids to build and use a solar battery charger." *Home Power #16*, pp. 14-19, April/May 1990.
9. "Teaching kids about batteries and photovoltaics." *Home Power #15*, pp. 5-12, February/March 1990.

Second Author

1. "North American wave and tidal collaboratives." (by M. Previsic, R. Bedard, G. Hagerman, R. Thresher, M. Robinson, and S. Calvert), Proceedings of the 6th European Wave and Tidal Energy Conference (edited by C.M. Johnstone and A.D. Grant), pp. 409-412. Glasgow, UK: University of Strathclyde, 29 August – 02 September 2005.
2. "The potential for offshore wind development in the United States." (by K. J. Smith and G. Hagerman) *Proceedings of the Second International Workshop on Transmission Networks for Offshore Wind Farms*. Royal Institute of Technology, Stockholm, Sweden, March 2001.