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HEARING ON
ENVIRONMENTAL DATA AND INFORMATION SERVICES
FOR THE RENEWABLE ENERGY INDUSTRY

BEFORE THE
SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

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INTRODUCTION

Good morning Chairman Baird, Ranking Member Inglis, and other Members of the Subcommittee. I am Alexander E. MacDonald, Deputy Assistant Administrator for Laboratories and Cooperative Institutes in the Office of Oceanic and Atmospheric Research at the National Oceanic and Atmospheric Administration (NOAA), in the Department of Commerce. Thank you for inviting me to discuss NOAA's science and research that has the potential to support the increased use and efficiency of renewable energy.

The Nation's renewable energy sources — solar, wind, and water — are largely driven by weather and dependent on climate. This fundamental connection of renewable energy to the atmosphere and oceans is at the core of NOAA's participation in today's hearing and explains our key role in developing renewable energy.

The U.S. energy sector is a $1 trillion-per-year enterprise[1] central to our Nation's economy. The Obama Administration has called for the expansion of our Nation's capacity to provide energy from renewable sources to help reduce our dependence on fossil fuels, increase our energy security, build the green jobs and economy of the future, and reduce greenhouse gas emissions. While numerous climate assessments completed by United States and international climate science bodies agree on the long-term impacts of greenhouse gases, the Deepwater Horizon/BP oil spill is a reminder of the potential catastrophic, short-term, and acute environmental impacts of a fossil fuel-based energy system. NOAA's scientific data, forecasts, and information can play a critical role in

[1] U.S. Energy Information Administration, Annual Energy Review 2008, Report No. DOE/EIA-0384(2008). http://www.eia.doe.gov/emeu/aer/overview.html

maximizing the potential benefits from all forms of renewable energy, and minimizing the environmental impacts of marine renewable energy.

Today, I will describe NOAA's current support of the renewable energy industry and the essential role of NOAA data, information, and services in sound renewable energy planning. Some of the challenges to increased use of renewable energy have the potential to be addressed by further developing NOAA's weather, climate, and ecological observations and predictions. While renewable energy sources offer a positive option, they are not necessarily environmentally benign. Therefore, I will also summarize NOAA's role in ensuring that renewable energy projects are developed consistent with NOAA's mission to conserve and manage coastal and marine resources to meet our Nation's economic, social, and environmental needs.

NOAA'S CURRENT CONTRIBUTIONS TO RENEWABLE ENERGY

NOAA provides weather, water, and climate forecasts and information over a full range of temporal and geographical scales. NOAA accomplishes this through remote sensing and imagery from satellites, surface networks of weather radars and observing systems, upper air balloons, ocean buoys, ships, aircraft, and seafloor observations. NOAA's network of integrated Earth observing systems monitor changes in ocean, land, air, and space that are critical to siting decisions by the energy sector. NOAA provides the marine renewable energy industry with relevant ecological data to facilitate siting decisions and construction and operational requirements to minimize and mitigate adverse effects on living marine resources and ecosystems. NOAA also works to ensure that siting decisions and operations do not adversely impact other key NOAA missions, such as wind power facility impacts on weather radar installations.

NOAA's contributions to energy facility siting, operation, and management are based on a wide range of legal authorities, including energy-specific authorities, as well as authorities related to conservation, management, observation, and forecasting (see Appendix A for a list of authorities). In addition, although licensing authority for most energy projects resides with other federal agencies, NOAA does have authority for licensing ocean thermal energy conversion (OTEC) facilities. Overall, NOAA plays an active and important role in the siting and management of energy facilities through legal authorities that direct NOAA to:

- Collect data on sensitive species and habitats, topography, tides and currents, and meteorological conditions. This data, along with information about protected areas and human use patterns, provides the basis for siting decisions.
- Evaluate potential environmental impacts of energy facilities on coastal and marine resources and recommend mitigation measures to minimize those impacts.
- Assess and predict the impact of oil spills and hazardous substance releases on natural resources, identify response strategies, and implement restoration.
- Forecast weather conditions. Based on the forecasts, energy facilities can adjust their operations to optimize energy production or minimize the negative impacts from inclement weather.

- Provide scientific expertise and technical and management assistance to federal agencies, states, the energy industry, and other stakeholders.
- Determine energy-related content of state Coastal Management Plans, mediate Coastal Zone Management Act (CZMA) energy-related disputes and decide appeals of state CZMA objections to energy projects to the Secretary of Commerce.

While many of the authorities are NOAA-specific, NOAA implements some of the authorities in cooperation with other federal agencies. The federal agencies with energy-related authorities include Federal Energy Regulatory Commission, Department of Transportation, Maritime Administration, United States Coast Guard, Department of Energy (DOE), Department of the Interior (DOI), and Environmental Protection Agency. In an effort to focus on key authorities related to energy facility siting and management, this testimony does not cover the full scope of NOAA's legal authorities. Many other important authorities support the extensive work that NOAA does related to energy issues. For example, legal authorities related to climate are not listed in this testimony, but NOAA's climate change efforts provide valuable contributions to the advancement of renewable energy.

Additionally, in providing mission-relevant information and services in support of renewable energy development, NOAA works in partnership with and draws upon the data and information of other federal agencies in this area, including but not limited to the DOI, DOE, the National Aeronautics and Space Administration, and the National Science Foundation. For example, NOAA and the Department of Energy's National Renewable Energy Laboratory together signed a Letter of Intent to allow the exchange of scientific resources, personnel, and technical knowledge to support the improvement or development of atmospheric and ocean sciences, instrumentation, climate modeling, and renewable energy. Furthermore, NOAA and DOE's Office of Energy Efficiency and Renewable Energy are exploring a Memorandum of Understanding to collaborate to achieve the necessary advancements in short-term environmental forecasts and long-term resource projections for the integration of renewable energy into the Nation's energy system.

NOAA also works closely with the private sector, and recognizes the contributions the private weather and climate service enterprise can make toward the Nation's renewable energy capabilities. NOAA's role in providing forecast data and information for the renewable energy industry will be guided by the 2006 NOAA Policy on Partnerships in the Provision of Environmental Information, based on the National Research Council's 2003 report, "Fair Weather, Effective Partnerships in Weather and Climate Services." The Nation benefits from government information disseminated both by Federal agencies and by diverse nonfederal parties, including commercial and not-for-profit entities. NOAA recognizes that cooperation, not competition, with private sector, academic, and research entities best serves the public interest and best meets the varied needs of specific individuals, organizations, and economic entities. NOAA will take advantage of existing capabilities and services of commercial and academic sectors to support efficient performance of NOAA's mission and avoid duplication and competition.

Observations and Forecasts for Operation of Renewable Energy Systems

NOAA's observations and forecasts are used by the renewable energy industry to efficiently operate its systems and plan for future sites. NOAA's historical climate records provide essential information required to optimize the siting of wind farms and solar energy plants. Not only are historical records essential to optimize the location of new production facilities, but accurate weather predictions are critical to renewable energy operations because they provide the information needed to ensure balance between electric supply and demand. For example, in order to increase operating efficiency, renewable energy operators must know how much energy a particular wind farm or solar energy farm will generate. Likewise, forecasts can help energy grid operators predict how much renewable energy will be available to distribute to the energy grid and inform the decision whether to supplement renewable energy with other generation sources, such as coal or natural gas plants. The more accurate the forecasts NOAA can provide, the more efficient the energy industry can become.

NOAA's predictions form the core of capability that is used by a thriving commercial weather industry to support the weather information needs of the Nation. In general, as NOAA's predictions have improved, the size and value of the commercial weather providing sector has grown commensurately, as it should for the improved renewable energy predictions discussed below.

Current Wind Observations

NOAA's wind observation capability includes surface measurements as well as measurements from aircraft, ships, satellites, Doppler radar, wind profilers, and radiosondes – instruments lifted through the atmosphere by weather balloons which provide wind data up to about 10 miles high. All of these data are critical for NOAA's success in forecasts and warnings, but wind is not typically measured at levels critical for wind turbine operators, about 100 meters above the ground. Also, none of these data sources provide information at the density that is needed by the wind industry. Even fewer observations are available offshore, and these data are critical for any offshore wind farms that are being planned.

While the observations at the 100 meter level are not available, NOAA's sophisticated computer simulations of the atmosphere can model and predict winds at 100 meters and some of these data are now becoming available to the private sector. However, these models were not designed to provide the information at the temporal and spatial resolution needed by the wind industry.

Current Wind Forecasts

The wind energy industry uses standard NOAA weather forecasts. These forecasts were developed to improve surface meteorological predictions and aviation needs. They have been extremely successful in addressing these goals but the weather models underlying these forecasts were never designed and optimized to provide the temporal or spatial resolution or the accuracy needed by the wind industry.

Solar Observations and Forecasts
NOAA's Surface Radiation network is a network of seven state-of-the-art Continental United States (CONUS) surface sites that measure diffuse, direct, and total solar radiation as well as surface reflectivity. NOAA also measures solar radiation at eight global monitoring sites. NOAA's Climate Reference Network measures total incoming solar radiation at about 140 sites in the CONUS and additional sites outside CONUS. These data provide a record of radiation coverage for CONUS.

NOAA has developed techniques to forecast solar radiation, and currently provides a forecast for ultra-violet (UV) radiation, which is used by the Environmental Protection Agency to warn the public of health risks. This product has the capability to be extended to address the radiation wavelengths relevant to solar renewable energy.

Precipitation Observations and Forecasts to Support Hydropower
NOAA's monthly and seasonal temperature and precipitation outlooks provide information for water management. In particular, NOAA hydrologic forecasts of seasonal snow melt and runoff are important to manage water flow feeding hydro-generation plants. Further, the National Integrated Drought Information System (NIDIS), a multi-agency effort which NOAA leads, provides information and early warnings of droughts while NOAA's Hydrometeorological Test Bed (HMT), a demonstration project, provides water information across a wide range of time and space scales with a focus on high precipitation events. HMT and NIDIS thus provide extensive expertise on water resources, helping the Nation design a future renewable energy system that maximizes our country's vast natural resources, while preserving water allocations to support our country's many needs.

Ocean and Coastal Observations and Forecasts to Support Ocean Thermal Energy Conversion and Marine Hydrokinetic Energy
Under the Ocean Thermal Energy Conversion Act (OTECA), NOAA has the responsibility for administering a consolidated licensing program for authorizing ocean thermal energy conversion (OTEC) facilities. OTEC is a technology which uses the differences between the temperature of deep, cold ocean water and warm ocean surface waters to produce electricity much like a heat pump. Although the technology has been proven to work, it has not been developed yet at a commercial scale. A substantial effort is underway by industry and the Navy to develop a commercial-scale OTEC facility with the most likely site being offshore of Hawai'i. Last November, NOAA brought together leading engineers in the offshore technology field to assess the feasibility of developing an OTEC technology at a commercial scale. The findings of that workshop are scheduled to be released this summer. Later this month, NOAA is holding a workshop in Hawai'i on the assessment of potential impacts from an OTEC facility. Both workshops are in preparation for a rulemaking for the licensing of OTEC facilities.

Marine hydrokinetic energy uses the energy of waves, tides, and currents in rivers and oceans to produce electricity. While these systems do not yet provide power to the electrical grid in the United States, a few tidal systems operate in other parts of the globe.

NOAA's observations and forecasts of the oceans, waves, tides, and rivers provide data critical for the development of OTEC and marine hydrokinetic energy. The U.S. Integrated Ocean Observing System (IOOS) generates and disseminates continuous data, information, models, and services on coastal waters, ecosystems, Great Lakes and oceans. NOAA is an integral partner in IOOS.

Observations and Forecasts to support Biomass Energy
NOAA provides forecasts of precipitation, cloud cover, temperature, winds, and water flow that are important to biomass production. As these resources are developed, NOAA will work to improve forecasts of precipitation and temperature, which are critical factors in determining variation in U.S. biomass supply.

Predictions of Climate Variability and Change to Inform Siting of Renewable Energy Systems
Continued expansion of the Nation's renewable power capacity will require considerable infrastructure investments, whether in facilities or the grid that will be necessary to efficiently provide Americans with the power they need. To optimally plan tomorrow's energy system, the Nation needs information to understand how the influences of climate and climate change, including natural variability and large-scale climate-drivers, such as El Nino, may affect renewable energy resources such as wind, solar, and water in the future. In the same way, information about the location and likely intensity of weather- and climate-driven energy demand is needed by the industry, such as projections of climate and climate change effects on degree heating and cooling days. NOAA observation data, including wind, temperature, cloud cover, solar radiation, and climate variability and change predictions are critical pieces of information for forecasting the future availability and location of renewable sources of energy and the likely future demand for energy in the different regions of the nation. These forecasts in turn inform industry and public sector investment decisions about the best locations to build facilities like wind farms or solar energy platforms, as well as grid design.

For example, utilities need information about the likelihood of future increases in degree heating days to ensure ample power generation and distribution to meet cooling needs. In the same way, developers of coastal wind and hydropower need predictions of sea-level rise and the likelihood of increase in severe coastal storms to site, engineer, and design those facilities to withstand future conditions. And lastly, hydropower developers require information about the future timing and availability of water to adequately design reservoir and power storage capability and dam operation.

However, it is important to note that the optimal location for renewable energy production may not be the optimal location for social or environmental reasons. For example, an optimal energy production site may be in the heart of a prime fishing ground, in an important endangered species migratory corridor, or in a location that interferes with our Nation's important radar assets. Not only can NOAA assist by providing relevant information on these other factors to optimize site selection, but it also has regulatory and oversight obligations that are addressed below.

Evaluating the Environmental Impacts of Coastal and Ocean Renewable Energy
NOAA is also a regulatory agency with responsibilities under the National Environmental Policy Act, the Endangered Species Act, the Marine Mammal Protection Act, the Magnuson-Stevens Fishery Conservation and Management Act, and the National Marine Sanctuaries Act. NOAA ensures that coastal and ocean energy projects are conducted in compliance with these authorities. NOAA provides information on health, abundance, distribution, and ecological requirements of living marine resources to ensure industry and other regulatory agencies, such and the U.S. Army Corps of Engineers, Federal Energy Regulatory Commission, and Minerals Management Service have information to meet their obligations under these environmental statutes. NOAA also works with industry and other regulatory agencies to ensure that projects they fund or permit are reviewed and authorized consistent with the relevant environmental statutes.

In regard to providing ecological data relevant to environmental permitting or review of coastal and ocean renewable energy, NOAA conducts investigations of the status of various fish stocks that support commercial and recreational fisheries, threatened and endangered species, and marine mammal stocks. It also conducts ecosystem assessments that help define the ecological relations in the ecosystems of which these species are a part and upon which they depend. This information is critical to making sound siting decisions and accurately identifying effects of energy projects. NOAA's regulatory role can also facilitate the development of mitigation measures that will minimize environmental impacts; thereby potentially resolving conflicts with competing users of a location. NOAA's investment in studying and understanding our coastal and marine ecosystems is essential to the development of an environmentally sound renewable energy industry.

Avoidance of Radar Interference from Wind Energy
NOAA and other federal agencies evaluate industry requests for turbine siting to minimize potential interference of turbines on our Nation's network of radars. NOAA is working with the Departments of Defense, Homeland Security and Transportation to develop software to model potential wind turbine impacts on radars in advance of turbine installation to better support the evaluation of industry siting requests. Turbines, when sited close to weather radars, can cause false returns that can disrupt forecaster situational awareness and weather radar algorithms. For example, a study has shown that when turbines are located within about 18 km (10 nm) of NOAA/NWS Doppler weather radars, the interference can cause tornado and severe thunderstorm detection algorithms to malfunction. NOAA is working with the academic community to develop radar software that mitigates the turbine interference in the weather radar's returned signal. The interference with air surveillance radars can be significantly different.

MEETING THE DATA AND INFORMATION NEEDS OF AN EXPANDING RENEWABLE ENERGY SECTOR
NOAA's observations, forecasts, and analyses are at the core of integrating weather-driven renewable energy in an efficient manner. NOAA has worked with the renewable energy industry, other federal agencies, and academic partners to understand current and future observation and forecast needs to support renewable energy. For example, the

wind energy sector identified its need for improved observations, global forecast models, predictions across a range of time scales, and high-resolution forecast models to support an improved operational weather forecast. In multiple public meetings, private sector weather service vendors, wind farm operators, utilities, and power balancing authorities have requested that NOAA provide these improved services. A strong collaboration with federal partners and the industry would result in improved siting of renewable energy facilities, more accurate weather forecasting to support efficient operations, and an opportunity for growth in the renewable energy sector. In the end, advancements in observations and forecasts that help address the emerging needs of the renewable energy sector contribute to the broader national interest in reducing our dependence on foreign fuels, increasing our energy security, building the green jobs and economy of the future, and reducing greenhouse gas emissions.

In addition to the need for improved forecasts and observations from NOAA, the need for coastal and marine spatial planning (CMSP) in the U.S. is critical to the development of renewable energy resources. CMSP is a comprehensive, adaptive, integrated, ecosystem-based, and transparent spatial planning process, based on sound science, for analyzing current and anticipated uses of ocean, coastal, and Great Lakes areas. As the Nation's primary ocean agency, NOAA will continue to play a leadership role in advancing the implementation of CMSP throughout U.S. waters for purposes that include the development of renewable energy. To this end, NOAA brings a unique mix of: diverse legal authorities for place-based ocean stewardship; robust and cutting-edge scientific and technical expertise to understand and observe ocean and coastal ecosystems and their uses; effective ocean management programs with decades of expertise in spatial planning and meaningful stakeholder engagement; and long-standing partnerships with coastal states, regional ocean governance organizations, tribes, and other federal agencies who share a common interest in sustainable, healthy oceans.

CMSP's comprehensive approach to planning the full range of human uses in the ocean provides many opportunities, and indeed imperatives, for substantive collaboration between Federal agencies, the private sector, and stakeholders on matters such as the siting and development of renewable energy sources. For these and other current and emerging ocean uses, private interests will play a key role in providing spatial data and insight into the requirements, plans and implications of siting decisions that maximize benefit while minimizing conflicts and impacts.

Onshore and Offshore Wind Energy: Forecasts and Observations
Since NOAA's current weather forecasts were not developed to support the wind energy industry specifically, and because there are limited observations that are publically available where wind turbines reside, NOAA's forecasts do not provide information at temporal scales that the wind industry requires. Further, because the amount of wind energy produced depends on wind speed cubed, even small differences in projected wind speed can yield large differences in the predicted wind energy produced. Although such differences are addressed and overcome on a daily basis in the E.S. and everywhere wind provides electricity, power production based upon an intermittent resource adds additional elements of complexity when managing power production and delivery. For

example, the Bonneville Power Administration imposed wind integration charges (WIC) of $5.85/MWh on wind producers due to scheduling discrepancies and the cost to maintain power reserves in the event that wind generation falls short of forecasts. The national electric system has evolved to support more temporally consistent energy sources like coal, nuclear, and natural gas, so integrating wind energy has presented some difficulties to system operators. NOAA can partner with the renewable energy industry to improve our understanding and predictions of wind energy and work together to provide better forecasts.

An additional challenge for wind energy forecasting is in the identification and prediction of so-called "ramp events." A ramp event is any large and sudden change in wind speed or direction that can significantly alter wind energy generation. NOAA's weather models were not developed to identify these features in such small scales and pose challenges to wind farm operators across the Nation. Power balancing authorities and system operators often "curtail" wind energy production when wind farms produce significantly different amounts of energy than what was expected, at least partly based on NOAA's wind forecasts. Better observations, forecast models, and wind forecasts (especially the timing and amplitude of ramp events) are a key to improving the ability to align electricity production from wind and other sources to meet demand most efficiently.

NOAA has the scientific expertise to partner with industry and help it to improve the understanding of atmospheric processes in the lower part of the atmosphere (called the boundary layer) where wind turbines reside and affect the operation, performance, and longevity of wind turbines. Finding out what is actually occurring in the boundary layer would entail the development of wind-energy demonstration projects, which would be research sites to study the lower part of the atmosphere. Based on NOAA's experience deploying atmospheric research demonstration projects, an array of industry-supported projects to advance an understanding of wind to support wind energy would: (1) collect observations of the boundary layer for studies of phenomena that affect wind resources; (2) provide data sets for weather-forecast model development and verification; (3) determine the most effective sensors for assimilation into weather-forecast models; (4) identify optimal sensors for a national observational network supporting wind energy. Off-shore turbine-height winds could be measured using buoy-based boundary layer profiling systems. Measurements of thermal-atmospheric eddies would support offshore wind energy. New observations that would inform the conditions that an offshore turbine tower will face include measurements of the vertical distribution of temperature in the ambient water, as well as of currents and waves.

These observations would advance the understanding of low-level winds and turbulence, which would allow the provision of forecasts of winds with greater accuracy in space and time. These observations also would help NOAA provide guidance to the developing national Network of Networks (NoN), called for by a recent National Research Council report, to ensure that the needs of the renewable energy industry are considered as this NoN is developed. With these observations, the wind energy industry would have the potential to meet its needs and contribute towards a national reference data set that would be managed by NOAA for the renewable energy industry that contains historical, real-

time, and even projected/modeled data (discussed below), all of which have been subject to quality-control measures.

NOAA is currently collaborating with DOE to improve the efficiency of wind energy through improved models and forecasts on a small, regional scale. The area will be selected based on responses to a Funding Opportunity Announcement released earlier this month. A valuable part of this collaboration with DOE and the private sector is the request that the private sector (wind farm operators and balancing authorities) share proprietary atmospheric observations that they already collect. NOAA would act as an "honest broker" by keeping these data private and protected, but using them in our weather models to make our forecasts more accurate.

NOAA has fulfilled this "honest broker" role before in other sectors. A valuable example is seen within the airline industry, when during the 1990s airlines began to send their proprietary weather data from aircraft to NOAA to assimilate and provide improved forecasts for aviation. NOAA has improved its model forecasts, including those for aviation, significantly over the last 15 years. The improvements resulted from more observations, at all atmospheric levels, to better define the current 3-dimensional weather conditions; more frequent observations to allow models to be initialized more frequently; faster computers allowing higher spatial resolution in the models; and better understanding of weather phenomena. Over the last 15 years, the errors for 6-hr wind forecasts, used for air traffic management, have been reduced by 50 percent over the United States. These improvements also benefited many other NOAA programs which depend on better predictions (e.g., thunderstorms).

Solar Energy: Forecasts and Observations

NOAA's potential contributions to expanding solar energy could include building upon existing meteorological and climatological observation networks, such as the Historical Climate Network. The most difficult challenge in solar energy forecasting is providing precise cloud-coverage measurements. NOAA has the scientific expertise to design and deploy solar demonstration projects to make detailed and comprehensive measurements of cloud parameters and aerosols using remote-sensing instrumentation. Such research would allow an evaluation of weather forecast models by comparing their model output to the observations from demonstration projects. After pinpointing where inaccuracies arise in the models, the forecasts of clouds and aerosols could be improved.

To respond to industry identified needs, NOAA in partnership with other federal agency and private sector partners could lend the scientific expertise necessary for the development of a national solar radiation and aerosol network. NOAA experience would contribute to the creation and maintenance of a national reference database of historical, real-time, and projected solar data. NOAA also has expertise in assimilating satellite solar radiation data to generate the best analysis fields for forecasting solar energy at various times scales, as well as for developing advanced methods for quickly and accurately computing net solar radiation under various weather conditions.

Ocean Thermal Energy Conversion (OTEC) and Marine Hydrokinetic Energy

As a source of renewable energy, OTEC has the potential to make a significant energy contribution in the locations where it is suitable. Islands that are currently almost entirely reliant on imported fossil fuel could take strides for self-sufficiency if the commercial development of OTEC proves feasible. However, while NOAA is working to develop a clear regulatory pathway for OTEC development, that pathway needs to include an assessment of the impacts, risks and mitigation requirements for OTEC facilities particularly in regards to the enormous volumes of water that will be required. Additional research will be needed to understand the environmental impacts of OTEC. This will provide greater regulatory certainty and confidence levels for OTEC developers, their financial backers and the public.

Marine hydrokinetic technologies currently depend on extensive testing of prototype devices on a pilot scale to guide technology design for eventual commercialization. Commercial scale projects will most likely have to compete with existing ocean user groups, but NOAA's potential contributions include resolving conflict by working with others under the Ocean Policy Task Force's Coast and Marine Spatial Planning Framework to develop regional coastal and marine spatial plans. Those plans, representing the best technological and spatial knowledge, should build on traditional mandates and agency roles.

Additional science, research and monitoring of coastal and ocean resources are needed to effectively inform siting of new renewable coastal and ocean energy projects. New observations of the vertical distribution of currents and of temperature in rivers and coastal areas, and of the living resources using those habitats, would also be needed for future siting and operations of marine hydrokinetic facilities. NOAA is well poised to provide this information by enhancing its current data gathering operations. In addition, NOAA requires comprehensive benthic habitat maps to fill gaps in current habitat characterization data that is needed to conduct essential fish habitat consultations.

Biomass/Biofuels

Improved and more geographically precise weather and climate forecasts of precipitation, cloud cover, temperature, winds, and water flow are needed for biomass/biofuel agriculture; improved vegetation index products; information about environmental impacts of land-use changes on coastal and ocean areas; and measurements and predictions of the distribution of atmospheric gases produced by biofuel production.

Climate Services for Renewable Energy

NOAA has a world-class scientific leadership in documenting and understanding climate variability and change, and in improving model forecasts of what the future climate will look like under different greenhouse gas emission scenarios. NOAA's capabilities and expertise in this discipline offer major contributions to the sound planning of a domestic renewable energy system by providing key climate services and information. NOAA also has the technical capability to provide the long-term data sets, the climatology, re-analyses (model-facilitated descriptions of past climate conditions), and projections into the future of wind and other renewable energy sources needed to support the private sector's decisions on selecting optimal locations for renewable energy facilities.

NOAA has the technical capability to conduct studies of how natural variability and anthropogenic climate change may affect renewable resources (wind, solar, water, marine hydrokinetic) in the future. The renewable energy industry has identified requirements for seasonal, annual, and longer-term predictions of renewable sources, as well as information about how renewable energy resources co-vary across time and space. NOAA's scientific expertise in weather and climate offer significant contributions to studies that would be necessary to optimize an electricity system based on weather-driven renewable energy, and address the advantages of increasing the diversity of energy sources, both in type and spatial location.

Little is known about the possible inadvertent impacts of deploying large numbers of renewable energy systems on the natural environment, across a range of time scales, including changes to local and regional climate. For example, wind farms could have the potential to cause small downwind changes in soil moisture or the number of frost days. NOAA could address these potential problems with targeted analyses in conjunction with academic and industry partners.

Providing meteorological observations, analyses, and forecasts is at the core of NOAA's mission. These needed products and services would fit appropriately within a NOAA Climate Service. Providing the atmospheric and oceanic research and services required for increased use of renewable energy is arguably one of the most effective ways that NOAA can support mitigation of climate change.

CONCLUSION

More detailed observations from the atmosphere, land, and ocean will feed into improved computer model forecasts for weather, water, and climate. This is at the core of NOAA's mission and it is well-positioned to partner with the private sector and support its efforts. These improvements offer substantial benefit not only for the renewable energy enterprise, but for the Nation as a whole. Thank you for inviting me to discuss NOAA's important current and potential roles in supporting this growing sector of our economy.

APPENDIX A. NOAA's Energy-Related Legal Mandates

Legal Authorities	Lead Federal Agency(ies)	Lead NOAA Office(s)	U.S. Code Citation
Energy-Specific Legal Authorities			
Deepwater Port Act (DPA)	Department of Transportation, Maritime Administration; United States Coast Guard	NOS, Office of Ocean and Coastal Resource Management, Office of National Marine Sanctuaries	33 U.S.C. §§ 1501-1524
Ocean Thermal Energy Conversion Act (OTECA)	Department of Commerce, NOAA	NOS, Office of Ocean and Coastal Resource Management	42 U.S.C. §§ 9101-9168
Ocean Thermal Energy Conversion Research, Development, and Demonstration Act (OTEC RD&D Act)	Department of Energy		
Outer Continental Shelf Lands Act (OCSLA)	Department of the Interior, Minerals Management Service	NOS, Office of Ocean and Coastal Resource Management, Office of National Marine Sanctuaries, and Coastal	43 U.S.C. §§ 1331-1356
Mapping and Observation and Forecasting Legal Authorities			
Coast and Geodetic Survey Act of 1947 (Provision of Data for Navigation of Marine and Air Commerce)	Department of Commerce, NOAA	NOS, NWS	33 U.S.C. §§ 883a-884
Hydrographic Services Improvement Act	Department of Commerce, NOAA	NOS	33 U.S.C. §§ 892-892d
Integrated Coastal and Ocean Observation System Act of 2009 (Subtitle C of Title XII of Public Law 111-11)	Department of Commerce, NOAA	NOS, Integrated Ocean Observing System Program	Not applicable. P.L. 111-1, Title XII, Subtitle C
National Weather Service Organic Act	Department of Commerce, NOAA	NWS	15 U.S.C. § 313
Ocean and Coastal Mapping Integration Act	Department of Commerce, NOAA	NOS, Office of Ocean and Coastal Resource Management	Not applicable. P.L. 111-1, Title XII, Subtitle B
Ocean Research and Resources Act	Department of Commerce, NOAA	OAR, Office of Ocean Exploration and Research	33 U.S.C. § 857-19
Weather Research and Development Act of 2000 (WRD Act)	Department of Commerce, NOAA	OAR	15 U.S.C. § 313
Research Authorities			
National Sea Grant College Program Act	Department of Commerce, NOAA	OAR, National Sea Grant College Program	33 U.S.C. §§ 1121-1131
Clean Air Act (CAA)	Environmental Protection Agency	OAR	42 U.S.C. §§ 7401-7671q
Magnuson-Stevens Fishery Conservation and Management Act (MSA)	Department of Commerce, NOAA	NMFS, Office of Habitat Conservation; NMFS regional offices	16 U.S.C. §§ 1801-1884
National Climate Program Act	Department of Commerce, NOAA	OAR, Climate Research Program	15 U.S.C. §§ 2901-2908
Marine Mammal Protection Act (MMPA)	Department of Commerce, NOAA	NMFS, Office of Protected Resources	16 U.S.C. §§ 1361-1423h
The Federal Plan for Meteorological Services and Supporting Research	Department of Commerce, NOAA; Department of the	NWS	16 U.S.C. §§ 1531-
Conservation and Management Legal Authorities			
U.S. Weather Research Program (USWRP) Authorization Act	Department of Commerce, NOAA	OAR	15 U.S.C. § 313
Management of Federal Information Resources	Wildlife Service All federal agencies.	NWS	
Fish and Wildlife Coordination Act (FWCA)	Department of the Interior, U.S. Fish and Wildlife	NMFS	16 U.S.C. §§ 661-667e
National Environmental Policy Act (NEPA)	All federal agencies. Service	PPI	42 U.S.C. §§ 4321-4375
Legal Authorities for All Federal Agencies			
Coastal Zone Management Act (CZMA)	Department of Commerce, NOAA	NOS, Office of Ocean and Coastal Resource Management	16 U.S.C. §§ 1451-1465
National Marine Sanctuaries Act (NMSA)	Department of Commerce, NOAA	NOS, Office of National Marine Sanctuaries	16 U.S.C. §§ 1431-1445c-1
Executive Order 13158 of May 26, 2000, Marine Protected Areas (MPAs)	Department of Commerce, NOAA	NOS, Office of Ocean and Coastal Resource Management	Not applicable.
Oil Pollution Act of 1990 (OPA90)	Department of Commerce, NOAA	NOS, Office of Response and Restoration	33 U.S.C. §§ 2701-2762
Federal Power Act (FPA)	Federal Energy Regulatory Commission	NMFS, Office of Habitat Conservation	16 U.S.C. §§ 791a-828c
Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), and National Contingency Plan (NCP)	Environmental Protection Agency	NOS, Office of Response and Restoration	42 U.S.C. §§ 9601-9675