U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

WIND AND WATER POWER PROGRAM

Offshore Resource Assessment and Design Conditions Public Meeting

Summary Report

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2011 Offshore Resource Assessment and Design Conditions Public Meeting

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Derived from Participant Input at the Public Meeting on Information Needs for Resource Assessment and Design Conditions June 23–24, 2011 Crystal City, VA

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On behalf of:

Wind and Water Power Program
Energy Efficiency and Renewable Energy

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List of Acronyms

BOEMRE	Bureau of Ocean Energy Management, Regulation and Enforcement
COE	cost of energy
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
EERE	DOE Office of Energy Efficiency and Renewable Energy
MHK	Marine and hydrokinetic energy
MOU	Memorandum of Understanding
NOAA	National Oceanic and Atmospheric Administration
NWP	Numerical weather prediction
OCS	United States Outer Continental Shelf
RADC	resource assessment and design conditions
WWPP	DOE EERE Wind and Water Power Program

1. Introduction

Increasing the share of U.S. electricity generated from renewable energy is crucial to mitigate the risks of climate change and shift the nation toward a sustainable, low-carbon economy. In his 2011 State of the Union address, President Barack Obama called for 80% of the nation's electricity to be generated from clean energy sources—including offshore wind as well as marine and hydrokinetic (MHK) technologies—by 2035 (White House 2011).[*] Through the North American Leaders' Declaration on Climate Change and Clean Energy, the Obama Administration also supports a 50% or greater reduction in global emissions by 2050, with developing countries reducing their emissions by at least 80% (White House 2009).[†]

The offshore energy industry requires accurate meteorological and oceanographic information to evaluate the energy potential, economic viability, and engineering requirements of offshore project sites. Currently available data, instrumentation, and models are generally inadequate to supply the information required to support wide-scale technology deployment. For example, an extremely limited number of U.S. offshore wind observations are currently available at hub height for wind turbines, and current approaches are inadequate to accurately scale up the surface wind measurements obtained by technology installed on widely scattered buoys. In addition to meeting industry needs, regulatory agencies must have access to databases and models that can accurately characterize offshore conditions to evaluate lease potential, determine economic fair return, and establish the engineering design loads needed to guide technical and safety approvals and subsequent operation and maintenance processes.

On June 29, 2010, the U.S. Department of Energy (DOE) and U.S. Department of the Interior (DOI) signed a memorandum of understanding (MOU) to coordinate deployment of MHK and offshore wind technologies on the outer continental shelf (OCS) of the United States. The MOU describes five action areas to support the deployment of offshore renewable energy, one of which is resource assessment and design conditions (RADC).

RADC actions planned in response to the DOE-DOI MOU include developing a roadmap and implementing a plan for acquiring the necessary information to safely and cost-effectively design, site, install, operate, and regulate offshore renewable energy plants. Input from the public was solicited to inform the development of the roadmap and implementation plan.

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[*] Obama, "State of the Union Address," January 25, 2011, http://www.whitehouse.gov/the-press-office/2011/01/25/remarks-president-state-union-address

[†] North American Leaders' Declaration of Climate Change and Clean Energy, August 10, 2009, http://www.whitehouse.gov/the_press_office/North-American-Leaders-Declaration-on-Climate-Change-and-Clean-Energy/

Public Meeting on Information Needs for Resource Assessment and Design Conditions

The Wind and Water Power Program (WWPP) in the DOE Office of Energy Efficiency and Renewable Energy (EERE) hosted a public meeting on June 23–24, 2011, in Crystal City, Virginia. The meeting focused on the critical meteorological and oceanographic measurements and data needed for successful deployment of offshore renewable energy technologies, including wind and MHK. The objective was to develop a tactical plan to guide future WWPP investments in filling the critical information gaps.

Following an initial plenary session in which invited speakers surveyed information availability and needs for various applications related to offshore renewable energy, the breakout groups convened to discuss existing gaps in observations and computational products for each of five focus areas. Professional facilitators guided each group's discussion through a common set of priorities:

- Identifying broad **challenges** facing offshore technology deployment
- Developing a list of **key information and data requirements** (e.g., instrumentation, data management tools, and modeling software) for successfully deploying offshore energy
- Creating detailed, **tactical pathway maps** that specify the measurements needed; the associated variables, impacts, and end users; and a tactical plan outlining the stakeholders and their roles and the project's scale, key components, and timeline.

To maintain a clear focus and maximize participation, these facilitated small group sessions tapped participants' diverse knowledge, expertise, and perspectives; distilled themes and organized concepts; and fostered consensus on the most promising issues and tactical plans that WWPP can pursue in the near future. The breakout groups were divided into the following five subject areas:

- **Forecasting:** Initialize, constrain, and improve appropriate forecast models for predicting winds, waves, and currents hours to days in advance
- **Energy Projections/Performance Monitoring:** Estimate energy that will be produced by an offshore renewable energy plant (once plants are in place, information will also be required to evaluate a plant's actual production and determine causes for changes in its performance)
- **Technology Design and Validation:** Design and validate energy devices that can withstand physical loads while operating at optimum efficiency in the marine environment
- **Facility Design:** Design offshore energy plants as a whole, including accounting for interactions among individual devices and siting issues

- **Operations Planning/Site Safety:** Effectively schedule and execute operation and maintenance activities, including safe facility access and response to extreme events.

Though each group approached the critical meteorological and oceanographic measurement and data needs for successful deployment of offshore renewable energy technologies from a different perspective, the output was fairly cohesive. Rather than a set of needs unique to each of the five subject areas, the meeting produced a suite of needs reflecting each group's focus area yet unified by common themes. Each group illuminated different facets of commonly identified data and knowledge needs. As such, the workshop results are presented as a single, unified discussion of the following common themes:

- **Modeling and simulation** challenges, knowledge needs, and information gaps
- **Resource evaluation and environmental** challenges, knowledge needs, and information gaps
- **Performance evaluation** challenges, knowledge needs, and information gaps
- **Economic and market** challenges, knowledge needs, and information gaps
- **Collaboration** challenges, knowledge needs, and information gaps.

2. Identified Challenges

The challenges facing offshore technology deployment span the breadth of technology development and deployment, affecting stakeholders across the public and private sectors. Identifying and discussing these broad concepts helped meeting participants frame and focus subsequent discussions.

Modeling and Simulation

Obtaining sufficient, accessible data from which to model new technologies and evaluate proposed installations constitutes a fundamental challenge due to disparate sources of data, the difficulty in collecting the necessary data, and the mismatches in scale that render the collected data difficult to reconcile. Different conventions employed by various data sources complicate use of the data even when it does exist. This variability is exacerbated by the lack of standardization for data required for permitting, siting, design, and operation. Constructing effective, validated models will require additional data, including numerous, physical, real-time, multipoint measurements as well as wind- and wave-coupled data.

Data availability is restricted by the ability to collect the needed information. Capabilities to collect significant data on wind speed, direction, shear, and other effects from offshore facilities are currently limited, as are the means by which to describe spatial and temporal variability at multiple scales. Modeling would greatly benefit from longer-term data sets and retrospective analyses.

Data validation and subsequent model validation are required to ensure that available data can be accurately and appropriately applied. Data and model users are often unaware of errors and assumptions, which can build inaccuracy into a system. Test beds could offer standardized, independent validation of data and the resulting models, enhancing subsequent predictions. Though initially complicating the process, assured model validation would ultimately allow accurate prediction of costs and device performance over the predicted lifespan of a facility.

Validated data and models are needed for wave conditions in general and the marine/atmosphere boundary layer in particular. Current wave models may not account for extremes, and wave sensors may incorrectly quantify some phenomena (e.g., long waves that are hard to observe), undermining confidence in load conditions for wind and/or waves in the event of a 50- or 100-year storm. Likewise, current understanding of the marine/atmosphere boundary layer and processes is perceived to be inadequate. This inadequacy may delay project development and acceptance of the technologies until this knowledge is improved. Additional information and analysis are needed to better understand how the marine/atmosphere boundary layer and wind characteristics change across regions, seasons, and time of day.

Resource and Environment

Data must also inform site selection and facility design, necessitating a range of observations. Surveys, site assessments, and characterizations are prerequisites to planning and constructing a facility or deploying offshore technologies. Models could help to predict potential issues associated with the operation and maintenance of these facilities (e.g., subsurface conditions). First, however, better models must be developed to more accurately predict facility performance, guide optimal placement, and ultimately enable realization of facility capacity. Improved models will, in turn, help address cost and safety concerns, reducing uncertainties and increasing confidence on a variety of levels.

At the core of these challenges are the critical needs for detailed site information and the ability to accurately incorporate that information into the modeling process. Clear, uniform standards and methodologies for the collection and use of data would greatly enhance efforts to plan the location and orientation of facilities (including subsurface to hub height design) and transmission equipment. Currently, spatial and temporal variations or deviations in the wind profile of offshore wind resources are inadequately defined to support optimal siting of wind power plants and their potential collocation with MHK facilities. In addition, current facility design should consider future needs and the appropriate scales to ensure sustained economic viability. Model validation must also consider extreme weather events unique to the OCS and the likely impacts of those events, including outages and damage potential—experience that the U.S. industry does not yet have. Such forward-looking design would require a standardized methodology for determining site-specific conditions and a thorough evaluation of all available resources.

Acquisition of detailed, hub-height, wind/meteorological data is of primary importance, as the current lack of such data increases uncertainty in projections. Wind measurement at the hub height of an offshore turbine is more difficult and expensive than land-based measurement, complicating the acquisition of meteorological-ocean (met-ocean) data for offshore regions that have not traditionally had offshore structures. Wind is a nonlinear, chaotic phenomenon that displays sensitivity to initial conditions, resulting in a high level of variability and unpredictability. Thus, wind speed measurements at hub height, if they were available, would not be sufficient to establish design or operations criteria. Such measurements are essential to estimate the available resource and determine how best to capture and utilize the existing resource. Long-term, averaged wind resource assessment at the specific location of a potential wind project may be necessary, though costly and time-intensive. Forecasting wind speed and direction over a 20- to 30-year span in a way that accurately reflects seasonal and annual weather patterns will help weigh the costs and benefits of offshore versus onshore generation. Wind speed and direction should also be examined in light of a project's expected wake effects and losses, project buffers, and their attendant effects.

In additional to the data needed to quantify potential facility performance and make optimal use of a geographic location, data must be gathered to assess the ultimate environmental impacts of a facility. As turbines may cause radar interference and potentially mask or mimic approaching aircraft, installations may pose a potential security risk. Ecological impacts are another important concern, and a clear understanding of potential impacts on the local or regional ecology can guide efforts to mitigate such impacts. Local fauna, including marine mammals, avian populations, and benthic organisms, should be closely studied to understand the potential impacts of wind or MHK projects; MHK permitting may be particularly time consuming due to the relative paucity of data on MHK impacts on marine life. Other industries may also be impacted by wind and MHK deployment, such as fisheries. Model construction should also examine the hydrodynamic impacts of deploying an entire array, in addition to an individual device.

Facility Operation and Performance

To achieve cost goals, offshore energy devices need to be highly reliable and durable. Effective modeling and environmental evaluation will contribute to the survivability of a facility, ensuring that it meets the necessary load factors imposed by the combined wind/wave criteria. Distance of a facility from shore complicates the construction phase as well as all subsequent operation and maintenance phases. Mooring/anchoring design must adequately account for environmental loads. Extreme events can produce major damage, cause loss of performance, and impede access to the plant for subsequent repairs. Cables to bring the power to shore must also be protected from a variety of risks, including anchor damage.

The best way to address accessibility concerns is by ensuring that the devices deployed are sufficiently robust to withstand the environment, including extreme events like hurricanes. Remote sensing technologies promise a means by which to circumvent many accessibility concerns, though error characterization for remote sensing is currently lacking.

Market and Economic Issues and Collaboration

Clear, short- and long-term, cost of energy (COE) goals for MHK and wind are needed to drive development. An established value proposition could help to establish a supply chain in the United States. The current lack of domestic offshore wind and MHK equipment manufacturers poses a major challenge to deployment. An improved cost versus risk scenario would also help to foster development, manufacturing, and deployment of offshore energy subcomponents in the United States. The hurdles posed by uncertainty and rising costs are exacerbated by the lack of long-term data and the lack of some clear financial incentive to obtain that long-term data. The political will to level the playing field with other technologies, many of which enjoy subsidies and economies of scale, is essential to the eventual success of the offshore industry. “Offshore installations are reversible; coal mines are not.”

Such an ambitious scale of industrial development and market drive demands careful investment of research funds as well as close public/private coordination and collaboration. To efficiently leverage available funding, universities, government, and industry must all work together to address modeling, environmental, and performance needs. In addition, improved short- and long-term forecasting will benefit all phases of facility planning and operation.

Broader challenges to technology acceptance must also be addressed. Some potential ocean/fresh water users view wind and MHK with skepticism and resist implementation. In some cases, the public has demonstrated wariness of offshore resource development. Continued education and development of information resources are essential. Assessment of customer needs and quantification of facility benefits in light of those needs could provide a powerful message for outreach and education efforts.

3. Knowledge Needs

Meeting the key challenges to successful deployment of offshore wind energy and MHK technology will require the acquisition of key information and data resources (instrumentation, data management tools, and modeling software). This discussion assumes the potential to remove many existing constraints and simply identifies the knowledge that the industry needs to successfully deploy facilities and realize the potential of offshore energy generation.

Modeling and Simulation

The industry needs to **improve physical parameterization**: the ability to sufficiently represent the complex characteristics of resources to precisely address temporal and spatial variability. Establishing the most effective way to organize data to improve power output estimates (e.g., time periods) could result in a dynamic information system to ensure the optimal location and arrangement of arrays. As part of this system, data collection efforts should recognize what constitutes "good enough," the point of diminishing returns in developing cost-effective devices. Similarly, the "required" level of accuracy should be reasonable and timed appropriately for development.

Fundamental improvements in design and construction can be achieved through development of **validated models** that incorporate easy-to-use, robust, open-source tools for predicting a variety of weather and oceanographic events, structural integrity, and environmental effects. Additional observations are necessary for model input validation (long-term). Wind and wave models need to be site specific, cover extremes, and include standards. Atmospheric temperature profiles for the marine boundary layer and sea surface are needed to accurately validate models, energy production, and wake array losses; remote sensing of the stability of the marine atmospheric boundary layer can be used to improve models. Statistical data is needed to characterize the ambient turbulence in tidal flows for input to model development. Other identified needs include a greater understanding of wind shear across a rotor; the applicability of Monin-Obukhov, a surface exchange formulation (or lack thereof); and validated models of breaking waves. Regarding numerical weather prediction (NWP) models, the following areas need to be examined: the applicability of models for offshore energy applications, ways to improve the models for energy applications, and ways to translate NWP and mesoscale models to individual turbines or facility sites.

Though not specific to facility design, **improved long- and short-term weather forecast accuracy** would provide clear benefits across the industry. Improved forecasting would help identify the best seasons of the year to perform pre-construction, construction, and operations and maintenance (O&M) functions to mitigate impacts to the environment, infrastructure, and personnel. Planning and design would benefit from improved prediction of icing conditions and extreme events, as well as improved knowledge of how variables such as air density, temperature, and humidity correlate with wind and wave data. MHK project planning requires wave and current data/forecasts on all time scales to predict capacity and to forecast impacts of extreme events on infrastructure. Personnel safety would benefit from area-specific lightning forecasting (defining safe windows for crews to perform work). Improved forecasting could also assimilate mesoscale observations better than present methods and improve model surface-layer flux parameterizations and boundary layer/entrainment zone mixing parameterizations. Improved forecast accuracy will demand more information on surface conditions (or fluxes) and atmospheric conditions through the boundary layer.

Resource and Environment

Once a promising energy resource has been identified, planning activities require **accurate, site-specific information** on wind, wave, and weather conditions. Information at the waterline and below is needed to inform structural design and ensure optimal system operations and maintenance. Improved understanding of winds (profiles of speed and direction) will involve stable stratification; turbulence magnitudes; and temporal, spectral, spatial, coherence, seasonal, diurnal, and extreme events data. Characterization and prediction of the boundary layer will require data on temperature, atmospheric density, and thermal coupling/stratification to 100 meters. Other needs include coupling of wind and wave data; initiation and evaluation of convection icing; and data on wave height, wave speed, currents, and wind ramps.

Evaluation of potential facility locations begins with the examination of **energy resource data** to identify promising resources. First, the nature of the resource must be defined (e.g., wind, wave currents). Collection of wind and MHK data should ensure that fluctuations are captured. Wind data from validated observations, particularly at turbine level, can inform complex flow or characterization models and guide facility design to ensure it meets all requirements for reliable turbine and facility operation. Design criteria may benefit from use of a finer sensing scale than the current 10-minute interval, perhaps upgrading to a 1–3 second sampling rate to ensure accurate characterization.

Deep understanding of **weather trends and the likelihood of extreme weather** for a proposed location is necessary for effective facility design. Designers should also consider diurnal air and ocean variation as well as seasonal trends. Likely storm conditions, seabed type, water depth, and other factors are needed to establish design specifications, especially for survivability. Data on extreme weather conditions should include icing, lightning frequency and intensity, and storm measurements (e.g., hurricanes and Nor'easters). To maximize the applicability and accuracy of resulting models, this data should consist of actual values of extreme winds and waves on several time scales and the probability of occurrence.

High-resolution **bathymetry and geotechnical data** are needed to optimize project siting and minimize stability risks and associated environmental impacts. Bathymetry characteristics over a large area are necessary. Siting decisions should consider seafloor characteristics and composition (e.g., soil character, strata, sediment movement) for each locale to ensure a proper foundation for the facility. Bathymetrics, current, and sediment data are also needed to create scour probability maps. Once a facility has been designed, charts must be updated to reflect new structures, such as pipelines.

Potential **environmental impacts** must be addressed as a part of deployment criteria, and site-specific and local wave impacts must be considered on a case-by-case basis. Environmental impacts of individual devices and arrays should be quantified to address permitting concerns and ensure proper plans are in place for monitoring and mitigation. Biological populations (e.g., avian, marine mammal, fish) should be thoroughly studied to eliminate potential impacts to protected and non-listed species. These studies should include water quality evaluation. Scour at the base of towers should be monitored with regard to decision thresholds (e.g., when action is needed to protect a foundation); the in-water influence of turbine design on sediment transport and scour potential (sediment stability risk maps) can impact the environment as much or more than wake effects. Likewise, MHK facilities must quantify how harnessing the tide will affect current and wave energy—and how it will subsequently impact the coastline. Thorough collection of data on potential environmental effects will benefit the permitting process and improve public relations through increased transparency.

Facility Operation and Performance

Facility operation begins with **effective design for safety and operation continuity**. Once the resource and environmental factors are understood, "design" can involve a spectrum of trade-offs between designing for known site factors versus designing to anticipate potential factors (more robust design for safety), minimizing the risk of potential consequences. Important factors to consider include the following:

- The ability to monitor environment and system performance
  - Wave and wind monitoring for safe access
  - Condition of turbines; efficiency, stress, erosion
  - Instruments on towers to measure turbulence
- The time needed for a maintenance/repair crew to travel to a facility, perform work, and return
  - Elapsed travel time to and from a facility (e.g., by helicopter or boat)
  - Elapsed time for a crew to transfer from boat to tower base and from tower base to boat
- The potential for extreme events reflected in robustness of design and accessibility of facility
  - Extreme weather event met-ocean data for expected service life of facility
  - Wave height limit for safe access
  - System damping to control how the system responds to waves and wind gusts

- Met-ocean data used in design, which must be listed in IEC 61400-3 standards (Annex A) for certification

System performance also depends heavily on **component design and construction**. Low-cost materials designed to withstand the marine environment (e.g., salt spray) will improve the economic viability of these facilities. Component performance and interaction data are also needed to manage risk; evaluation of array effects, for example, should consider more than turbulence. Load resistance factors and subsurface conditions and variability are important design considerations for risk management. Remote sensors and their acceptance promise particularly great benefits to the industry. The ability to remotely adjust or diagnose under-performing components, such as a turbine, would improve both system performance and safety (by speeding repair and not requiring on-site personnel).

Once a facility has been constructed, **system monitoring across all levels**—component, unit, substation—is needed to optimize performance. First, thorough monitoring allows for continued refinement of models used to construct future facilities by improving the prediction of wind turbine output using wind field parameters, the accuracy of wake loss characterization, and wind measurements over the rotor diameter. Monitoring can benefit other future design considerations, such as blade material and design (e.g., to reduce radar impacts or other adverse effects). Uncertainty profiles and measurements to establish error bars are also needed. Temporal output profiles and distribution input (data about utility interface) can minimize intermittent power influx to the grid and guide development of energy storage/controls to improve capacity. Above all, information collected must be disseminated in a reliable and timely manner so that the data can benefit other projects and improve the industry as a whole.

In addition to system performance, **ongoing measurements in free stream sites**—wind approaching the turbine or in a parallel location—near a facility can serve as a control or reference to monitor effects of the facility itself. One or two measurement platforms at multiple levels to 100 meters (minimum) or 200 meters (preferred) on co-located meteorological towers ("met towers") can aid real-time knowledge of met-ocean parameters and device tuning. Fixed platforms can be augmented by portable sensing platforms, such as drone aircraft, which would entail a lower cost than a fixed-location met tower. Coastal radar and LIDAR improvements can also augment fixed sensing.

Market and Economic Issues and Collaboration

A variety of other factors affect the wind and MHK markets. These issues include **project funding** (e.g., costs and risks to secure investment throughout the supply chain and the legal knowledge to execute the project within existing standards), **supply chain limitations** (e.g., cost and availability of materials and manufacturing, economically feasible designs, installation equipment availability), and **resource stakeholder effects** (e.g., limits due to commercial and recreational fishing areas, shipping and other traffic, U.S. Coast Guard). The stakeholder effects increase the need to understand the proposed framework to allocate “marine resource leases” to promote healthy marine technology ventures.

Most pertinent, however, are limitations resulting from a current lack of **collaboration and data sharing between the private sector and government**. Shared data for scientific purposes and project development across the private sector and government will improve the effectiveness and profitability of the industry. New, publicly funded (e.g., DOE, Bureau of Ocean Energy Management, Regulation and Enforcement [BOEMRE], National Oceanic and Atmospheric Administration [NOAA]) technology measurements, such as remote sensing, could better characterize the marine boundary layer in key regions; a collaboration mechanism through which to share such offshore remote sensing data for public research applications is necessary to maximize impact. Partnering with utilities to assess needs would improve perspectives on the facilities needed and complete the perspective from research, to construction, to implementation, to market use. A central clearinghouse for archived model data will facilitate model selection and comparisons. Critical questions to address are whether the cost should be absorbed by government or private companies, and what data standard should be adopted to ensure universal applicability of the archived data.

4. Information Gaps

Identification of the relevant challenges and knowledge needs for the effective deployment of offshore energy facilities led the participants to identify existing information gaps. These, again, span the breadth of technology development and deployment, from means of quantifying resources and understanding the physics of facility operation, to ensuring efficient operation of the facility, public acceptance of these means of energy generation, and increased collaboration and coordination among stakeholders. The data gaps listed below reflect those identified by meeting participants as particularly prominent.

Modeling and Simulation

Physical parameterization needs to be improved, including the ability to forecast structural demands and spatial and temporal modeling of the boundary layer, including features affecting the turbines. Prediction of wind across turbine disk or turbine control height is affected by turbulent transport related to boundary layer mixing and surface fluxes; therefore, improvements in turbulent mixing parameterizations and air-sea exchange parameterizations are required to improve forecast accuracy. Improving the **availability of quality data for energy projections** requires spatially and temporally significant measurement of parameters (energy content of known quality). **High-fidelity structural, aerodynamic, and hydrodynamic device simulation capabilities** and test beds will improve device survivability and structural response to the environment. Software models for single wind and MHK devices could greatly improve durability and extend component performance life, increasing cost effectiveness of the installation. **Modeling and validation of array and wake effects** would offer more accurate prediction of wind resources and a better understanding of environmental consequences. Installation design would benefit from optimizing the separation distance between arrays, improved accuracy of loss predictions for array-based projects, and optimal placement of turbines and MHK devices.

Understanding of loss factors and variation across regions can improve the effectiveness and efficiency of array design. Improved accuracy of array simulation, modeling of wind, and MHK modeling at partial and full scales would improve installation design. This will require validated data to translate into partial and full-scale models. Collecting actual data at the micro level would be the preferred, though not always economically feasible. **Wind plant turbulence characterization** and characterization of associated turbine response can validate design tools for optimizing wind plant performance. Turbulence within the wind farm differs from turbulence in the free stream and it can induce fatigue loading and performance deficits that decrease reliability and lowers energy output. Better characterization of wind plant turbulence will improve the **understanding of boundary layer recovery between wind plants**. Better understanding of energy deficit and turbulence resulting from wind plants would improve the ability to predict parameters (e.g., distance) for recovery of winds to undisturbed conditions and eliminate the potential inflow effect to another wind plant.

Environmental modeling and simulation would benefit from **comprehensive, fine spatial resolution ocean observations**. This would also improve model forecasting confidence and resource assessment and enhance understanding of current, wave, and tide dynamics and interplay. Detailed **modeling of extreme met-ocean events**, including their strength, duration, and frequency, requires observations and instrumentation to collect the data and software to quantify impacts on MHK and other offshore renewable energy devices or structures. High resolution, frequency, and **precision profiles of wind and other meteorological variables** would improve resource assessment and power prediction. Accurate measurements of vertical profiles of wind (speed direction), temperature, turbulent variances, and humidity are needed for model initialization. Improved **wind-wave-current coupling models** and parameterizations of air-sea coupling (including wave interactions) with uncertainty quantification are needed to improve facility performance. Met-ocean data can be applied to **decision making/planning tools to ensure personnel safety** during operations and maintenance activities (planned and unplanned).

Resource and Environment

Improved environmental measurements for resource assessment, plant design, and operations and maintenance for wind and MHK requires additional observation and instrumentation. Additional **observations of site characteristics** can provide models with real data on resource and device performance needed to validate energy production projections and facility design optimizations; this will benefit all renewable technologies (wind, MHK, and ocean thermal energy conversion). Construction of a **complete wind shear profile** would markedly improve resource and site evaluation. Such a profile requires long-term (seasonal) and short-term (10 minute average) wind speed data, observations at various altitudes from surface to hub-height (90 meters) and beyond, and atmospheric stability measurements (air temperature, humidity, etc.). **Wind and turbulence profiles** would benefit from high-resolution (space/time) measurements of winds and turbulence to approximately 200 meters from moored platforms. Further study of the **stability of seabed sediments** will improve wind and MHK foundations and/or anchors, which is critical to optimal siting and site development. **Satellite observation in conjunction with surface measurements** of boundary layer wind profiles can be assimilated into models for predicting winds relevant to design and operation of offshore energy systems. Resource measurements need to include **uncertainty and methodological validation**, such as instrument and methodology intercomparison, temporal-spatially representative measurements of known quality, and different environmental variables measured in the same location.

Improved forecasting through data assimilation of meso-scale and micro-scale observations requires improved observations and methods of assimilating currently existing and new observing system data. When data are inserted into the model, the impact of the data on the forecast is highly sensitive to the method of data assimilation. Additionally, the inherently chaotic nature of the dynamics of the atmosphere can cause small-scale information to generate noise in a forecast model, which can be dispersed, quickly losing its value to the forecast.

Current methods of assimilating small-scale data have not consistently overcome these challenges.

Facility Operation and Performance

Increased data processing needs for the future demands **high-performance computing** capacity. Assimilation and archiving metadata will benefit from improved computing ability. Close monitoring and evaluation of factors affecting facility operation and improved ability to review that data will also help identify additional **variables impacting equipment** and the corresponding potential of impacts on the integrity of equipment.

Market and Economic Issues and Collaboration

Data management and delivery or access for model development and validation can be improved by allowing greater access to existing, archived data collected by government or non-governmental organizations and the private sector. Creating an archive of selected data (e.g., forecast products) currently being routinely discarded can address many data gathering needs at little or no additional cost. Including data management, delivery, and access in planning new instrumentation programs (e.g., CLT) or modeling studies (e.g., FEMA Region III Study) will improve coordination of efforts and reduce duplication of efforts. To spur data sharing, **collaboration in the offshore permitting process** must be required. The industry will also benefit from **international collaboration to share experiences and best practices** already identified.

The data being shared should be consolidated into a **central data clearinghouse**, facilitating the exchange and archiving of observational and operational data for (offshore) renewable energy and existing met-ocean data. This clearinghouse should differentiate between raw and quality controlled data, to address current problems with data reliability. **Management and dissemination of environmental data** will benefit from such a complete library or database and provide a method for encouraging collaboration and a methodology and standardization for data input.

5. Next Steps

During the meeting, specific information gaps were identified by the participants. Those information gaps were further expanded upon by identifying a specific solution(s) and the development of critical elements associated with a tactical plan to address those deficiencies.

Physical Parameterizations

Information Gap Description:

Description of Need: *Describe the information need. Is it related to **observation/instrumentation** for collecting data; **data management/ delivery**; and/or **modeling/software**? To what technologies does it apply (e.g., wind, MHK)?*

- Current ability to forecast structure is poor including features affecting the turbines.
- Prediction of wind across turbine disk or turbine control height is affected by turbulent transport related to boundary layer mixing and surface fluxes, therefore, improvements in turbulent mixing parameterizations and air-sea exchange parameterizations are required to improve forecast accuracy

Description of Variable: *What variable(s)/parameter(s) is/are being measured?*

- Goal: improve wind and turbulent kinetic energy; address fluxes of heat and moisture as momentum (moisture is all forms including condensate)

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- Accurate prediction of micro-scale and mesoscale features including: sea breeze, coastal jets, wind ramps, timing of periods of strong turbulence, rough seas.
- Validation data: sub-hourly temperature and wind observations sufficient to resolve PBL structure. Surface flux data would be very beneficial.

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- Coordinated national effort among researchers (government, university, private sector) to investigate physical and modeling problem. Observations required for short periods of intensive operations over targets of opportunity at different sensors.

Impact**:** *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- Improve power forecasts and consequently less use required of spot energy market, better management of spending reserve and optimal inclusion of renewable energy into the grid.

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- All users of the model forecasts including specialized forecast operations, including O&M, operators, more generally public and other forecast users.

Physical Parameterizations (continued)

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the* ***stakeholder(s)*** *(government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the* ***nature of their role*** *(e.g., collect or provide data, develop instrumentation, design models) and potential* ***needs/concerns****.*

Stakeholder	Role	Stakeholder Needs/ Concerns
Researchers (government, academic, others)	Perform the research and development and validation of meteorological variables	Funding for scientists and funding for computer resources
Users of the forecasts	Validate power forecasts and can assist with resources for research (because they will benefit)	
Lead balancing authority	Provide data to validate power forecasts (wind farm production or aggregate power plant prediction at high temporal resolution)	
Researchers (government, academic, others)	Perform the research and development and validation of meteorological variables	Funding for scientists and funding for computer resources

Key Steps/Components:

1. Identify past field campaigns with data which could be used to evaluate currently existing parameterizations in offshore areas
2. If no adequate data exists, conduct brief field campaign at several times of the year
3. Evaluate skill and performance issues among current parameterizations and investigate reasons for the limitation in skill
4. Develop and validate parameterizations
5. Make parameterizations available to integrate into operations including ensembles to leverage gains made by different approaches

Timeline/Timeframe:

1. 6 months
2. If necessary 3 years
3. 2 years
4. 2-3 years for fruitful results but ongoing long-term effort continues
5. 1-2 years – provided data for validation is available
6. Agency and industry dependent
7. Steps 1-5 6 years if step 2 is not necessary, making improvements available when project begins to be placed in service

Potential Challenges/Barriers:

- Verification metrics – instead of RMSE
- Funding for scientists, instrumentation, and computing resources
- Coordination among diverse stakeholders
- Overcoming long-standing scientific challenges to understanding planetary boundary layer behavior – especially for (stable boundary layers, internal boundary layers, coastal wind gradients, coastal low-level jets) and formulating that understanding into parameterizations which produce excellent results

Other Guidance:

- All software development should be open source so benefits are accessible to everyone
- Project time horizon requires project beginning soon in order for benefits to be realized when offshore energy systems are placed in service

Availability of Quality Data for Energy Projections

Information Gap Description:

Description of Need: *Describe the information need. Is it related to* ***observation/instrumentation*** *for collecting data;* ***data management/ delivery****; and/or* ***modeling/software****? To what technologies does it apply (e.g., wind, MHK)?*

- Spatially and temporally significant measure of parameters (energy content of known quality) needed to provide accurate energy predictions

Description of Variable: *What variable(s)/parameter(s) is/are being measured?*

- Wind speed, air temperature, relative humidity, barometric pressure, sea surface temperature currents, waves, tides, 3D

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- Spatial density, time frequency, error

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

Impact**:** *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- Improve quality, reduce cost, enable new strategy for design and operation

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- Equipment developers, designers, development grid operability, forecasting

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the* ***stakeholder(s)*** *(government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the* ***nature of their role*** *(e.g., collect or provide data, develop instrumentation, design models) and potential* ***needs/concerns****.*

Stakeholder	Role	Stakeholder Needs/ Concerns
Energy planners	Policy, large scale analysis	Enormous generation scale
Technology developers	New methods	Proprietary
Developer	Construct and operate	Speed of data available
Finance	Provide capital	Application

Key Steps/Components**:**

- Reference/control sites to evaluate new technology
- Standard for identifying data quality—establish methodology

Timeline/Timeframe:

Potential Challenges/Barriers***:***

- Requires central sites, miss important parameters, different objectives

High-fidelity Structural and Aerodynamic/Hydrodynamic Device Simulation Capabilities

Information Gap Description:

Description of Need: *Describe the information need. Is it related to* ***observation/instrumentation*** *for collecting data;* ***data management/ delivery****; and/or* ***modeling/software****? To what technologies does it apply (e.g., wind, MHK)?*

- Modeling/software models for single wind and MHK devices for aerodynamic/hydrodynamic performance and structural response/short-long term survivability

Description of Variable: *What variable(s)/parameter(s) is/are being measured?*

- Environment and resulting stress, strain and fatigue life, as well as performance

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- The tools and information should allow the user to demonstrate to the design, permit & financial community that the correct design has been selected

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- Very device specific. Large to small scale

Impact**:** *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- Improved device performance, prediction and design

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- Large spectrum of industry users

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the* ***stakeholder(s)*** *(government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the* ***nature of their role*** *(e.g., collect or provide data, develop instrumentation, design models) and potential* ***needs/concerns****.*

Stakeholder	Role	Stakeholder Needs/ Concerns
National labs	Run program, coordinate, perform some phases	Funding and sustained support
Universities	Provide research	Funding and sustained support
Device developers	Provide technical requirements and validation	Cost and usability, accuracy
Consultants	Participate	Cost and usability, accuracy

Key Steps/Components **and** Timeline/Timeframe:

- Project for each category of device
- Time frame is device dependent. Some devices are mature while others are in early stage of development

Potential Challenges/Barriers***:*** Which devices to focus resources, validation data

Other Guidance**:**

Modeling and Validation of Array and Wake Effects

Information Gap Description:

Description of Need: *Describe the information need. Is it related to **observation/instrumentation** for collecting data; **data management/ delivery**; and/or **modeling/software**? To what technologies does it apply (e.g., wind, MHK)?*

- More accurate prediction of wind resources; better understanding of environmental consequences; separation distance between arrays; improve accuracy of loss predictions for array-based projects and facilitate optimal placement of turbines

Description of Variable: *What variable(s)/ parameter(s) is/are being measured?*

- Turbine technology characterization (power curve, thrust variable, locations); boundary layer profile (turbulence, atmospheric stability, wind shear)
- Validation: flow characteristics within project (inflow boundary layer)—SCADA data plus nacelle anemometer plus up wind/ambient

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- Developing single turbine wake effects (MHK only)
- Developing datasets/studies to validate current models/access to SCADA/boundary layer and data set; validating wind farms

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- Large datasets, sophisticated modeling (highly quantitative [wind])
- MHK—targeted, lab scale (small) before programming to larger

Impact**:** *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- Ability to predict (or) affect cost/maximum revenue
- Improves regional planning

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- Policy makers (planning)
- Spill-over for short-term forecasting and regional siting

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the **stakeholder(s)** (government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the **nature of their role** (e.g., collect or provide data, develop instrumentation, design models) and potential **needs/concerns**.*

Stakeholder	Role	Stakeholder Needs/ Concerns
Government	Provide funding for studies for model development (public/private partnership)	Degree of data sharing
Industry	Provide data for rep. projects	Protecting data but positive up upsides
National labs/academia	Neutral third party to conduct analyses	

Key Steps/Components**:**

- Wind – identify representative projects/partnerships
- Single turbine wake effect model study
- Identify appropriate validation models, relevant data, upflow
- How to measure and characterize turbulence measurement for field scale/average scale modeling

Timeline/Timeframe:

- Wind: existing (1-2 years), New Data (3-5 years)
- MHK: phase 1 (1-2 years), phase II (3-5 years)

Potential Challenges/Barriers***:***

- Show me the data, inflow data (critical to overall validation)

Understanding of Loss Factors and Variation Across Regions

Information Gap Description:

Description of Need: *Describe the information need. Is it related to* ***observation/instrumentation*** *for collecting data;* ***data management/ delivery****; and/or* ***modeling/software****? To what technologies does it apply (e.g., wind, MHK,)?*

- Modeling/software
- Wind
- Actual (hard science) data at micro level (preferred)

Description of Variable: *What variable(s)/parameter(s) is/are being measured?*

- Wind speed—approaching and existing the turbine

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- Large scale – would require the deployment of a small array of turbines and instruments to measure wind speeds

Impact**:** *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- A better understanding (characterization) of wake losses
- Impact—wind farm layout

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- Facility designers, developers, optimal layout for minimum loss

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the* ***stakeholder(s)*** *(government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the* ***nature of their role*** *(e.g., collect or provide data, develop instrumentation, design models) and potential* ***needs/concerns****.*

Stakeholder	Role	Stakeholder Needs/ Concerns
Universities	Collect data/design models	Research funding
National Labs	Collect data/design models	Research funding and permits
Developers/providers/consumers	Finance	Funding & cost/benefit; is data of use
Government		Funding; is the data of significance

Key Steps/Components**:**

- Begin with land based models to reduce costs; extrapolate and relate to offshore—provides crude estimate which is likely sufficient

Timeline/Timeframe:

Potential Challenges/Barriers***:***

- Costs; government red tape/bureaucracy

Wind Plant Turbulence Characterization

Information Gap Description:

Description of Need: *Describe the information need. Is it related to* ***observation/instrumentation*** *for collecting data;* ***data management/ delivery****; and/or* ***modeling/software****? To what technologies does it apply (e.g., wind, MHK)?*

- Related to observation/instrumentation.
- Turbulence within the wind farm differs from turbulence in the free stream and it can induce fatigue loading and performance deficits that decrease reliability and lowers energy output.
- If we can characterize/understand wind plant turbulence and associated turbine response then we can use that information to validate design tools for optimizing wind plant performance

Description of Variable: *What variable(s)/ parameter(s) is/are being measured?*

- 3D wind velocities upstream and downstream in the wind farm. Including wake characterization ingested by downstream turbines. Instrument at least 2 turbines with strain gauges with a 3rd optional turbine downstream. Measure atmospheric stability for mixing purposes. Measure yaw error, power output, rotor speed and torque, and blade bending, and tower bending. Measure waves spectra for force

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- Data should inform LES and CFD modeling for array simulators

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- Project will take full wind season to conduct and needs to be done in field with wind farm operator and with experts in making field measurements in wind energy. Require logistic support from vessel operators

Impact**:** *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- Optimizing wind plant performance to maximize power capture and minimize turbine failure/fatigue

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- Turbine designers and developers

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the* ***stakeholder(s)*** *(government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the* ***nature of their role*** *(e.g., collect or provide data, develop instrumentation, design models) and potential* ***needs/concerns****.*

Stakeholder	Role	Stakeholder Needs/ Concerns
National Labs	Design and conduct research	Instrumentation, test venue, funding
Developers	Provide access to wind plants	Lost energy, downtime, safety
OEM	Supply by turbine data and design into as needed	Intellectual property

Key Steps/Components**:**

- Test planning, procurement and logistics, execution of tests, analysis and distribution of results

Timeline/Timeframe:

- 2 yr program; 1 year to plan and get buy in and 1 year to execute

Potential Challenges/Barriers*:*

- Difficulties of making measurements in ocean.
- Uncertainty with methodologies.
- Reliability of critical sensors

Other Guidance**:** Test may need to be conducted at more than one site to get representative data (ensure no anomalies) and make relevant to entire US coast. Integrated work into standards and design process

Array Simulation Capabilities

Information Gap Description:

Description of Need: *Describe the information need. Is it related to **observation/instrumentation** for collecting data; **data management/ delivery**; and/or **modeling/software**? To what technologies does it apply (e.g., wind, MHK)?*

- Modeling/software for wind & MHK scale model and full scale data for calibration and verification to optimize facility layout

Description of Variable: *What variable(s)/ parameter(s) is/are being measured?*

- All the key environmental parameters and device performance parameters and resulting forces/moments on the devices

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- The tools and information should allow the user to demonstrate to the design, permit & financial community that the correct design has been selected
- The model should predict device performance/loads at any member/location in the array

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- Two key tools are needed: (1) flow fields (wind & current), (2) wave field. Effort will be a university/national lab/consultant consortium

Impact**:** *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- Improve system performance, prediction and design. Also, reduced environmental impact

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- Facility designers and permit/environmental agencies, as well as financial groups. Will use to verify the project

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the **stakeholder(s)** (government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the **nature of their role** (e.g., collect or provide data, develop instrumentation, design models) and potential **needs/concerns**.*

Stakeholder	Role	Stakeholder Needs/ Concerns
National lab	Run program, coordinate, perform phases	Funding and sustained support
Universities	Provide research, Algorithms, data	Funding and sustained support
Facility developers	Provide technical requirements & validation	Cost and usability, accuracy
Permit/Regulatory/Financial Agencies	Provide technical requirements & validation	Cost and usability, accuracy

Key Steps/Components**:**

1. Identify tech. gaps/needed capabilities (survey state-of-the-art)
2. Assemble technical team
3. Assign roles
4. Develop capabilities & meta tools development
5. Validate with field data
6. Update code
7. Final deliverables

Timeline/Timeframe:

1. 12 months 7. 6 months
2. in parallel
3. in parallel 5.5 years total
4. 36 months
5. 6 months
6. 6 months

Potential Challenges/Barriers***:*** Budget/long-term support, getting the correct validation data (input and response), super computer for the basic research

Other Guidance**:** Could consider scale model tests for some validation

Boundary Layer Recovery between Wind Plants

Information Gap Description:

Description of Need: *Describe the information need. Is it related to* ***observation/instrumentation*** *for collecting data;* ***data management/ delivery****; and/or* ***modeling/software****? To what technologies does it apply (e.g., wind, MHK)?*

- Understanding what energy deficit and turbulence occur from wind plants that may affect inflow to another wind plant, and ability to predict parameters, (e.g., distance) for recovery of winds to undisturbed condition

Description of Variable: *What variable(s)/ parameter(s) is/are being measured?*

- Wind speed, direction, time state variables, turbulence intensity and spatial/temporal characteristics (spectral characteristics)

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- Resolution as needed for accurate wind turbine and plant performance prediction - for group of wind plants

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- Need meso-scale tools and data → validate with region including several wind farms in relatively close proximity

Impact**:** *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- Potential to optimize performance of groups of wind plants, and assure that plants don't under perform from being sited too closely

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- Developers, facility designers, operators— key users in plant siting,
- Secondary use— potential improvement for broad scale grid integration

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the* ***stakeholder(s)*** *(government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the* ***nature of their role*** *(e.g., collect or provide data, develop instrumentation, design models) and potential* ***needs/concerns****.*

Stakeholder	Role	Stakeholder Needs/ Concerns
Academia	Modeling and analysis to characterize meso-scale wind patterns with multiple plants	Data accessibility and modeling of wind plant array effects and computer resources
Wind farm operators	Provide data for onsite or nearby observation and insight into operations impacts	Proprietary data
DOE	Support efforts for optimizing broad area wind development	Resource prioritization, convergent project definition
Academia	Modeling and analysis to characterize meso-scale wind patterns with multiple plants	Data accessibility and modeling of wind plant array effects and computer resources

Key Steps/Components**:**

1. Accurately model outflow of single wind plant/statistical parameterization
2. Assess meso-scale progression of array outflows
3. Assess impact of resultant inflow to other wind plants
4. Explore optimization strategies for plant siting

Timeline/Timeframe:

1. 3 yr project

Potential Challenges/Barriers***:***

- Accurate wind farm outflow representation – computational resources high
- Access to industry data

Comprehensive Fine Spatial Resolution Ocean Observations

Information Gap Description:

Description of Need: *Describe the information need. Is it related to* ***observation/instrumentation*** *for collecting data;* ***data management/ delivery****; and/or* ***modeling/software****? To what technologies does it apply (e.g., wind, MHK)?*
Comprehensive, fine spatial resolution ocean observations would 1) improve model validation, 2) improve model forecasting confidence, 3) improve resources assessment, 4) enhance understanding the dynamics and interplay among current, wave, tides, etc.

Description of Variable: *What variable(s)/parameter(s) is/are being measured?*
Temperature, salinity, sediment, density, currents (in profiles and tine series) waves are the parameters to be measured.

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

1. Vertical resolution of approximately one meter (especially near the elevation of devices)
2. Seasonal duration (months), and multiple year effect
3. Horizontal resolutions are regionally dependent

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- Local to regional in high potential energy regimes.

Impact: *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- Provide critical observed data for model validation, forecasting, impact assessment in high potential MHK energy regions
- Improve accuracy of estimated of power extraction

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- Developers and facility designers – identify high energy regime
- Regulators

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the* ***stakeholder(s)*** *(government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the* ***nature of their role*** *(e.g., collect or provide data, develop instrumentation, design models) and potential* ***needs/concerns****.*

Stakeholder	Role	Stakeholder Needs/Concerns

Key Steps/Components***:***

1. Review existing private, local, state, national, and international data sources (e.g., IOOS, ARGO)
2. Identify high MHK energy regions
3. Hold workshops with industry, academia, and end users to construct a detailed scheme for observations
4. Deployment/maintenance

Timeline/Timeframe:

- Start 2012
- Year in planning
- 5 years of observation

Potential Challenges/Barriers***:*** 1) High funding requirement, 2) maritime/navigation traffic, 3) difficulty in maintenance, 4) instruments to meet to accuracy desire

Other Guidance**:**

Modeling of Extreme Metocean Events

Information Gap Description:

Description of Need: *Describe the information need. Is it related to* ***observation/instrumentation*** *for collecting data;* ***data management/ delivery****; and/or* ***modeling/software****? To what technologies does it apply (e.g., wind, MHK)?*

- Understand the characteristics of the extreme event, to include the strength, duration, and frequency of the event.
- Requires observations/ instrumentation to collect the data; modeling/software to understand impacts on wind, marine hydrokinetic (MHK), and other offshore renewable energy devices or structures.

Description of Variable: *What variable(s)/parameter(s) is/are being measured?*

- In extreme events: wind speed, wave height, wave period, and subsurface current speeds. Extreme events include ice, hurricanes, and nor'easters.

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- Timeliness and accuracy of the data delivery is important. For example, within five minutes of the observation of the variable, it should be easily available to all interested parties.

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

1. Once in place, it has to be a continuously operating system.
2. It needs to cover the entire area around a wind farm and the buffer area.
3. It should be reliable and robust system designed to survive extreme events.

Impact**:** *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

1. The benefits are improved safety for personnel and reduced damage to equipment.
2. Increased reliability of the generated equipment
3. Improved efficiency and reduced cost of energy
4. Relatively large effort*

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

1. Facility designers to design the facility
2. The operators of the wind farm who can use the information for safe operation.
3. Can be used for load and generating planning**

Modeling of Extreme Metocean Events (continued)

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the* ***stakeholder(s)*** *(government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the* ***nature of their role*** *(e.g., collect or provide data, develop instrumentation, design models) and potential* ***needs/concerns****.*

Stakeholder	Role	Stakeholder Needs/ Concerns
NOAA	To design and implement an observation system	
FERC	Understand and manage risks to the supply of electricity	
OSHA, BOEMRE, Industry	To provide regulatory oversight use Use data for design and operation	

Key Steps/Components**:**

1. Study & scope out the solution
2. To design solution
3. Install the system
4. Operations of the system
5. Monitoring the system

Timeline/Timeframe:

- 5 to 10 year effort

Potential Challenges/Barriers***:***

1. Expense
2. Mission definition
3. Jurisdictional issues

Other Guidance**:**

* Possibly low impact. The payoff is large but events are rare and unpredictable.
** Regulators can use the data in developing regulations; financial institutions can use it to gauge risk, warranties, and insurance.

High Resolution, Frequency, and Precision Profiles of Wind and Other Meteorological Variables

Information Gap Description:

Description of Need: *Describe the information need. Is it related to* ***observation/instrumentation*** *for collecting data;* ***data management/ delivery****; and/or* ***modeling/software****? To what technologies does it apply (e.g., wind, MHK)?*

- Accurate measurements of vertical profiles of wind (speed direction), temperature, and turbulent variances are needed for resource assessment, power prediction.
- Account measure of these variables plus humidity,... needed for model initialization, evaluation, improvement (numeric's, physical parameterization, etc.) accurate forecasting

Description of Variable: *What variable(s)/parameter(s) is/are being measured?*

- Vertical profiles that include the rotor layer (probably at least to 500 m ASL) of wind speed, direction, turbulent variances, temperature (and density)

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- Vertical resolutions: 10–20m vertical; Time resolution – 1–10 min. averages
- Accuracy - <0.3m/s wind; <0.3°C temperature
- Duration depends on application – several years for resource assessment, hazards/ extremes several months for process studies

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- Profile measurements needed at multiples locations over areas considered for WE development – spatial density requirements need to be determined; measurements desired for several years. Spot and/or occasional measurements useful and should be analyzed to inform planning for larger scale projects, assess efficacy of current practices, recommend alternatives

Impact: *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- Improving confidence in model predictions, forecasting, resource assessment; reduce risk and cost of financing. Improve decision making for safety, planning, turbine selection (matching to dominant conditions)

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- Forecasters, modelers, project planners, financiers, operations personnel (forecast users)

High Resolution, Frequency, and Precision Profiles of Wind and Other Meteorological Variables (continued)

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the **stakeholder(s)** (government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the **nature of their role** (e.g., collect or provide data, develop instrumentation, design models) and potential **needs/concerns.***

Stakeholder	Role	Stakeholder Needs/Concerns
Industry—developers, finance, operations	Users of information—use long-term estimator of rotor-level winds, effects of hazards	Accurate resource estimates
NOAA forecasting		Improved confidence in projections
Government (BOEMRE)—permitting		Improved forecasts, future research directives
DOE—future of offshore wind energy		Assessment of potential for useful production/ generation levels

Key Steps/Components:

- Identify and thoroughly analyze existing high-quality vertical-profile data sets and data sources, to inform future planning and decision making for data-acquisition projects. Evaluate candidate instrument technologies systems to choose optimum systems to address needs. Plan deployment(s) of instrumentation arrays — depending on funding levels available (e.g., is a cruise with a research vessel a possibility). First focus on regions slated for development with largest uncertainties. Analysis—data acquisition. Implement new findings into “best procedures”

Timeline/Timeframe:

- 2012 – identify, analyze existing data sets
- 2013 – initiate planning; begin instrument evaluations, intercomparisons. identify funding levels for research, ‘workshop’ to begin planning processes for deployment
- 2014 – data acquisition projects—establish offshore measurement reference site (platform based) for instrument evaluation
- 2015 – commence deployments, perform concurrent analyses, model evaluation
- 2015 – 2022—analysis model improvement & evaluation activities; ongoing instrument evaluation, incorporate new findings into addressing needs of stakeholders

Potential Challenges/Barriers:

- Funding levels inadequate to properly address gaps; data sharing with industry, inertia due to currently accepted practices
- How to address spatial variability—concept will change during course of data acquisition requiring flexibility in deployment strategies
- Evolving measurement/instrument technology—concept will change during course of data acquisition requiring flexibility in deployment strategies

Other Guidance: Initially, any available information should be used, if of sufficiently high quality; if deployments are contemplated, understanding will evolve and flexibility should be factored into planning

Wind-wave Current Coupling

Information Gap Description:

Description of Need: *Describe the information need. Is it related to **observation/instrumentation** for collecting data; **data management/ delivery**; and/or **modeling/software**? To what technologies does it apply (e.g., wind, MHK)?*

- Improved models and parameterizations of air-sea coupling (including wave interactions) with uncertainty quantification

Description of Variable: *What variable(s)/parameter(s) is/are being measured?*

- Subsurface currents; surface wave spectrum (full); wind/turbulence profile

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- Accurate descriptions of variables' profiles and function of time (0-10 min)
- Validation via data gap solution and uncertainties need to be part of solution

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- Major R&D effort—but it would pay off beyond these energy interactions

Impact: *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- Improved forecasting of energy resources (wind, wave, current); reduced deployment costs through reduction of uncertainties

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- Developers, resource assessors, regulators—virtually all would use information to improve energy projections

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the **stakeholder(s)** (government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the **nature of their role** (e.g., collect or provide data, develop instrumentation, design models) and potential **needs/concerns**.*

Stakeholder	Role	Stakeholder Needs/ Concerns
BOEMRE/DOI	Existing/permitting, plus R&D	Fair lease value
EERE/DOE	Energy projections/RD&D of MRE	Accurate projections
Science/DOE	Basic science—energy related	Physical effects/climate model
NSF	Basic science—geo-science	Met-ocean modeling
Industry	End user	Energy forecasts and ROI

Key Steps/Components:

- Develop coupled models for resource assessment; not site-specific
- Validate with appropriate observations with uncertainty assessment
- Translate results into standards, create industry friendly tool

Timeline/Timeframe:

5 year program

1. 6 months
2. If necessary 3 years
3. 2 years
4. 2-3 years for fruitful results

Potential Challenges/Barriers:

- Significant investment needed; incorporation into standards; making results non-site specific

Metocean Data Applied to Decision Making/Planning Tools to Ensure Personnel Safety

Information Gap Description:

Description of Need: *Describe the information need. Is it related to* ***observation/instrumentation*** *for collecting data;* ***data management/ delivery****; and/or* ***modeling/software****? To what technologies does it apply (e.g., wind, MHK)?*

- Decision making/planning tool to ensure personnel safety during operations and maintenance activities (planned and unplanned).
- Requires data management/delivery and software; for wind and MHK

Description of Variable: *What variable(s)/parameter(s) is/are being measured?*

- Wave height, wind speed, wind direction, temperature (air & water), lightning potential, visibility, icing potential, wind gusts

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- Accurate, reliable, USER FRIENDLY
- Post-activity observations collected for system validation

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- While most of the data elements are available, the major scope of work entails the delivery system and a high-priority need for spot measurement and tool refinement on lightning observations and potential

Impact: *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- Increased human safety, reduced loss of time and money

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- Site managers, planners, field workers, insurance providers

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the* ***stakeholder(s)*** *(government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the* ***nature of their role*** *(e.g., collect or provide data, develop instrumentation, design models) and potential* ***needs/concerns****.*

Stakeholder	Role	Stakeholder Needs/ Concerns
NOAA, NWS	Data (see variables list)	
Academia	Software development	
Operators	Usability	

Key Steps/Components:

1. Identify data sources
2. Weight (%) the importance of each variable in personnel safety
3. Define rating scale for each variable (i.e., 1-5)
4. Algorithm development
5. Local lightning observation & analysis to develop probabilities
6. User friendly i/o software interface
7. Validation and refinement

Timeline/Timeframe:

- 1 year

Potential Challenges/Barriers:

- Lightning forecasts, cost, availability

Other Guidance:

- The end result would be a report that not only provides the data, but assigns a numerical value to the relative risk of performing operations on a given day; would provide report for at least 5-day forecast.

Data Management for Model Development and Validation (continued)

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the **stakeholder(s)** (government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the **nature of their role** (e.g., collect or provide data, develop instrumentation, design models) and potential **needs/concerns**.*

Stakeholder	Role	Stakeholder Needs/Concerns
End users	Specify requirements for design, permitting, operations – model output	Modelers
Modelers	Specify metadata so can determine suitability of dataset to yield	Dataholders/collectors

Key Steps/Components:
(See above)
- End users/Process Managers
- Modelers
- Measurement data holders (Regional organization already engaged in CMSP/IOOS)

Timeline/Timeframe:
A. Immediate (now 0-6 mo.)
B. Near term (6 mo. – 1.5 year)
C. Long term (plan now – ongoing)

Potential Challenges/Barriers:

A. Silo mentality of various Government agencies who measure or model for their own agency needs
B. Additional labor and expertise to select routine products and additional labor to hire and maintain
C. Silo mentality and unawareness of need/benefit – here is where regional CMSP and IOOS organization can be particularly helpful but detailed implementation needs to be thought through

Improved Environmental Measurements

Information Gap Description:

Description of Need: *Describe the information need. Is it related to **observation/instrumentation** for collecting data; **data management/ delivery**; and/or **modeling/software**? To what technologies does it apply (e.g., wind, MHK)?*
- Observation/instrumentation
- Applies to wind and MHK

Description of Variable: *What variable(s)/parameter(s) is/are being measured?*
- Wind and stability profiles up to 200 m in atmosphere
- Ocean current profiles up to 200 m in depth (and turbulence)

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*
- Validated uncertainty values
- 2 m spatial resolution with wind

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*
- National-level effort

Impact**:** *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*
- Improved uncertainty of plant performance

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*
- All of the above

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the **stakeholder(s)** (government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the **nature of their role** (e.g., collect or provide data, develop instrumentation, design models) and potential **needs/concerns**.*

Stakeholder	Role	Stakeholder Needs/ Concerns
National Lab		
Universities		
Commercial institutions		

Key Steps/Components:
- Prioritize execution by resource value potential
- Validate remote sensing
- Develop capability for remote atmospheric temperature profile

Timeline/Timeframe:
- < 5 years

Potential Challenges/Barriers***:***
- Political support due to timeframe (…divide into phases)
- Temperature measurement requires technology transfer and development
- Cost and coordination

Offshore Remote Sensing Intercomparison Study

Information Gap Description:

Description of Need: *Describe the information need. Is it related to **observation/instrumentation** for collecting data; **data management/ delivery**; and/or **modeling/software**? To what technologies does it apply (e.g., wind, MHK)?*

- Standoff, multiple vertical profile measurements of winds can be obtained currently with Doppler lidar. Some of the more powerful systems could measure wind profiles over the ocean (from a land base) out to 10-15 km, possibly further.
- Measurements often involve using assumptions such as "local homogeneity of the winds" to obtain vector fields from radial velocities. An exploration of the error characteristics of such remote sensing methods is required to have wider impact and industry acceptance. Because meteorological towers at sea are costly, well-accepted remote sensing wind measurements could allow significant cost reductions in offshore resource assessment and potentially enable novel approaches for optimal wind farm control.

Description of Variable: *What variable(s)/parameter(s) is/are being measured?*

- Radial velocity of wind, directly measured with Doppler lidar, towers would measure full velocity vector, multiple look-directions across several coordinated Doppler lidars would allow retrieval of full wind vectors

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- Experiments should be designed to define error characteristics and intercomparison of modern remote sensing methods.

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- 4 year: 1) Deployment, 2) 3) Analysis & Intercomparison, 4) Standards Development & Publications

Impact: *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- Cost reduction: remote sensing can measure horizontal and vertical variation of winds, potentially also from land-based deployment locations.

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- Wind Energy Developers, Financial Stakeholders, Wind Farm Operators

Offshore Remote Sensing Intercomparison Study (continued)

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the **stakeholder(s)** (government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the **nature of their role** (e.g., collect or provide data, develop instrumentation, design models) and potential **needs/concerns**.*

Stakeholder	Role	Stakeholder Needs/ Concerns
National Laboratories, NOAA, for example, groups specializing and developing remote sensing, and also tower based measurements necessary for validation, NCAR. University remote sensing groups.	Measurements, wind retrievals, error analysis, Acceptance Tests, Creation of Standards	Instrument Scientists: reliability, sufficient support for long deployments.
Wind Energy Development Companies who are buying remote sensing products.		Instrument Companies: sensitivity for IP issues while maintaining openness for community.
Companies marketing leading remote sensing products, i.e., Halo Photonics, Lockheed Martin Coherent Technologies, Leosphere, QinetiQ		AWEA/DOE/Financiers: Definition of authoritative and relevant standards for acceptance of remote sensing data for offshore wind developments
AWEA, some representation from financing industry valuable		Inter-institutional research groups should be encouraged and artificial or accidental barriers should be remoted, e.g., University/DOD groups, for example, experience cost sharing issues.

Key Steps/Components**:**

- Offshore remote sensing intercomparison study. Components: representative instruments from short range profiling lidar, long range Doppler lidar, focusing lidar (close range), acoustic profiles, tower measurements, and/or sondes.
- Data analysis including emphasis on methods and science of wind vector retrievals. Intercomparison of measurement products.
- Error characterization.
- Standards development.

Timeline/Timeframe:

4 year overall project, requiring:

1. Long term (order of 1 year) deployments
2. 2 years of analysis and intercomparison
3. Open publication of intercomparison and characterization of error
4. Industry/DOE/Financier – Standards Development

Potential Challenges/Barriers**:**

- Reliability!! Remote sensors may be difficult to maintain for long periods to obtain dataset reasonably representative for a one year period.
- Sufficient dedication of funds to the analysis phase is required – two year analysis period and interaction amongst groups and stakeholders to be emphasized. Removal of barriers for all kinds of interconnected research groups.

Observations of Site Characteristics

Information Gap Description:

Description of Need: *Describe the information need. Is it related to* ***observation/instrumentation*** *for collecting data;* ***data management/ delivery****; and/or* ***modeling/software****? To what technologies does it apply (e.g., wind, MHK,)?*

- Real data on resource and device performance needed for validation of energy production projections and facility design optimizations.
- Applies to all renewable technologies (Wind, MHK, OTEC, etc.).

Description of Variable: *What variable(s)/parameter(s) is/are being measured?*

- Wave height, wind speeds, suspended sediment, bathymetry, SST, turbulence (water and air) loading capacity, current regime, debris probability and type, etc.
- All variables are needed to a degree of granularity with enough resolution for a specific site.

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- The data collected should be specific and of high enough quality to assess the site.

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- Researchers (to collect data), equipment & tools, analysis of data, dissemination of data.
- Scale dependent upon project, (either array or sole turbine).

Impact**:** *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- Short-term: individual projects would have device deployment successful.
- Long-term: help develop market, lower cost of energy of technology.

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- Model developers (to fix and enhance models).
- Project developers (model validation, energy resource characterization).
- Project consultants & regulatory agencies (to advise & site projects w/developers, and secure financing).

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the* ***stakeholder(s)*** *(government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the* ***nature of their role*** *(e.g., collect or provide data, develop instrumentation, design models) and potential* ***needs/concerns****.*

Stakeholder	Role	Stakeholder Needs/ Concerns
Nat'l Labs/academic institutions	Create and validate models	Quality & resolution of data
Government agencies	Funding and data collection	Overall impact, cost-benefit, magnitude of impact industry wide
Project/Industry Developers	Funding and use of analysis	Cost - complete data for price, decreasing investor risk, size & timing of dataset
Nat'l Labs/academic institutions	Create and validate models	Quality & resolution of data

Key Steps/Components and Timeline/Timeframe:

1. Locate site of impact—ongoing (industry & project dependent)
2. Determine and secure funding—ongoing
3. Identify data (resolution) needed—ongoing
4. Collect data—project specific (dependent upon developer & model needs)
5. Disseminate results—immediate
6. Model validation – immediate

Potential Challenges/Barriers**:** Cost, site specificity, standards of data, technological & instrumentation challenges, time of study

Complete Wind Shear Profile

Information Gap Description:

Description of Need: *Describe the information need. Is it related to* ***observation/instrumentation*** *for collecting data;* ***data management/ delivery****; and/or* ***modeling/software****? To what technologies does it apply (e.g., wind, MHK)?*

- Observation data that has been validated or financially accepted regarding the atmospheric conditions above sea level and up to hub-height or above (primarily wind average technology)

Description of Variable: *What variable(s)/parameter(s) is/are being measured?*

- Wind speed data (both long term season trends as well as 10-min avg.) as well as change in wind speed at various vertical heights up to or beyond hub-height (90 meters)
- Atmospheric stability measurements (air temperature)

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

1. Validation of remote sensing technologies (lidar).
2. Instrumentation of existing light towers offshore, up to hub-height with data being publically available (more costly, less impact)
3. Growth of space-based (satellite and radar) technology to inform resource assessment offshore
4. Inventory of data sets (codar, sodar, satellite, buoy-based)

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- Validation of remote sensing is smaller scale than instrumenting or building met masts offshore for *in situ* measurements (fewer stakeholders)
- Broad scale for growing technology (multiple agencies, NASA, NOAA, DOE could benefit as well as multiple stakeholders (developers, utilities, O&M, regulators)

Impact**:** *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- Validation of remote sensing is less costly and can be deployed faster than using *in situ* hub-height measurements (i.e., met masts)
- Provides reference facilities for modeling and other estimated atmospheric observations. Provides continuity and confidence in data

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- Validation of remote sensing: developers and facility designers, possibly utilities if used for forecasting. Information is used for energy projections, verifying financing
- Expanding *in situ* measurements and growing other tech: developers and facility designers as well as for academic institutions for research

Complete Wind Shear Profile (continued)

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the **stakeholder(s)** (government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the **nature of their role** (e.g., collect or provide data, develop instrumentation, design models) and potential **needs/concerns**.*

Stakeholder	Role	Stakeholder Needs/ Concerns
Industry	Deploy offshore wind	Costs of site assessment, confidence in reliability of wind turbine
Government agencies (DOE, NOAA)	Fund R&D to improve technology, provide data for weather modeling/forecasting	Provide data and tech for use by industry
Academic	Research of atmospheric boundary layers	Accessibility of data to do research and improve or develop models
Industry	Deploy offshore wind	Costs of site assessment, confidence in reliability of wind turbine

Key Steps/Components**:**

- Fund the further development of existing technologies (RADAR, SAR) for resource assessment
- Establish reference stations offshore, instrument appropriately, and provide data publically
- Build out of data services and make data publically available

Timeline/Timeframe:

- Instrumenting existing towers (1-2 yrs)
- Validation of remote sensing (2-3 yrs)
- Growing other technologies (satellite Aperture Radar) (2-3 yrs)
- Building a network offshore (10+ yrs)

Potential Challenges/Barriers:

- Costs of constructing offshore met masts
- How to provide data to public
- National campaign for constructing a network of networks offshore requires close partnerships with multiple agencies (NOAA, BOEMRE, DOE, etc.) over several years

Wind and Turbulence Profiles

Information Gap Description:

Description of Need: *Describe the information need. Is it related to **observation/instrumentation** for collecting data; **data management/ delivery**; and/or **modeling/software**? To what technologies does it apply (e.g., wind, MHK)?*

- High resolution (space/time) measurements of winds and turbulence to ~ 200 m from moored platform

Description of Variable: *What variable(s)/parameter(s) is/are being measured?*

- Mean wind vector; spatial structure of turbulence (3-D)

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- 10-min. windows for averaging—validate with uncertainty assessment
- 10-meter vertical resolution—validate with uncertainty assessment
- Cost-effective/robust (not just research tool)

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- Fairly straightforward

Impact**:** *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- Cost-effective energy projections

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- Developers, regulators et al for energy projections

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the **stakeholder(s)** (government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the **nature of their role** (e.g., collect or provide data, develop instrumentation, design models) and potential **needs/concerns**.*

Stakeholder	Role	Stakeholder Needs/ Concerns
Industry	End user	Ease of operation/robust; accuracy
BOEMRE/DOI	Regulator	Fair lease value
OAR/NOAA	Instrument builder	
EERE/DOE	Facilitate MRE; validation	Accuracy

Key Steps/Components**:**

- Validation is critical
- Incorporate methods into standards

Timeline/Timeframe:

- 2-year program

Potential Challenges/Barriers***:***

- Validation will require met towers; stable platform challenging; standards incorporation

Stability of Seabed Sediments

Information Gap Description:

Description of Need: *Describe the information need. Is it related to* ***observation/instrumentation*** *for collecting data;* ***data management/ delivery****; and/or* ***modeling/software****? To what technologies does it apply (e.g., wind, MHK)?*

- Related to observation/instrumentation. Interaction of seabed and wind/MHK foundations/anchors is critical to site development. Could affect loading to towers/foundations and uproot anchors. Help optimal siting of technologies.

Description of Variable: *What variable(s)/ parameter(s) is/are being measured?*

- Seabed sediment properties (particle size, density, stability, critical sheer stress).
- Detailed bathymetry. Wave spectra to drive numerical predictions of near bed velocities for applied sheer stress. Current measurements.

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- To validate sediment transport model and scour model

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- Development of new methodologies. Full site study. Methods to be transferred to other sites

Impact**:** *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- Siting optimization and optimizing and defining mitigation solutions

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- Developers, EDC's

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the* ***stakeholder(s)*** *(government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the* ***nature of their role*** *(e.g., collect or provide data, develop instrumentation, design models) and potential* ***needs/concerns****.*

Stakeholder	Role	Stakeholder Needs/ Concerns
National Labs	Design and conduct experiment	Boat access, funding
Developers	Provide site access	Financial
OEM	Use data/methods/maps in site development/model	
National Labs	Design and conduct experiment	Boat access, funding

Key Steps/Components**:**

- Collect site specific data. Develop numerical predictions of near seabed velocities and shear stress driving erosion with and without wind/MHK structures. Compare site data on stabilities to simulated forcing for erosion to develop scour risk

Timeline/Timeframe:

- 2 yr study—planning and data collection and initiate models. Develop site conceptual model. Execute model and risk analysis and micro-scale scour modeling

Potential Challenges/Barriers***:***

- Measurements in ocean. Simulating effect of wind/MHK structures or wave climate (could be its own topic)

Satellite Observation Method

Information Gap Description:

Description of Need: *Describe the information need. Is it related to **observation/instrumentation** for collecting data; **data management/ delivery**; and/or **modeling/software**? To what technologies does it apply (e.g., wind, MHK)?*

- Need for boundary layer wind profiles that can be assimilated into models for predicting winds relevant to design and operation of offshore wind systems

Description of Variable: *What variable(s)/parameter(s) is/are being measured?*

- Wind profiles, state variables (Temperature, Relative Humidity), cloud characterization and movement, wave properties (height, steepness)

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- Thorough wind profiles of marine boundary layer (BL) can further specify state of model – specifics depend on modeling and assimilation needs

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- Use existing satellite observation to recover winds and ocean state over broad geographic region

Impact**:** *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- Better estimate of wind and waves over region that has few observations. Potentially very large impact if modeling outcome shows improvements

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- Developers, facility designers, regulators for resource assessment and facility design. Possibly import for forecasting.

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the **stakeholder(s)** (government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the **nature of their role** (e.g., collect or provide data, develop instrumentation, design models) and potential **needs/concerns**.*

Stakeholder	Role	Stakeholder Needs/ Concerns
NASA	Cooperation in furnishing satellite data and modifying measurements	Mission conflict
NOAA	Cooperation in furnishing satellite data and modeling assimilation support	Resources to support research
Academia	Research and analysis contribution	Limits to resources/computational limits
Private Enterprise	Potential research and analysis support, operational role unlikely	Scope of role

Key Steps/Components**:**

1. Understand current capability relevant to BL profile and surface waves and other variables of interest
2. Develop assimilation strategy for BL wind modeling to estimate turbine level winds, etc.
3. Develop validation strategy to assess effect of satellite observations on model output

Timeline/Timeframe:

- 3 year project

Potential Challenges/Barriers***:***

1. Are data observations capable of sufficient accuracy and recovery rate to improve the models
2. Are there specific techniques for accurate assimilation of data with limited recovery rates (are statistical methods required?)
3. How can this be validated with independent, limited *in situ* data?

Uncertainty and Methodological Validation included with Resource Measurements

Information Gap Description:

Description of Need: *Describe the information need. Is it related to **observation/instrumentation** for collecting data; **data management/ delivery**; and/or **modeling/software**? To what technologies does it apply (e.g., wind, MHK)?*

- Instrument intercomparison, methodology intercomparison
- Temporal-spatially representative measurements of known quality needed
- Different environmental variables measured in the same location

Description of Variable: *What variable(s)/parameter(s) is/are being measured?*

- Wind speed (u,v,w) 3D wind speeds; temperature; subsurface ocean current velocities

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- Spatial density of measurements; time frequency; data inclusion into information databases should include uncertainty and methodology documentation

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- Remote sensing documentation project with one tower

Impact**:** *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- Industry needs to know this to site offshore projects
- Regulatory agencies need information on data quality for siting purposes
- Enhanced renewable energy development
- Validation of remote sensing as a resource assessment methodology

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- Equipment developers, designers, development grid operators, forecasters

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the **stakeholder(s)** (government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the **nature of their role** (e.g., collect or provide data, develop instrumentation, design models) and potential **needs/concerns**.*

Stakeholder	Role	Stakeholder Needs/ Concerns
Energy planners (federal, state)	Policy, large scale analysis	Large geographic scale, cost
Technology developer	New methods, technology/equipment	Proprietary data, correlation to standard
Developer	Construct and operate plants	Acceptance, data sharing
Finance organizations	Provide capital	Applicability

Key Steps/Components**:**

1. Reference site/test site to test instruments
2. Databases such as the DOE MHK resource assessments where data and methodologies are included with the assessment and third-party validated (data vetting)
3. Intercomparison between reference sites across time to assess spatial variability
4. Industry-agency partnerships that require data sharing (cost sharing)

Timeline/Timeframe: *(numbers correspond with key steps bullets)*

1. None
2. Within the year (by the end of 2012). Tidal resource assessment is currently available, wave, ocean current, and ocean thermal will be available within the year
3. None
4. Ongoing

Potential Challenges/Barriers***:***

- Different agencies/programs have different data and data accuracy requirements; best practices can't always be funded without data collection; reference sites may not be representative of all regions

Improved Forecasting through Data Assimilation of Meso- and Micro-Scale Observations

Information Gap Description:

Description of Need: *Describe the information need. Is it related to* ***observation/instrumentation*** *for collecting data;* ***data management/ delivery****; and/or* ***modeling/software****? To what technologies does it apply (e.g., wind, MHK)?*

- Poor forecast skill resulting from poor initial conditions. Requires improved observations and improved methods of assimilating currently existing and new observing system data. When data is inserted into the model, the impact of the data on the forecast is highly sensitive to the method of data assimilation. Additionally, the inherent dynamics of the atmosphere causes small-scale information to generate noise in a forecast model and the information is dispersed, quickly losing its value to the forecast. Current methods of assimilating small-scale data have not consistently overcome these challenges

Description of Variable: *What variable(s)/parameter(s) is/are being measured?*

- Need to improve initial state for all model forecast variables

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- Models cycled with new assimilation methods produce better forecasts of feature s affecting offshore boundary layer winds than the same models recycled with currently existing assimilation methods

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- Coordinated national effort among researchers (government, university, private sector) to investigate physical and modeling problem. Observations required for short periods of intensive operations over targets of opportunity at different sensors

Impact**:** *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- Improve power forecasts and consequently less use required of spot energy market, better management of spending reserve and optimal inclusion of renewable energy into the grid

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- All users of the model forecasts including specialized forecast operations, including O&M, operators, more generally public and other forecast users

Improved Forecasting through Data Assimilation of Meso- and Micro-Scale Observations (continued)

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the **stakeholder(s)** (government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the **nature of their role** (e.g., collect or provide data, develop instrumentation, design models) and potential **needs/concerns**.*

Stakeholder	Role	Stakeholder Needs/ Concerns
Researchers (government, academic, others)	Perform the research and development and validation of meteorological variables	Funding for scientists and funding for computer resources
Users of the forecasts	Validate power forecasts and can assist with resources for research (because they will benefit)	
Lead balancing authority	Provide data to validate power forecasts (wind farm production or aggregate power plant prediction at high temporal resolution)	
Additional extra role for major data assimilation centers such as NCEP	Expertise in assimilation and use simulation recycling for operational models	Funding for scientists and funding for computer resources

Key Steps/Components**:**

- Follow WFIP, (DOE funded) project plan
- Researchers develop/improve methods—ongoing

Timeline/Timeframe:

- WFIP plan—3-5 years to arrange logistics for offshore area and complete project
- Ongoing, incremental improvements every year or few years but long-term commitment required

Potential Challenges/Barriers**:**

- Verification metrics—instead of RMSE
- Assimilation at high resolution is very computationally expensive—requires long-term computing resources for operational implementation
- If ensemble assimilation methods are preferred, implementing requires resources and infrastructure for ensemble forecast system with sufficient number of ensemble members
- Sparse data coverage over water on routine basis; Need temperature, wind, and moisture data throughout depth of atmosphere over and upstream of all areas of interest

High-Performance Computing (HPC)

Information Gap Description:

Description of Need: *Describe the information need. Is it related to **observation/instrumentation** for collecting data; **data management/ delivery**; and/or **modeling/software**? To what technologies does it apply (e.g., wind, MHK)?*
Sufficient high performance computing capacity is needed. Must handle increased processing needs for the future. Data availability for assimilation. Needs to be able to archive metadata.

Description of Variable: *What variable(s)/parameter(s) is/are being measured?*
Ability to run numerical prediction. Need resources for super-computing certification and accreditation (hot backup)

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- Ability to run high resolution rapid refresh models and ensembles of these models. Certification and accreditation (IT security), backup computer capability.

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- Participation by all offshore renewable energy interests in real-time.

Impact**:** *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- High precision and more accurate output on a more frequent basis

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- Resolve planners, private sector forecasters, transportation sectors users, speculators (future trading), construction, O&M, safety, strategic planners

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the **stakeholder(s)** (government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the **nature of their role** (e.g., collect or provide data, develop instrumentation, design models) and potential **needs/concerns**.*

Stakeholder	Role	Stakeholder Needs/ Concerns
NOAA/DOE	Foundational R&D and operational forecasting	Stable funding, priority recurring upgrades
Renewable energy industry	Uses output to customize energy forecasts, spot wx forecasts	Quick & accurate forecasts
Academics	Basic and applied research to improve assimilation modeling	Ability to run research (complete) projects
Regulators	Siting of developed areas, managing risk	EA and understanding resource potential (leasing)

Key Steps/Components**:**

- Create recurrent stakeholder meetings for learning and articulating the need for HPC
- Commit to maintaining and improving HPC capacity regularly
- Engage OMB/Congress/NOAA strategic plan

Timeline/Timeframe:

- Engage users, stakeholders, budget process immediately
- Build upon FY 14-15 time frame
- Maintain backup and IT security

Potential Challenges/Barriers**:** Financing, federal deficit, understanding of OMB analysts of importance of HPC to mission

Other Guidance**:**

Variables Impacting Equipment

Information Gap Description:

Description of Need: *Describe the information need. Is it related to* ***observation/instrumentation*** *for collecting data;* ***data management/ delivery****; and/or* ***modeling/software****? To what technologies does it apply (e.g., wind)?*

- Monitoring of factors affecting operation at facility scale and, through measurement, identify the potential for impacts to the integrity of equipment and the planning of operations.

Description of Variable: *What variable(s)/parameter(s) is/are being measured?*

- Scour potential
- Wake effects
- Local impacts of extreme events
- Turbulence (air & water)
- Abrasion potential
- Current patterns

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- Identify cost-effective instrumentation or R&D gaps
- Identify cost-effective software or development needs

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- To be determined based on earlier assessment of need

Impact**:** *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- Condition monitoring on plant/facility scale to avoid catastrophic failure and plan efficient operations and maintenance schedules

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, IO&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- Industry; regulators and insurance companies

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the* ***stakeholder(s)*** *(government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the* ***nature of their role*** *(e.g., collect or provide data, develop instrumentation, design models) and potential* ***needs/concerns****.*

Stakeholder	Role	Stakeholder Needs/ Concerns
Science & university research	Assess gaps, design instrumentation package and software	Funding
Industry	Define needs, implement on commercial scale	
Government	Define needs, provide funding, apply in regulatory context	

Key Steps/Components**:**

1. Gap analysis to identify need and current tools available to meet those needs
2. Create instrumentation package, disseminate information, or fund development as required

Timeline/Timeframe:

- To be determined based on earlier assessments
- 2 to 5 years

Potential Challenges/Barriers*:*

- Funding availability
- Critical mass within industry to support
- Field trials, in the absence of offshore facilities

Data Management and Delivery or Access for Model Development and Validation

Information Gap Description:

Description of Need: *Describe the information need. Is it related to **observation/instrumentation** for collecting data; **data management/ delivery**; and/or **modeling/software**? To what technologies does it apply (e.g., wind, MHK)?*

A. Wider access by NGOs/private sector to existing, archived data now restricted to government
B. Archival of selected data (e.g., forecast products) that are now being routinely discarded
C. Including data mgt/delivery/access in planning new instrumentation programs (e.g., CLT) or modeling studies (e.g., FEMA Region III Study)

Description of Variable: *What variable(s)/ parameter(s) is/are being measured?*

- Applies to all: webcam, geological & geophysical, biological, vessel traffic (e.g., VA Aquarium traffic study)

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- Metadata minimum requirements (start, stop, date/time, interval between outputs, averaging periods, gust periods
- Facility designer input needed for data specifications (x,y,z spatial, contact person/organization, need domain experts to establish protocol), accuracy and resolution of instruments

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- 1A – requires nationwide engagement of government data holders
- 1B – requires nationwide engagement: manage by existing CMS regional governance
- 1C – requires nationwide engagement: manage by existing CMS regional governance and IOOS Organizations

Impact**:** *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

A. Immediate model validation is very large
B. Near-term (months) model validation large (but takes more effort)
C. Longer term (years) model validation very large (a little up front planning for big impact when implemented)

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- All of the above
- Immediate users are modelers(private & public sector) Specifically for model validation—can be sanitized
- need to inform modeling community (FEMAIII)

Require Collaboration in the Offshore Permitting Process

Information Gap Description:

Description of Need: *Describe the information need. Is it related to* ***observation/instrumentation*** *for collecting data;* ***data management/ delivery****; and/or* ***modeling/software****? To what technologies does it apply (e.g., wind,)?*
Data is needed in real-time with business sensitive agreements as input to forecast models. This forecast benefits: characterization, safety, climatology, environment assessment (EA).

Description of Variable: *What variable(s)/parameter(s) is/are being measured?*
Oceanic and meteorological observations in real-time need to be measured.

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*
- Standardization of metadata and data formats—aids in quality control and allows, data sharing in real-time

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*
- Participation by all offshore renewable energy interests in real-time

Impact*: What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*
- Benefits to power generation revenue, safety of operations, all weather forecasts and warnings (aviation, marine, land-based, wind, water) speeds the permitting process (EA), reduce uncertainty and risk

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, IO&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*
- Developers, operators—all users in the offshore domain
- USCG, insurance
- Marine, Aviation, National Weather Service (NWS)

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the* ***stakeholder(s)*** *(government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the* ***nature of their role*** *(e.g., collect or provide data, develop instrumentation, design models) and potential* ***needs/concerns****.*

Stakeholder	Role	Stakeholder Needs/ Concerns
NOAA or other non-profit	Receives data and makes it available (dissemination)	Real-time data, metadata, forecasts
Developers, operators	Data providers	Better forecasts, reduced risks, higher profit
Regulators, (BOEMRE, USCG, FERC)	Rules of operation	Safety of operations, balancing authorities
Marine spatial planning aviation MIL/FAA)	Impacts operations of flight, marine, academics – research, etc.	Safety of operations, research, strategic planning

- Key Steps/Components*:*
- Periodic coordination group of all stakeholders
- Non-disclosure agreements—protect industry interests
- Metadata standards and formats; Data portal and archive

Timeline/Timeframe:
- Prior to 1st permitting
- Include in current meetings on leasing and permitting
- Prior to accepting proposals; persistent

Potential Challenges/Barriers*:*
Business sensitivity; Cost for installing operation and maintenance of sensors, communication issues

Other Guidance: Bring up current partnership examples where data sharing benefits all industries involved: IOOS, Tsunami, Oil Industry partnership, MDCRS (aviation)

International Collaboration to Share Experiences and Best Practices

Information Gap Description:

Description of Need: *Describe the information need. Is it related to **observation/instrumentation** for collecting data; **data management/ delivery**; and/or **modeling/software**? To what technologies does it apply (e.g., wind, MHK)?*

- Data management delivery for wind power

Description of Variable: *What variable(s)/parameter(s) is/are being measured?*

- Proprietary information not available; cause of methodologies and models employed maybe cultural, legal, geological in nature and may not be transferable. Best practices/lessons learned—definitions

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- Clearinghouse; search engine and intelligence gathering; provide developers with lessons learned to data-errors, mistakes, bad assumptions

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- Monitoring of projects as they are planned, designed and built

Impact**:** *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- Reduce downtime in planning construction phases
- Reduce costs due to error/miss-information
- Fewer insurance claims

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- Governments, insurance companies, developers, investors; construction crews

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the **stakeholder(s)** (government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the **nature of their role** (e.g., collect or provide data, develop instrumentation, design models) and potential **needs/concerns**.*

Stakeholder	Role	Stakeholder Needs/ Concerns
Insurance companies	Gather and report loss down time and why	
Developers	Share successes; flaws; use shared information	
Investors	Invest wisely based on cost/benefit error free	
Engineering/construction crews	Avoid reinventing the wheel; avoid mistakes; “that didn’t work, let’s do it again”	

Key Steps/Components**:**

Timeline/Timeframe:

Potential Challenges/Barriers***:***

- Cultural differences in standards and what is considered best practice/lesson learned; willingness to share; willingness to use information once known

Other Guidance**:**

- Insurance companies posses best real-time data with re-occurring errors

Data Clearinghouse

Information Gap Description:

Description of Need: *Describe the information need. Is it related to **observation/instrumentation** for collecting data; **data management/ delivery**; and/or **modeling/software**? To what technologies does it apply (e.g., wind, MHK)?*
Create an exchange and archive of observational and operational data

Description of Variable: *What variable(s)/parameter(s) is/are being measured?*
Temporal and spatial measure of operational/observation (something similar to a Wikipedia method of contributors and data being ranked by their peers)

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- Should be broadly accessible, human and machine readable, must be user friendly, host data on clearinghouse servers, include metadata, users rank data uses and other users instead of QA/QC process.

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- Design, deploy, and maintain a server and web interface, provide help desk functions, respond to user concerns

Impact*: What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- Adds value to existing data by making it easy to find, access and contribute to. It will have the most impact on the planning, designing, operating and regulating of offshore renewable projects

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- Science, operators, facility managers, logistics, regulators, researchers, financial institutions, insurance providers, etc.

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the **stakeholder(s)** (government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the **nature of their role** (e.g., collect or provide data, develop instrumentation, design models) and potential **needs/concerns**.*

Stakeholder	Role	Stakeholder Needs/ Concerns
Industry and consultants	User and contributor	Reliable, sustained, long-term and secure
Researching community	User and contributor	Searchable by data and metadata
Government	User and contributor	Lack of industry participation
Public	User and contributor	Understandable and ease of access

Key Steps/Components***:***

- Identify past, future and current data sources
- Mine them for information
- Determine how best to present and store data
- Implement semantic wiki and databases (semantic web.org)
- Develop data mining tools
- Launch with sufficient infrastructure
- Implement monitor and re-evaluate

Timeline/Timeframe:
1 year from starting the design stages to launch

- Ongoing maintenance and incremental development

Potential Challenges/Barriers***:***

- Data has to be well documented to be valuable
- Perceived as duplicating existing efforts

Other Guidance**:** The clearinghouse needs to be built around searchable data and be dynamic enough to handle a variety of data from geographic, to time frames, to data type, etc. Consider partnership with a software developer

Centralized Data Inventory for Existing Met-Ocean Data

Information Gap Description:

Description of Need: *Describe the information need. Is it related to **observation/instrumentation** for collecting data; **data management/ delivery**; and/or **modeling/software**? To what technologies does it apply (e.g., wind, MHK)?*

- Central clearinghouse for accessing data; SharePoint
- Differentiate between raw and QC data site
- High resolution (space/time) measurements of winds and turbulence

Description of Variable: *What variable(s)/parameter(s) is/are being measured?*

- Measurements; models; meta data; list of studies/reports

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- Need to be user friendly/accessible
- State-of-the-art
- Can provide links to existing sites

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- Single entity managing but national/distributed use and contributions

Impact**:** *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- Provides more data to more people; reduces duplication; saves time & resources; creates contact list; strengthens ties between MHK and offshore wind

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- Researchers/developers

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the **stakeholder(s)** (government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the **nature of their role** (e.g., collect or provide data, develop instrumentation, design models) and potential **needs/concerns**.*

Stakeholder	Role	Stakeholder Needs/ Concerns
Government	Centralized distribution point	Publicizing
Lab/research	Contributors and users	
Business	Use as starting point	

Key Steps/Components**:**

1. Identify who will manage it
2. Set standards
3. Publicize to industry/academia
4. Maintenance

Timeline/Timeframe:

- 1-2 years

Potential Challenges/Barriers***:***

- Distributed nature to make it worthwhile requires extensive buy-in

- Other Guidance**:** This is an information site in addition to data storage

Management and Dissemination of Environmental Data

Information Gap Description:

Description of Need: *Describe the information need. Is it related to **observation/instrumentation** for collecting data; **data management/ delivery**; and/or **modeling/software**? To what technologies does it apply (e.g., wind, MHK)?*

- A complete library or database of all available data compiled in one location
- Method for encouraging collaboration and methodology for data input

Description of Variable: *What variable(s)/parameter(s) is/are being measured?*

- Quality of data
- Magnitude of impact
- Practical application of data (site of priority)
- Having enough data

Solution Specifications:

Specification: *What criteria should the solution meet? What are the technical specifications, validation requirements (e.g., for software based tools)?*

- Quality of data and resolution and location should be high enough quality and impact

Project Scale: *Describe the scale of the project (e.g., occasional spot measurements that could be managed by a few stakeholders versus the development and deployment of a new tool requiring a concerted national effort)*

- Already in development with Tethys (~ 5 yrs past). Resources needed include National Labs and location to host and maintain database

Impact**:** *What are the benefits to addressing the gap? Where will it have the most impact? What is the impact relative to effort?*

- Facilitating and informing regulatory, impacts siting & permitting
- Potentially lowers costs for developers (no overlap of data collection)

End-Users and Users: *Identify the end-users of the information (e.g., developers, facility designers, utilities, O&M Services, regulators, financial institutions, warranty and insurance providers); and how they will use it. What is the information used for?*

- Regulatory agencies
- Developers
- National Labs

Tactical Plan to Implement Solution/Address the Information Gap:

Stakeholders and Roles: *List the **stakeholder(s)** (government agencies, industry, standards organizations, academic institutions, national labs, etc.) who could address this gap; describe the **nature of their role** (e.g., collect or provide data, develop instrumentation, design models) and potential **needs/concerns**.*

Stakeholder	Role	Stakeholder Needs/ Concerns
Regulatory/Gov't Agencies	Inform siting & permitting, inform priority issues/data gaps	Quality of information
National Labs	Enhances models, informs issues, results of impacts	Quality, IP
Project Developers Academic Institutions	Facilitates regulatory process & project approval Peer review, data collection, individual project analysis	Cost, intellectual property Quality, IP
Regulatory/Gov't Agencies	Inform siting & permitting, inform priority issues/data gaps	Quality of information

Key Steps/Components and Timeline/Timeframe**:**

1. Develop Tethys w/capacity to take in data—underway
2. Populate library with available data—immediately (upon development)
3. Publicize and advertise—immediately now
4. Confirm population and maintenance—ongoing

Potential Challenges/Barriers**:**

- Keeping up to data, peer review and maintenance
- Intellectual property rights, getting people to share data without fear of losing first-mover advantage
- Publicizing and creating reputation and user confidence
- Global data—understanding what has been done in Europe already

Appendix A. Attendees

Name	Organization
Greg Adams	BOEMRE
Tamara Arzt	BOEMRE
Larry Atkinson	Old Dominion University
Roger Bagbey	Cardinal Engineering LLC
Bruce Bailey	AWS Truepower, LLC
Kenneth Baldwin	University of New Hampshire
Robert Banta	National Oceanic and Atmospheric Administration
Sukanta Basu	North Carolina State University
Larry Berg	Pacific Northwest National Laboratory
William Birkemeier	US Army Corps of Engineers
Whitney Blanchard	National Oceanic and Atmospheric Administration
Paul Bradley	National Oceanic and Atmospheric Administration
Jocelyn Brown-Saracino	Department of Energy/New West Technologies
Ron Calhoun	Arizona State University
Stan Calvert	Department of Energy
Andrew Clifton	National Renewable Energy Laboratory
Joel Cline	Department of Energy
John Cushing	Bureau of Ocean Energy Management, Regulation, and Enforcement
Richard Dart	Ocean Renewable Energy Coalition
PJ Dougherty	SMI Inc.
Larianna Dunn	Department of Energy
Richard Eckman	National Oceanic and Atmospheric Administration
James Edmonson	Grand Valley State University
Dennis Elliott	National Renewable Energy Laboratory
Michael Evers	Marine Corps Installations East
Bill Fetzer	Catch the Wind, Inc.
Matthew Filippelli	AWS Truepower, LLC

Name	Organization
Louise Flynn	Ecology and Environment
Caitlin Frame	Department of Energy
Carrie Gill	Department of Energy
David Green	National Oceanic and Atmospheric Administration
Kevin Haas	Georgia Institute of Technology
George Hagerman	Virginia Tech Advanced Research Institute
Howard Hanson	Southeast National Marine Renewable Energy Center
Jennifer Harper	Federal Energy Regulatory Commission
Jennifer Harris	Ecology and Environment
Sue Ellen Haupt	National Center for Atmospheric Research
Mike Hay	Mainstream Renewable Power
Catherine Hoffman	Bureau of Ocean Energy Management, Regulation and Enforcement
Graham Howe	AXYS Technologies Inc.
Beverley Huey	Transportation Research Board
Stephen Jascourt	University Corporation for Atmospheric Research
Jordan Kristopik	Marwood Group
Daniel Laird	Sandia National Laboratories
Brian Lounsberry	Cardinal Engineering LLC
Angel McCoy	Bureau of Ocean Energy Management, Regulation and Enforcement
Lori Medley	Bureau of Ocean Energy Management, Regulation and Enforcement
Oliver Meissner	The Consilio Group
Robert Mense	Bureau of Ocean Energy Management, Regulation and Enforcement
Walt Musial	National Renewable Energy Laboratory
Brian Naughton	Department of Energy/New West Technologies
Ralph Nichols	Savannah River National Laboratory
Gary Norton	Department of Energy
Rachel Pachter	Cape Wind Associates
Rickey Petty	Department of Energy
Mauricio Quintana	Aquantis

Name	Organization
Jesse Roberts	Sandia National Laboratories
Michael Robinson	National Renewable Energy Laboratory
William Seelig	Sound and Sea Technology
William Shaw	Pacific Northwest National Lab/Department of Energy
Andrew Stern	National Ocean and Atmospheric Administration
William Tayler	Office of the Deputy Assistant Secretary of Navy
Eugene Terray	Woods Hole Oceanographic Institute
James Thomson	University of Washington
Peter Vickery	Applied Research Associates
Steve Woll	Weatherflow Inc
Eric Wolvovsky	Bureau of Ocean Energy Management, Regulation and Enforcement
Jason Wynne	Department of Energy/Energetics
Zhaoqing Yang	Pacific Northwest National Lab
Dane Zammit	Virginia Center for Wind Energy

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