WRITTEN TESTIMONY OF

Mr. John Saintcross, Program Manager, Energy and Environmental Markets
NEW YORK STATE ENERGY RESEARCH AND DEVELOPMENT AUTHORITY (NYSERDA)

BEFORE THE COMMITTEE ON
Science and Technology

U.S. HOUSE OF REPRESENTATIVES

Regarding: New Roadmaps for Wind and Solar Research and Development

Tuesday, July 14, 2009

Good afternoon, my name is John Saintcross. I am the Program Manager, Energy and Environmental Markets at the New York State Energy Research and Development Authority (NYSERDA). In this position, I am responsible for the centralized procurement of renewable resources under the Renewable Portfolio Standard in New York and the auction/sale of allowances under the Regional Greenhouse Gas Initiative and Clean Air Interstate Rule Program. There is the potential in my program area for launching a new Advanced Renewable Energy Program aimed at building a pipeline of diverse, promising renewable energy technologies that will enable achievement of New York State's long-term climate protection objectives. The legislation we are discussing today is highly relevant to the types of activities such a program might support.

The Energy and Environmental Markets Program is one of four program areas managed under NYSERDA's Clean Energy Research and Market Development organization. Some other program activities relevant to today's discussion include an environmental evaluation and monitoring program engaged with the industry in the objective measurement and analysis of the impacts on wildlife from wind energy and competing power generating resources, a clean energy technology manufacturing incentive program that supports manufacturing process development, product manufacturing, and ongoing product innovation, and the development of a new university/industry research collaborative to expand New York State capabilities in the clean energy sector. With respect to this later initiative, our initial focus will be split between the development of financially sustainable test centers in New York that will provide testing services for photovoltaics and small wind turbines during product development, final system testing for certification purposes and the creation of a battery storage consortium that will capitalize on the State's existing technical and industrial capabilities to advance New York's clean energy and storage technology industries. Because a trained workforce is essential to ensure New York has the capacity to implement and sustain the State's renewable energy initiatives, NYSERDA, in partnership with other state agencies, is developing a network of renewable energy training facilities across the State that will better prepare the State's workforce to analyze, design, sell, install, service, and maintain renewable energy technologies and systems. Currently, one institution of higher learning is offering curricula specific to wind turbine technology and similar programs are under development at another six facilities.

NYSERDA is a public benefit corporation created in 1975 through the reconstitution of the New York State Atomic and Space Development Authority. NYSERDA's earliest efforts focused solely on research and development with the goal of reducing the State's petroleum consumption. Subsequent research and development projects focused on topics including environmental effects of energy consumption, development of renewable resources, and advancement of innovative technologies. NYSERDA strives to facilitate change through the widespread development and use of innovative technologies to improve the State's energy, economic, and environmental wellbeing. NYSERDA's workforce reflects its public service orientation, placing a premium on objective analysis and collaboration, as well as reaching out to solicit multiple perspectives and share information. NYSERDA is committed to public service, striving to be a model of efficiency and effectiveness, while remaining flexible and responsive to its customers' needs.

NYSERDA's programs and services provide a vehicle for the State of New York to work collaboratively with businesses, academia, industry, the federal government, environmental community, public interest groups, and energy market participants. Through these collaborations, NYSERDA seeks to develop a diversified energy supply portfolio, improve energy market mechanisms, and facilitate the introduction and adoption of advanced energy and environmental technologies.

The NYSERDA annual budget of approximately $600,000,000 is funded through multiple sources. NYSERDA currently administers the System Benefits Charge (SBC) from a small surcharge on an electricity customers' utility bill that is allocated toward energy-efficiency programs, research and development initiatives and other energy programs. Funding for the Renewable Portfolio Standard (RPS) is also a critical part of what we do to lessen our heavy dependence on fossil fuels and reduce harmful air emissions.

NYSERDA commends the committee for taking up the issue of wind technology development, performance and improvement through applied and transformational research and demonstration. Recent passage in the House of the American Clean Energy and Security Act (H.R.2454) and the recent movement of Senate bill S.433 out of the Senate Committee on Energy and Natural Resources signal an increasing awareness that national energy policy is approaching a crossroads. A strong federal commitment to renewable energy, energy efficiency and other climate protection strategies could become common practice. NYSERDA recognizes the significance of this legislation and respects the debate ensuing over how the nation should best migrate toward a cleaner future.

NYSERDA is here before you today to speak to the promise of wind energy and related technology challenges from two perspectives; the first, as a user of the technology to satisfy state policy goals and second, as an entity committed to the pursuit of technological advancement and maturity for clean energy resources. NYSERDA, as the administrator of the New York Renewable Portfolio Standard (RPS) program on behalf of the New York State Public Service Commission, acts as a user of the technology. In this role, NYSERDA centrally procures, on a competitive basis, the economic and environmental improvements associated with the generation of electric energy from qualified renewable resources, such as wind power. The current program goal established in 2004 is to increase the percentage of renewable electric energy sold to New York consumers to at least 25 percent by 2013. However, Governor Paterson's 2009 State-of-the-State message to the New York State Legislature pledged to meet 45 percent of New York's electricity needs through expanded energy efficiency and clean renewable energy goals by 2015, the most ambitious clean energy program in the nation. As part of this initiative, the Governor requested that the Public Service Commission consider increasing the percentage of renewable electric energy sold in New York to 30 percent by 2015.

NYSERDA has conducted three procurements for large scale, grid-connected generation under the RPS program. Of the State's installed wind generation of 1,275 megawatts, approximately 1,100 megawatts are being delivered to consumers through RPS program contracts with NYSERDA. Currently, there are over 8,000 megawatts of wind capacity awaiting interconnection agreements with the New York Independent System Operator. Interestingly, according to the Department of Energy (DOE) Study, *20 Percent Wind Energy by 2030*, New York's contribution to the national goal would translate into 1,000 to 5,000 megawatts of installed wind capacity in the State by 2030. Clearly, New York's goals are quite ambitious, as the State has already installed over a quarter of the maximum expected by the study. The RPS program has been in effect for only a few years and to meet State goals, additional installed wind capacity is highly probable. Administration of that segment of the RPS program aimed at supporting smaller distributed renewable technologies such as small wind, photovoltaics and farm waste digester gas-to-electric resources, all located behind the retail meter, is expected to result in about 30 MW of installed photovoltaic capacity alone. In total, by the end of 2009 the State is expected to have satisfied 30 percent of its renewable energy targets and expects to realize direct economic benefits approaching 2 billion dollars over the lifetime of the affected technologies. Wind energy represents over 90 percent of the energy associated with program activity to date and the State of New York is counting on wind project performance and reliability to satisfy statewide program goals. Noting recent activity in the House and in the Senate with respect to a federal renewable energy standard, it becomes clear that New York will not be alone in its reliance on increased performance and reliability of wind technology.

The progress this technology has made in the last decade should be recognized. However, any vision that has wind power playing a more prominent role in the nation's energy mix must include a plan for increased support that would encompass applied wind research, development and demonstration to ensure continued improvement in technology performance and reliability.

NYSERDA, in administering the RPS program pays only for performance that translates into energy delivered and no funds are expended if energy is not produced. However, there is no comfort in under-performance. Lagging performance translates into deferred progress in meeting New York State environmental and energy security goals and potentially reduced consumer confidence in the technology. While New York has seen its success as described earlier in this testimony, progress toward renewable energy goals has been deferred as well. If it were not for under-performance by one large wind farm, New York would be at 32 percent of its RPS targets rather than at 30 percent. I would like to say unambiguously why this particular project underperformed but it is difficult to identify the root cause for less than expected production. NYSERDA is generally aware that the industry is earnestly working to understand completely why overall capacity factors have lagged expectations. In competitive energy markets such as that employed in New York where generators of all types vie to sell their energy to end-users, information on turbine failure or under-performance in general is considered sensitive. This complicates the process of learning of the specific challenges the turbine(s) may be facing and targeting research accordingly. In the case of newer wind projects, component failures are covered by warranty guarantees, and only the manufacturer has knowledge of root causes during the warranty period.

For the past couple of years, the industry has debated the underlying reasons for under-performance and as the hearing charter makes clear, the American Wind Energy Association has identified gaps in research that could prevent the nation from realizing the value from its abundant wind resources. While experience with the technology is limited in New York because of the early stage of deployment under the RPS program, NYSERDA is no stranger to these issues. Similar questions regarding historical performance and technological evolution were discussed by stakeholders in a DOE-sponsored wind technology program budget meeting in 2008 in which NYSERDA participated. Similar issues surfaced again in a recent symposium in New York where researchers presented views on industry trends, experiences and challenges.

Let me offer the following observations in regard to several challenges faced by the industry, based on NYSERDA experience and engagement with industry and university researchers. European experience shows that the mean time to failure for key turbine components such as gear boxes, main bearings, generators and rotor blades can be less than 10 years for a technology that was designed to have a life of 20 years. NYSERDA learned of a replacement of gear boxes for one make of turbines in New York after less than 2 years of operation. In addition, experience with off-shore technology in Europe indicates that computational modeling of wind flow at project boundaries and within turbine fields could be better refined as actual experience often departs from that which was predicted. Such refinement will be essential to improving turbine design because inaccurate estimation of turbine component loading will keep the industry from achieving cost and performance goals and hinder the design of new and larger turbine components. While the industry strives to increase turbine size and energy capture, the costs of land-transport of turbine components may become prohibitive. In-situ (on-site) fabrication of turbine towers and rotor blades may need to be considered as components grow larger. In-situ fabrication could require the development of new blade materials and blade fabrication processes that are robust enough for less-clean and uncontrolled site environmental conditions. Increased energy capture will translate in the need for longer blades and redesigned blade structures to manage greater stresses. Added stress on blades must be accommodated by the drive trains. Design validation of larger turbines will require new testing equipment. For instance, the magnitude of torque that must be applied to these large drive trains for testing is among the largest for any rotating piece of equipment. To meet operating and maintenance cost reduction goals, the industry will need to develop and deploy advanced condition monitoring devices to signal impending failure/performance degradation so maintenance can be performed on a preventive basis, rather than in reaction to unscheduled turbine outages. Increased reliance on the technology will place greater pressure on the turbine component supply chain. Increasing the number of component suppliers is desirable over the long-term but the pace of development must be managed in order to preclude degradation in materials and fabrication process quality. These are just a few of the challenges that should keep the industry, universities, laboratories and organizations, such as NYSERDA, busy.

NYSERDA believes these challenges are manageable and not unlike challenges other technologies face. The evolution from scientific research and analysis progressing toward product and material development, product demonstration and validation, analysis of commercial feasibility and ultimately to operating practices and codes, remains a continuum of integrated activities. It is along this continuum where NYSERDA makes its home. As an organization that for over three decades has committed itself to objective research and development, NYSERDA is committed to working with the private sector, institutions of higher learning and the federal government to characterize challenges along this continuum and collaborating where appropriate to overcome them.

By example, with respect to wind energy technology, NYSERDA supported early large and small turbine project demonstrations starting in the late 1990s, and developed early stage wind resource estimation/site prospecting programs. These NYSERDA funded activities leveraged private capital to foster the development of a pipeline of wind projects and developable site areas. NYSERDA assisted one firm in the development of state-of-the-art wind resource estimation models, resulting in the commercial release of a Web-based resource estimation service for wind developers that is now in wide use. NYSERDA is now working with this same commercial enterprise to develop a diagnostic software tool for wind plant operators. This tool will be able to manipulate the significant quantity of environmental and operating data associated with a turbine and signal potential component problems in advance of failure, thereby triggering the execution of preventive measures by plant operators. NYSERDA is currently partnered with other public and private sector organizations in a collaborative that will explore the development of an off-shore ocean wind project in New York. As a member of the collaborative, NYSERDA is currently providing technical services to the membership as they engage with parties interested in developing such a project. NYSERDA expects to work with collaborative members and private sector interests to identify challenges to project development and costs that could benefit from research and development activities that NYSERDA and other parties would fund. Such research could benefit greatly from co-funding from an increased federal wind technology budget as proposed in the legislation “Wind Energy Research and Development Act of 2009” being considered by the Committee.

With respect to a federal vision for renewable energy and the hope of decreasing the pace of climate change, and for states such as New York, that share that vision, NYSERDA cannot state emphatically enough that greater emphasis on wind research and development is essential. Increased federal support for collaborative research between the private sector, laboratories, universities and public benefit organizations such as NYSERDA, could not come at a more critical time. If the promise of wind energy is to be realized over the long-run in pursuit of aggressive climate goals, solutions to the technology challenges we speak of today must also be aggressively pursued.

NYSERDA, in administering the New York RPS, will respect the interests of private power producers and equipment suppliers to manage the technology and satisfy the due-diligence requirements of the investment community. However, to the extent the technology is called upon to produce a far greater share of the nation's energy, there is risk it may not deliver completely on the promise without further investment in research and development including field demonstration.

New York is unique in that the application for wind technology will be on two frontiers: land-based and off-shore, either in the Great Lakes or the ocean. NYSERDA believes in a research agenda that addresses needs on both of these frontiers yet expresses a need to increase the focus of our collective energies toward off-shore development.

New York could benefit from this new legislation and the funding associated therewith in many ways, but I will only speak to several in this testimony. As stated earlier, New York is already home to nearly 1,300 megawatts of land-based wind capacity that is situated some distance from load centers. Energy production is not coincident with demands in the large load centers in New York. To make progress towards its renewable goals, New York will likely see a significant increase in similar land-based development over the next five years. Advances in the development of energy storage technologies, that could store wind generated energy and release it to the electric grid when demanded, would help the State and offer similar benefits to other regions in the nation.

Advances in diagnostic tools are necessary to allow operators to proactively respond to problems and reduce unscheduled outages. Wind projects in New York are situated on complex terrain, and the current state of resource modeling as such relates to turbine micro-siting, plant layout and turbine structural loading could stand improvement.

In addition to renewed interest in advancing the state of wind technology for on-shore turbines, New York believes that the focus of wind research should shift to turbines situated in the ocean or the Great Lakes that share its border. Such a shift in direction will bring new challenges. It has become generally recognized that computational modeling of wind resources and fluid flow within turbine arrays must become more sophisticated. Offshore wind array performance is very sensitive to atmospheric boundary layer stability, which tends to vary temporally at a given site. Current array models need to be improved as they do not adequately represent these stability effects. Better models are needed to predict the impact of turbulence inside the wind plant. Accurate characterization of atmospheric behavior and more accurate wake models will be essential to understand and design turbines to withstand wind plant turbulence. To the extent these advanced computational capabilities result in turbines being sited more appropriately and, once installed, operating more efficiently and reliably, the costs to consumers in New York and across the nation will decrease. Improvements in this regard will benefit both on and off-shore turbine applications.

The challenges of measuring and verifying the wind resource in expansive offshore tracts is great. Conventional practices in Europe involve the installation of a fixed meteorological mast with a pier-type foundation driven into the seabed. Such structures cost at least several million dollars to install, with costs a function of water depth and maximum wave height. Across large project areas, more than one tower may be needed to document the spatial resolution of the resource. Alternatives to fixed towers include the use of surface-based remote sensing technologies such as LIDAR, which can be mounted on stub masts or possibly on spar buoys, and floating towers that are relatively stable because they are tethered to the seabed. These alternatives show great promise but require further field testing and validation before being widely accepted as “bankable” data monitoring approaches by developers, investors, and lenders.

The predominant turbine design in use in the United States is not suited for application off-shore. It is widely accepted that turbines for off-shore use will be larger on the order of 2 to 4 times the scale now in use for land-based turbines. There is strong interest in using such turbines in the Great Plains as well. Public opposition or sensitivity to the physical scale and increased aerodynamic sound from larger blade rotation may pose less of a problem when siting in places in the midsection of the country where population density is not great. Migrating to such scale for on-shore application and designing a turbine specifically suited for the off-shore operating environment will require a bold effort in engineering, prototyping, testing and manufacturing.

New York could benefit from these and other research activities described in the work of the American Wind Energy Association Offshore Wind Working Group that is attached for reference[1]. For off-shore development to move forward and performance of land-based turbines to be improved, NYSERDA believes that state-funded research in this arena needs to be significantly leveraged with federal funding that is of material scale and duration as proposed in the legislation before the Committee.

In closing, NYSERDA, as a user of wind technology to satisfy New York climate goals and as a science-based, research organization focused on the development and commercialization of clean energy technologies, strongly encourages the Committees to consider substantially increasing federal funding for wind technology research and development. NYSERDA has a history of collaborating with the Department of Energy, its laboratories, institutions of higher learning and the private sector on research, and would welcome the opportunity to continue this relationship in support of achieving ambitious but necessary climate change and energy independence goals.

[1] Research and Development Needs for Offshore Wind, R&D Subcommittee, Offshore Wind Working Group, American Wind Energy Association, April 2009

Research and Development Needs for Offshore Wind

American Wind Energy Association
Offshore Wind Working Group 3 April
2009

R&D Subcommittee Chairman:
Willett Kempton – U. of Delaware, willett@udel.edu
Subcommittee Members:
Peter Mandelstam – Bluewater Wind
Michael Mercurio – Island Wind Power
Walt Musial – National Renewable Energy Laboratory
Greg Watson – Massachusetts Technology Collaborative
John Ulliman – American Superconductor
Susan Stewart – Penn State
Subcommittee advisors:
Ed Demeo – Renewable Energy Consulting Services, Inc.
Soren Peterson – Rambøl Engineering
Steve Lockard – TPI Composites
J. Charles Smith – Utility Wind Integration Group

Introduction

Rationale: This report summarizes the findings from the Offshore Wind Working Group (OWWG) subcommittee on research and development (R&D). The largest and most energy-intensive area of the United States, the Northeast and Mid-Atlantic coastal states, is far from large terrestrial wind resources such as the Great Plains. Fast growing population centers in the southeastern U.S. are also much farther from terrestrial wind resources than to potential offshore wind resources. The Gulf and West coasts similarly have large loads closer to the ocean than to large terrestrial wind resources. To reach 20 percent wind integration, as laid out in the Department of Energy's 20% Wind Energy by 2030 report, the offshore wind potential of the U.S. coasts will be important. Several projects along the East and Gulf coasts are already designed and moving through the permitting process. Nevertheless, levelized cost of electricity (LCE) is still higher than market in many areas. The R&D proposed here is designed to lower LCE, thereby leading to more widespread implementation - making the achievement of 20% wind integration more widespread regionally and not concentrated primarily in the heartland.

Process followed: In 2007, the OWWG created a document to outline the R&D needs of the offshore wind industry in the United States. The overall OWWG put forward suggestions for needed R&D and the subcommittee additionally solicited suggestions from industry experts on offshore wind. The list was reviewed by the entire OWWG, resulting in edits and revisions. The Subcommittee and experts then rank ordered this list and combined related topics. The R&D efforts below ranked in the top half by priority and are roughly listed in priority order. The lower-ranked half is not reported here. Higher ranks were given each R&D suggestion that:

1. Is essential to begin and develop the offshore wind industry (note: the U.S. today has zero offshore turbines installed)
2. Will lead to new turbines, other components, or installation methods that are better, cheaper or more reliable, or bring such components to market more quickly
3. Will lead to lower levelized cost of energy
4. Is uniquely required by offshore wind energy
5. Would lead to commercial development, possibly by multiple firms
6. Will help the U.S. Federal Government, States, or communities make better decisions or

reduce uncertainties regarding offshore wind

7. Begins long-term research that needs to be started now
8. Is unlikely to be done by companies on their own
9. Provides diversity - the entire list includes at least one of each of the following:
   - shallow water
   - transitional depth (25 - 60 m depth)
   - deep water (> 60m)
10. Affects large resource areas

Some of these R&D areas are described in more detail in "A Framework for Offshore Wind Energy Development in the United States" by the Offshore Wind Collaborative in Massachusetts, and we have drawn from that document for some R&D recommendations.

In March 2009, the same subcommittee was re-convened to update the list of R&D needs, and to estimate approximate budget and scheduling for the highest-ranked items on the list. In the fall of 2008, a team of over 80 AWEA members and advisors from industry, government and academic institutions identified $201 million as the DOE funding level that will be necessary to support the research and development and related programs needed to provide at least 20% of America's electricity from wind by 2030. This funding level includes $108 million for Wind Turbine Technology (components, reliability and offshore applications), with $15 million annually allocated specifically for offshore wind. In light of these cost allocations, the OWWG has created cost estimates for each of the following action items under a "blue sky" scenario.

Research and Development Priorities

The following R&D areas appear in the rank order developed by the committee. R&D areas that were ranked at the halfway point or below are not shown.

1. <u>Fundamental design evaluation for 5 - 10 MW offshore machines</u>

The currently predominant turbine design has been optimized for land applications. Optimization for offshore removes or alters many design parameters. There is a need to develop a basic analysis of fundamentally different designs. For example, one of many possible outcomes could be that a viable 5 – 10 MW offshore machine might be two-bladed, downwind, mostly-passive yaw with a lattice tower. First phase of this effort would be extensive engineering analysis of fundamentally different design configurations, with publicly-owned intellectual property. Second phase begins prototyping, possibly with public-private partnerships and leading to commercial products. Note that there has not yet been a public commitment from any U.S. manufacturer for serial production of offshore-class turbines. The first development projects already in the pipeline will probably use marinized versions of land designs and draw on European experience. But for designs as described in this section, manufacturers may need support and/or incentives to begin the development of optimized ocean turbines.

1a. Highly experienced design teams should be commissioned to implement new design requirements that take into account relaxed constraints in the offshore environment, such as noise and esthetics. A first-cut design study should be done, including multi-turbine grids, downwind, two bladed rotors, passive yaw, high speed rotors, direct drive systems, etc, with competition between at least two design teams. This effort should produce guidance for subsequently building several fundamentally different prototypes by private firms, or public-private partnerships.

Optimized offshore turbines will likely favor larger sizes than are available today. New size-enabling technologies will be required to push wind turbines to the 5-10 MW size. These technologies include lightweight composite materials and composite manufacturing, lightweight drive trains, modular highly reliable direct drive generators, hybrid space frame towers and integrated gearboxes. Ultra-large turbines also present new opportunities that are not practical in smaller sizes. For example, control systems and sensors that monitor and diagnose turbine status and health do not grow in cost as turbine size increases, so larger turbines will enable a higher level of controls and condition-monitoring intelligence. Research is needed on control methods using innovative sensor and data processing technologies to mitigate turbine subsystem loads, to improve energy capture and to improve integration into the electric grid. New rotor technologies will include advanced materials, improved aero and structural design, active controls, passive controls, and higher tip speeds. Methods to enlarge the wind turbine rotor to increase the energy capture in ways that do not increase structural loads, cost, or electrical power equipment should be employed. Concepts such as active extendable rotors, bend twist coupled blades or more active control surfaces may become practical. Structural loads due to turbulence can be limited by using both passive and active controls on the longer blades. However, since gravity loads grow with the blade length cubed, one must seek technologies that offer higher material performance as blades grow. New materials and manufacturing processes are used to simultaneously reduce total blade weight for 10 MW turbine blades. Blade designers will have to consider the extremes of marine moisture and corrosion and the incidence of storm conditions unlike those encountered on shore, including extreme tropical weather in the Southeast and Gulf and ice in the Great Lakes. In addition to these problems, the higher humidity levels offshore create added problems associated with icing in higher latitudes.

1b. Potentially a separate project would be development of floating wind turbines. These are necessary to large offshore wind exploitation on the West Coast. The development of optimized floating wind turbine systems will require additional innovation to reduce the weight of turbine and tower components as a large portion of the buoyancy structure exists to support the dead weight aloft. The exact relationship in this weight advantage needs to be analyzed through further studies and will be dependent on the specific platform architecture. This may be achieved through high-speed rotors, lightweight drive trains, composite towers or substructures using lightweight aggregates.

1c. A parallel open design competition should be set up, open to university student teams or others with design expertise but not employed in wind manufacturing. This effort would facilitate interest and some expertise among American institutions of higher learning, and among newly graduating engineers, and could possibly be synergistic with 1a and 1b in generating “out of the box” design concepts. It would be judged by volunteer professional engineers with wind expertise, possibly at the site of a national wind conference. The program would include five one-year competitions, each judged and with prizes awarded – budget would be $400,000/year for 5 years.

Budget and Scheduling

Design and development is a long term effort and should be broken down into multiple phases and technology pathways. For turbines and fixed-platform, bottom-mounted tower designs, we envision an initial phase for a public private partnership with industry that allows designs, components, or full systems to be developed at varying levels of funding. First year funding is $10 million but ramps to a $20 million/year program with expectation of 10 year duration and 50% cost sharing on all major hardware development.

Floating projects would be done the same way but the hardware phase should not start until conceptual designs have been proven on desktop studies with full dynamic modeling, so that designs have been fully validated prior to co-funding prototype builds. The first stage would be a conceptual design competition for approximately $10 million (about 10 awards) and would lead to the selection of the 5 best designs, which would then submit a detailed design. The next step would be a demonstration project building phase beginning in about 3 years.

2. Large Scale National Offshore Wind Testing Facilities A major R&D priority is the need for a large scale national offshore wind testing facility. This would presumably be done with DOE, working in cooperation with multiple turbine manufacturers. This would

provide testing facilities for the new larger offshore-class machines, which are too large for existing U.S. facilities. There are two components to this facility, component testing and site testing.

2a. Large offshore turbines will require test facilities for components such as blades, drive trains and generators. Currently no facilities exist in the U.S. where one can test a 5 MW size blade and none exist anywhere that can perform the necessary testing for a 10 MW wind turbine blade. Gearbox and generator testing are also essential to developing low-maintenance components. Testing is essential to reliability improvements and, in turn, is critical to long-term cost effectiveness. DOE estimated in 2002 that at least $24 million is needed to construct component test facilities.

2b. The site testing would allow DOE and manufacturers to understand the requirements for offshore wind. This could serve as a site for pilot projects at sea to demonstrate fundamental turbine and substructure technologies, to measure the true MET Ocean environment and to reveal issues relating to permitting and potential environmental impacts. New initiatives could be conducted in the public domain to maximize benefits to a wide industry base, including potential new entries from the offshore oil and gas industry. The output should yield critical design methods and codes, uniform standards for structural reliability, design specification guidelines, industry accepted safety margins, and valuable data to validate design models, codes and assumptions. This could be a North American testing facility with Canadian partnership to share resources and data for a more cost effective approach. The DOE should begin scoping the costs and requirements of such a site and solicit feedback from industry.

Budget and Scheduling
Funding is needed for 2a - large component test facilities for blades, gearbox and generators. This is a near term effort that could start fairly quickly. The test facility could be one site, or blades in one site and gearbox/generator in another. Total cost could be $25 million to $50 million, for 10 MW component facilities. For 2b, an in-ocean testing facility should be scoped. It may make sense for Federal lab management of a few turbines, used for generic testing and development of standards. Due to mobilization cost of offshore installations as well as O&M costs, in-site installations would likely be shared with commercial developments and/or turbine manufacturers.

<u>3.</u> Offshore Design Computer Codes and Methods The development of accurate offshore computer codes to predict the dynamic forces and motions acting on turbines deployed at sea is essential before the next generation of turbines can reliably be designed. One of the immediate challenges common to all support structure designs is the ability to predict loads and resulting dynamic responses of the coupled wind turbine and support structure when subjected to combined stochastic wave and wind loading. The offshore oil industry must consider only the wave loading when extrapolating to predict extreme events, but offshore wind turbine designers must consider wind and wave load spectrums simultaneously.

Hydrodynamic effects need to be included with analysis tools that incorporate combined wave loading models for regular and irregular waves. Time domain wave loading theories, including free surface memory effects, are used to relate simulated ambient wave elevation records to loads on the platform. The complexity of the task to develop accurate offshore modeling tools will increase with the degree of flexibility and coupling of the turbine and substructure. Usually, greater substructure flexibility results in greater responses and motions to wave and wind loading. Perhaps the most important and least understood analysis task is the determination of the extreme load generated by these two different dominant stochastic load environments. Only recently has research begun on developing this type of extreme load extrapolation technique.

Additional offshore loads arise from impact of floating debris and ice and from marine growth buildup on the substructure. Offshore turbine structural analysis must also account for the dynamic coupling between the translational (surge, sway, and heave) and rotational (roll, pitch, and yaw) platform motions and turbine motions, as well as the dynamic characterization of mooring lines for compliant floating systems.

Budget and Scheduling
This requires a sustained effort to get validated models and design tools. Historically a 10 year effort or more requiring a sustained group of 10 modelers at about $3 million /year.

4. Cost Effective Offshore Wind Foundations

A large cost fraction for offshore wind systems resides in the foundations and substructures. Taking into account installation costs, long-term maintenance, coupled turbine loads and weight, as well as the cost of the substructure itself, the optimal turbine/substructure system needs to be established. Due to the wide range of variables this effort will require extensive trade-off studies and a much better understanding of what the existing and long-term offshore infrastructure can deliver. Before considering deeper waters, an earlier goal should be to develop primary support structures that can be deployed out to nominal depths of 50 meters. A qualified engineering team should evaluate prototyped designs such as those being used at the Beatrice site, determine the feasibility and cost to do this in the U.S., and make recommendations for what alternative designs should be considered, if any. For example, new drop-in foundation designs that avoid costly offshore vessel dependence and work at sea may provide better alternatives to the current options. Fixed bottom systems comprising rigid lightweight substructures, automated mass-production fabrication facilities and integrated mooring/piling deployments systems that minimize dependence on large sea vessels should be developed as a possible low-cost option.

This effort should be extended to deeper waters at a slightly lower priority. Several designs should be evaluated for bottom-mounted turbines to 100 meter depth and floating foundations beyond 100 meters of water. Floating systems require anchors to maintain position and stability. The anchor systems available in the oil and gas industry are expensive and have not been optimized for mass production or for wind energy. For floating systems, platforms that do not depend on mooring line tension as their primary means for achieving stability would benefit from the development of new low-cost drag embedment type anchors or vertical load anchors (VLA). Deployable gravity anchors show promise for all platform types because of their simplicity. Finally, better models of scour processes are needed in conjunction with improved design methods for scour protection.

Budget and Scheduling
Similar design team approach as for recommendations 1a and 1b above - we recommend design team awards for industry professional, possibly drawing on industry experts in offshore foundations (oil and gas construction). These teams would innovate on what they know and demonstrate new foundation technologies designed for wind. One or two phases with a total cost of $60 million (4 year effort at $15 million/year at 50/50 cost share) leading to new commercial foundations.

5. Marine Grid, Power Conditioning, and Infrastructure Development

To reach the nation's 20% wind goal, we will need large turbine arrays, e.g. over 100 turbines installed in a single array. These are being planned both in large land installations, for example in the Great Plains, and for offshore wind. But for such arrays, the current distribution of power conditioning may not be optimum. Also, improved marine power transmission cables are needed.

5a. Currently, each turbine must independently provide all electrical components and controls needed for grid synchronization and power conditioning. For an array of hundreds of turbines, it may be more economical to redesign both generator and power conditioning, and to centralize much of the power conditioning on clusters or trunks of turbines, or for the whole array. The individual machine might have minimal power conditioning. As one of several examples, each turbine might only produce variable-voltage, constant current DC for a series DC bus along each row of turbines. The centralized power electronics would synchronize to grid phase, frequency and voltage. For remote sites, the centralized array power conditioning might not even produce AC; it might produce high-voltage DC to feed a HVDC power line, and let the load side of the HVDC transmission produce AC and do the grid matching.

5b. For large scale offshore deployment of multiple projects, there will be substantial advantages in developing large capacity submarine power cables and associated converter stations. This effort might begin as technology neutral, including a diversity of approaches including high-voltage direct current (HVDC) with thyristor valves in the converter stations, smaller HVDC using IGBT valves, and superconducting cables for example. These would be used to connect to large installations further offshore and to interconnect multiple offshore wind farms, e.g. along the East Coast. Currently there are no U.S.-made marine-certified cables for offshore wind. The goal is to develop high capacity, high efficiency and cost-effective marine cables.

Budget and schedule
5a should identify two teams with high-voltage, high-current, power electronics expertise to develop alternatives to power conditioning in each turbine. This would take $2 million/year for years 1-3 for design, review and evaluation. Then develop prototypes of power conditioning (not entire turbine), cost-shared with industry at $20 million/year for years 4-6. Item 5b will require $10-15 million/year.

<u>6.</u> Certification and Standards Development

Research funding is needed to build confidence that adequate safety is being provided without excessive caution that will raise costs unnecessarily. The Minerals Management Service (MMS) has been authorized to set the standards for structural safety for all offshore wind turbine structures. We have a common goal to create safe structures. The wind industry and MMS should work together to build a reasonable regulatory system and a set of offshore standards that will promote the safety needed to instill investor confidence without hindering deployment.

Budget and Scheduling
Research funding should be an ongoing effort to be sustained at $1 million/year. Include supporting research to address analysis required to understand structural reliability issues working with the Minerals Management Service.

7. <u>Improved data on the offshore wind resource and development constraints</u>

7a. Conduct a survey of the continental shelf physical resources using existing data bases in the near term. Using existing data from multiple sources, locate and quantify the practical wind resource of the U.S. Continental Shelf to 100 meter depth. Combine direct oceanic wind data, geological and bathymetric data, existing tower designs, and easily-accessible conflicting uses that appear on navigation charts. This would yield total areas of viable resource and breakdown by state. This could guide private developers, national and regional planning, technology development and state-level policies such as state Renewable Portfolio Standards. For wind, document both strength and autocorrelations across sites in order to determine the value of offshore interconnections; this could identify areas that would, if connected, reduce intermittency and potential opportunities for marine interconnections. This is a near term project that should be started immediately. Early priority should be given to the East Coast.

7b. Survey the outer continental shelf using GIS land-use overlays to characterize marine use activities, ocean ecology, and other parameters relevant to offshore wind development. This activity should be conducted in close cooperation with each state’s local and regional stakeholders. These studies need to take into account a wide range of environmental and land/sea use issues in advance of wind development prospectors; including sensitive ecosystems, avian flyways, aviation fly zones, shipping channels, military zones, fisheries, existing easements, and other competing uses. Because this high level data is not intended for siting decisions, site-level studies will still be necessary for individual projects. Also, point conflicts such as historical shipwrecks may be better left to developer site-level surveys. Early priority should be given to the U.S. east coast.

7c. Install a series of meteorological towers of 100 m height, along coastal areas believed to have good resources, based on 7a and 7b. On-site, hub height met towers would both improve the characterization of the ocean meteorological environment and provide some of the due diligence data needed by investors, thus shortening the site study and development cycle. Due to the cost of mobilization, a series of towers installed, for example, by a consortium, would be far cheaper than installation of single towers at a time by developers. These platforms could also be used for other instruments, such as bird radar, SODAR or LIDAR, which require either greater height or stationary platforms, rather than buoys. Organizational effort here emphasizes Federal agency staff and university experts to establish and maintain public data access, maintain facilities and build expertise.

7d. Measurements and models are needed to characterize the nature of wind and waves since offshore wind turbine designs depend on accurate understanding of the physical ocean environment. This must be done at different geographic locations since offshore structural design requirements will be based on site specific data. The series of meteorological towers described in 7c would provide additional needed measurement components, if they were strategically dispersed to 6-7 locations that would include representative measurements to classify the impacts of warm weather climates (e.g. lightning, hurricanes, warm water conditions, etc.) as well as cold weather climates (e.g. icing in the Great Lakes, perhaps in cooperation with Canada). A European Union effort is underway to improve meteorological predictions of wind power output. By joining this effort, greater gains could be made per unit cost, while insuring that resulting methods and models are applicable to North America.

Budget and Scheduling
Item 7a is very high priority and can proceed immediately without waiting for item 7b, 7c or 7d. The cost would be $2 million/year for five years. Use university experts or environmental firms with track records on ocean-specific wind analysis, expertise on using existing data and models, and proven ability communicate in a form usable to state policy-makers (e.g. how many MW are practical in this state). Use known teams and existing data so as to get practical actionable results soon, with later refinement by items 7b, 7c and 7d.

Item 7b might be able to leverage Interior or National Oceanic and Atmospheric Administration (NOAA) funds.

Item 7c would require $120 million over 2 years to deploy 30 towers, each 100 meters with multiple instruments. Also, $5 million/year over 5 years for a team bridging National Buoy Data Center (NBDC) and university and Federal ocean meteorology experts. This team would initially specify tower locations, archive and provide open data access (NBDC) and maintain instruments and calibration (NDBC). Then the team will perform and publish strategic analysis (ocean meteorology experts) and, once the towers are in place, publish data use guidelines usable by private developers and by state and Federal energy planners (energy policy experts).

Item 7d would draw on the met towers in 7c and thus, the additional funds for meteorological characterization would be $1 million/year over 5 years.

<u>8.</u> Offshore Wind Farm Arrays

Offshore wind array performance is very sensitive to atmospheric boundary layer stability which tends to vary temporally at a given site. Current array models do not adequately represent these stability effects and need improvement. Better models are needed to predict the impact of turbulence inside the wind plant. Accurate characterization of the atmospheric boundary layer behavior and more accurate wake models will be essential to understand and design turbines to withstand wind plant turbulence. Since turbulence causes wear and tear on the turbines, as the industry grows it will be a high priority to be able to quantify the degree of turbine generated turbulence under a wide range of conditions and to develop tools to design wind plants that minimize turbulence at the source.

The configuration and spacing of wind turbines within an array has been shown to a have a marked effect on power production from the aggregate wind plant as well as for each individual turbine. Typical offshore wind farms lose 10% of their energy to array effects. Improvements in array layout may allow some recovery. Uncertainties in power production represent a large risk factor for offshore development. Today's wake codes attempt to model performance but empirical data show inadequate representation of individual turbine output. Large cost reduction opportunities exist in improving wind farm performance models.

The impact of one wind plant on another is likely to be a larger problem than for land-based systems because the open ocean contains continuous tracks of unobstructed windy territory. Wind plants introduce downstream turbulence that regenerates over some distance but analytical models to predict optimum spacing between arrays are very immature. Wind plants installed upstream must take into account their effect on downstream wind plants in terms of energy capture predictions as well as structural loads due to modifications of the wind characteristics. The understanding and managing of "wind rights" and set backs will be important.

Budget and Schedule
This effort will require a sustained team of 3-4 people over a 5 year effort at $1.5 million/year.

<u>9.</u> Potential Effect of Offshore Wind Development on Coastal Tourism

Tourism and recreation-related development is one of the major factors shaping development patterns in coastal zones and can affect coastal lands, near-shore waters and beaches. The coastal zone is a limited resource being used by many different stakeholders, including local residents, foreign and domestic tourists, and industry. Data from the U.S. Census Bureau indicate of those who were surveyed in 2003, over fifty million had visited a beach within the past twelve months. Although it is often alleged that an offshore wind farm in the United States will have a specified effect on tourism, the impacts (negative or positive), if any exist, have not been empirically studied. A survey should thus be conducted to collect data on beachgoer selection trends, beachgoer preferences, and demographics to examine the link between beach selection and the presence of offshore wind farms.

Budget and Schedule
Initial prospective surveys in 6 states with near-term development plans will cost $400,000 over 2 years. Coastal tourism data combined with on-beach surveys at two development sites, before, during construction and 2 years after project completion, will cost $1 million/year over 4 years.

<u>10.</u> Advanced Deployment and Maintenance Strategies

The largest components of higher offshore LCE cost is the higher cost of construction and maintenance in offshore environments, including installation and logistics. A database of offshore equipment and cost is needed so that costs can be accurately represented and cost reduction efforts can be assessed. Lifting systems should be developed that will enable the use of alternative towers, turbines and rotors to reduce or eliminate the need for specialized heavy-lift ships. For example, the development of a streamline system for installation to float out turbine and towers assembled in dry dock to a project area would reduce cost and cost over-runs due to bad weather conditions. European wind farms have incurred up to 30% cost overruns because of bad weather on some projects.

The reliability of wind turbines must be improved for offshore systems. Fewer repairs would further eliminate the need for expensive vessels. New offshore strategies must be developed that minimize work done at sea. It is essential that new turbine designs, starting with the preliminary concepts, rigorously place a higher premium on reliability and in-situ repair methods. Materials must be selected for durability and environmental tolerance. The design basis must be continuously refined to minimize uncertainty in the offshore design load envelope. There must be an emphasis on the avoidance of large maintenance events that require the deployment of expensive and specialized equipment. Much of this should be done at the design stage through ruggedized components, improved quality control and inspection, and increased testing at all stages of development. Offshore machines must be proven on land first before they are deployed in numbers and the industry must establish guidelines to determine when a machine is ready for deployment at sea.

Potential developments of new manufacturing processes and improvements of existing processes that will reduce labor, reduce material usage, and improve part quality, is an area of great potential for offshore cost reductions. Offshore installations may allow for manufacturing and assembly to occur in close proximity to well developed industrial facilities as well as the offshore site. The use of large barges for transport then allows the full turbine to be transported from the manufacturing and assembly facility to the final point of installation.

To further reduce offshore maintenance, coatings that would last the life of the project for the primary structure, tower and blades should be developed. Materials to protect secondary structures (platforms, j-tubes, etc.) should also be developed. Current European offshore wind shows that deposits of insects and salt spray, and pitting, cost 2-3% of electrical output. New methods for cleaning, and/or recoating blades at sea should be developed and tested.

Budget and schedule
The R&D subcommittee does not have a firm basis for estimating the cost of this effort. We estimate $5 million for vessel-based research and $5 million for O&M focused research, the latter would be cost-shared with industry.

<u>11. Integration of large offshore power into Eastern grid</u> Because the offshore wind resource of the coastal Eastern states is estimated to be substantially greater than the load of these states, practical use of this resource will require advances in the integration of large fluctuating resources into the grid. A comprehensive set of integration options might include at least the following two.

11a. Transmission strategies for coastal areas need to be understood, and may be different from mid-continental areas. For example, transmission inland may be used to absorb power when offshore wind power exceeds 100% of load in coastal electric systems. Another strategy is to build transmission along the coast, offshore (like the European so-called SuperGrid); this would connect offshore wind facilities and use meteorological diversity to level output fluctuations.

11b. Devices and methods for management of wind fluctuations should be tested and modeled. These include planning of greater loads during winter when the offshore wind resource is greatest (e.g. electric heat displacing combustion furnaces in buildings), management of centralized storage and active management of storage inherent in loads (e.g. heat storage added to building heating systems). Two methods for storage include centralized purpose-built electrical storage, and use of plug-in vehicles for electrical storage during excess wind and release during insufficient wind.

Budget and schedule
11a. This effort would require $2 million/year for a three-year transmission study, including use of existing Eastern grid, and alternative designs for offshore Atlantic connector.

11b. This effort would require $2 million/year for 4 years and would include two parallel efforts: first, field experiments using managed loads, storage heaters, and plug-in vehicles to level wind output; second, a modeling effort combining site storage techniques, centralized storage, and transmission.

12. Avian and Marine Ecology Research Extensive avian research has been conducted in European wind farms without finding a major problem associated with mortality due to wind turbine collisions. However, concerns still exist and European experience is insufficient to fully demonstrate the impact of wind turbines on birds in the United States.

12a. Prospectively and area-wide, a single ornithological study should be conducted over the entire Eastern United States flyway. More detailed research should focus on areas most suitable for wind energy deployment.

Many species of fish and other marine life are more abundant in shallow waters favored also by current offshore wind projects. These species may include both resident and migratory seabirds (including gulls, terns, gannets, cormorants, storm-petrels, shearwaters and others) which come to these banks for food year round. Because the U.S. continental shelf is less shallow than in Europe, there may be a greater concentration of marine life in these shallow areas than similar areas in Europe. The feeding ecology of seabirds and other water fowl needs to be studied on offshore banks and over submerged ledges.

12b. Before and after construction studies should be conducted at early wind farms in the United States with public disclosure of the findings. Estimating post construction mortality of birds at terrestrial projects is a matter of physically searching the area around turbines and correcting for misses and scavenging. Offshore, new remote sensing methods to detect bird strikes need to be designed and field tested. Careful studies are needed to determine the effects of offshore turbines on various avian species, building on extensive work conducted in Europe and in the U.S. onshore wind turbine market.

Budget and Schedule
For the prospective area-wide study mentioned in 12a, the cost is estimated by extrapolation from a New Jersey comprehensive study, underway in 2009, extrapolated by area to cover Virginia through Maine out to 30 nautical miles. On this basis, flyway survey cost over two seasons would be $132 million - however, a more refined cost estimate is needed. 12b. This effort requires two site studies (pre- and post-construction) managed by Federal agencies and not by developer, with results publically available. $7 million per study, synchronized to timing of early two developments in diverse ecological zones.

13. Recommended methods for evaluating costs and benefits of projects During both the Long Island offshore wind process and the Delaware power purchase agreement process, there was considerable debate over the cost and benefit analyses of each project. Development of recommended criteria and methods for evaluating the costs and benefits of offshore wind projects, including guidelines for evaluating direct, indirect and induced job impacts, would help to eliminate debate on this issue. These criteria and methods could optionally be used by states, developers, or non-governmental groups to evaluate specific offshore wind proposals.

Budget and Schedule
This effort would require $400,000 over 2 years.