Revised Draft Work Plan For NWCC and NREL Distributed Wind Research Project
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Overall Project Objectives

Primary

• Develop information that serves as a common foundation of knowledge for the NWCC and others to understand and discuss issues associated with furthering the adoption of distributed wind power;
• Develop a description of the benefits, costs, and technical requirements associated with developing wind projects in a distributed model;
• Describe past and current European utility and government policy drivers, and market, industrial, and social characteristics that encouraged and are encouraging European distributed wind models and contrast these to the current U.S. market and policy climate;
• Describe where distributed wind is constrained or encouraged by market, institutional, or regulatory factors;

Secondary

• Identify attractive generic combinations of economic, technical, and social characteristics for distributed wind applications in the U.S.;
• Develop information required to identify specific opportunities for distributed wind systems on a preliminary feasibility level; and
• Identify technical options that can enhance distributed value of wind projects.

Note: "PERI" may be used in the text below to include PERI and any or all of the subcontractors on its project team. "(report)" indicates documentation and text for corresponding sections of the final report will be written as part of the task.

Task 1. Data Collection

Objective: Develop economic, technical, and societal information on distributed windfarm installations from U.S. and European literature and experience.

Summary of task steps:

1. Define and prioritize U.S. and European data requirements
2. Assemble in-house data
3. Develop draft questions and desired data for U.S. interviews
4. Develop draft questions and desired data for European Consultants
5. Develop list of targets and schedule U.S. interviews.
6. Conduct U.S. interviews and literature review
7. Conduct European interviews and literature review
Detailed Description of Work

PERI will collect information in the following areas relative to distributed wind projects using a combination of U.S. information from (1) in house data and literature review, and (2) interviews with developers, manufacturers, and utilities; and European information from (1) literature identified by PERI and its European consultants, (2) in house data and interviews by its European consultants.

U.S. and European Information
1. Project cost elements
2. Interconnection requirements
3. Social aspects
4. Technical impacts (positive and negative) on Utility Systems
5. Utility quantification of benefits, including treatment of capacity value
6. Utility and government policies
7. Local economic benefits

Primarily European Information
8. Roles of participants
9. Market infrastructure (financial, wind assessment, supply, O&M, industries)
10. Financial characteristics
11. Market share
12. Approach to dealing with high capacity/load penetration
13. Representative project development schedules
14. Typical wind resource levels

To reduce the amount of time wasted collecting unnecessary information, the first step in data collection will be to prioritize data needs and identify primary and secondary areas of information required. For instance, PERI will identify cost elements that could benefit from the smaller scale of distributed projects. An example is land use costs, i.e., land co-use and use of existing roads, and certain legal and permitting requirements may impact favorably on distributed projects. Another example is that Minnesota has passed legislation that exempts wind projects under 5 MW from preparing an environmental impact statement. PERI will then conduct a review of information in house and in the literature. Since there have been relatively few U.S. distributed wind projects, several tend to have unique characteristics that may not apply broadly to a larger, more active market. PERI will account for this factor in its selection and use of U.S. data.

Finally, PERI will identify remaining data needs for its interviews and finalize its list of corresponding interview targets. Examples of possible contacts that PERI will make include representatives from Micon, Zond, Nordex, FORAS Service Corporation (a developer), utilities in Michigan, Nebraska, and Iowa, and selected school districts in the Midwest that have experience with distributed wind installations. PERI will also investigate current work being performed by the Minnesota Department of Public Service to review the benefits of cluster wind development for utilities under a DOE grant.

Many distributed projects have unique characteristics that affect their costs and it will not be possible to collect complete data on all cost elements for all projects. Given these limitations, and to reduce the analytic burden and associated cost for this task, PERI may choose to develop a range of typical project descriptions from which it can use to conduct sensitivity or other cost analyses. PERI's choice of the number of typical projects will depend on the range of data that it develops. At a minimum, PERI will form two typical projects so it can bound the sensitivity of project energy costs for a range of distributed project sizes.
To form typical costs and technical specifications, PERI will identify common characteristics among planned and actual projects. Examples of typical technical specifications include (1) maximum number of wind turbines and capacity connected to a distribution feeder, (2) voltage and load levels of distribution feeders, and the relative amount of wind generation capacity added to a distribution feeder compared to the electrical load of the customer and the total distribution feeder, and (3) electrical performance factors required by the utility or regulator, such as minimum power quality requirements. PERI will secure documents describing interconnection requirements for U.S. and European utilities for this analysis.

Distributed wind project energy costs will also be sensitive to factors affecting operating, maintenance, and management costs. For a given size project, O&M costs depend largely on the amount of wind generation and the relative availability of infrastructure support for operating wind turbines, and for maintenance services available to wind generation owners. PERI expects that actual O&M data for distributed projects will be scarce and will therefore have to be augmented with engineering judgement to form a parameterization of data for project size ranges and other factors.

PERI will collect European data concurrently with the US data to identify key aspects of the European market experience that drove the adoption of distributed wind installations. PERI will use recommendations from the NWCC and NREL to identify appropriate consultants, and will obtain concurrence on its final selection. Data collection efforts will focus on Denmark and Germany. PERI will also investigate comparisons of the U.K. market to those two countries. PERI will define needs and priorities for its U.S. and European data collection at the same time. PERI will prepare a written list of all information requirements and deadlines for its European consultants.

Task 2. Analyze Distributed Wind Project Costs and Interconnection Requirements

Objectives: Develop a quantitative assessment of (1) distributed wind project cost elements and (2) the sensitivity of project cost elements to project scale, number and size of turbines, development schedule, geographic factors, and other key infrastructure or market-related factors. From that assessment, identify key drivers and best practices relative for effective implementation of distributed projects. Using relative measures of impact such as ratios, assess on a preliminary, or typical project level, the sensitivity of wind project value (COE or payback) to project scale, number of turbines, and development schedule. Evaluate generic interconnection requirements and assess ability of current wind turbine manufacturers to meet them.

Summary of Task Steps:

1. Characterize cost differentials, tradeoffs, and sensitivities of project cost elements due to project scale, number and size of turbines, geographic factors, development schedule, and other factors identified by PERI. (report)
2. Identify key drivers and best practices for effective implementation of distributed projects. (report)
3. Characterize relative impact of project scale, number and size of turbines, and development schedule on project valuation using appropriate decision criteria (levelized COE, or payback). (report)
4. Construct list of generic interconnection requirements at distribution level (report)
5. Use data to characterize interconnection requirements for distributed wind projects. (report)
6. Write assessment of turbine manufacturer ability to meet interconnection requirements of local utilities (report)

PERI will use the data developed under Task 1 as the basis for characterizing capital and operating costs of distributed wind projects. The cost of a wind project is especially sensitive to financial terms, the size of turbines, the number of turbines, the location of the project, and the development schedule. PERI will
assess sensitivities to these and other key factors and will compare European financing costs to those in the U.S. From this analysis, PERI will identify positive drivers and best practices for effective implementation of distributed projects. PERI will also examine threshold levels for factors affecting costs. For example, a possible investigation will be to use European data to assess the differences between early stages of market development, when the infrastructure and experience base is low, and later stages, to determine if and when O&M costs decrease.

Interconnection costs can be either higher or, in some cases very low, on a per kW basis, for a distributed project. The cost of interconnecting single turbines installed by retail customers to their electric service depends on site specific factors, and the size of the turbine. PERI will characterize these and a complete set of other project cost elements for a range of project scales, turbine sizes, and development schedules. Finally, PERI will present these characterizations in graphical and tabular form to show the impact of various cost elements on individual project cost elements and on the overall project cost for a complete range of distributed and transmission-connected wind projects.

PERI will also relate cost impacts to relative changes in project valuation criteria. PERI will not calculate measures for total project value. Rather, it will use relative measures to compare the impacts of the various factors affecting cost. PERI will use in-house tools and leading commercial turbine characteristics, i.e., power curves and hub heights, to develop wind energy production estimates required for this analysis. PERI will present results in a clear, graphical format.

In addition to cost parameters, PERI will also characterize interconnection requirements at the distribution level using a combination of in house and collected data. U.S. and European utility interconnection guideline documents will be reviewed, as will IEEE and European standards. PERI will first construct a comprehensive list of generic requirements. Next PERI will characterize each requirement with an overview and its application to different turbine types and utility interconnection characteristics and needs. When possible, PERI will characterize a range of requirements around applicable standards. Finally, PERI will evaluate manufacturers' ability to meet these requirements with current technology.

An example of a major generic interconnection requirement is ensuring adequate power quality. The specific design of wind turbines, the characteristics of the local wind resource, and the design of the distribution feeder determine the power quality impacts on the distribution system. Due to these factors, there can be significant differences in the power quality impacts of installations. PERI will develop an overview of these differences in power quality impacts along with recommendations on how to minimize potential power quality problems for distributed wind generation. Furthermore, the ability of wind turbine manufacturer’s to mitigate power quality problems caused by connection to the distribution system will be evaluated. PERI will account for differences between European and U.S. requirements in its characterization.

**Task 3. Outline and Identify Potential "Distributed Utility" Benefits**

**Objectives:** Discuss the potential "distributed utility" benefits that wind power may be able to earn on U.S. utility systems. Provide insight into overall utility system performance with and without distributed wind power, and the impacts on system operating parameters resulting from distributed wind facility operation. Identify and describe the conditions associated with the utility systems and wind resources necessary for distributed opportunities to be present. Develop tools to allow specific utility systems or geographic areas to be evaluated for distributed opportunities. Develop insights on valuation of distributed benefits from actual projects in the U.S. and Europe.
Summary of Task Steps:

1. Prepare a list of potential distributed benefits from in house information, supplemented with literature search. (report)
2. Discuss characteristics and conditions necessary for them to occur; challenges influencing opportunities for distributed wind to be adopted; and impacts on system operating parameters resulting from distributed wind installations. (report)
3. Develop a checklist to evaluate potential for opportunities in specific utility systems. (report)
4. Prepare a case study using actual project data and experience to investigate the various components of value for a distributed project. (report)

PERI will rely heavily on its in-house expertise to develop a comprehensive list of potential distributed utility benefits and a thorough overview of the potential magnitude of opportunities for wind energy to capture these benefits. In addition, PERI will utilize literature and external reviewer input to check for completeness. The primary sources of additional literature are expected to be publications sponsored by EPRI, DOE and its National Laboratories.

PERI will provide an overview of only those distributed benefits applicable to wind projects, including, but not limited to the following list:

- Distribution Facility Deferral
- Distribution Loss Reduction Benefits
- Distribution Voltage Control and Power Factor Correction Benefits
- Energy Displacement Benefits
- Capacity Value Benefits
- Demand Charge Reduction Benefits
- Transmission and Subtransmission Facility Deferral
- Transmission Loss Reduction Benefits
- Environmental and Other External Benefits

PERI will draw from its experience in previous analyses to provide a detailed discussion of the utility system conditions and characteristics required for wind to capture each of the benefits listed above. PERI will discuss the specific requirements and limitations for distributed wind generators to capture these benefits, with a focus on the impact that they have on the relative and absolute size of the benefits. The discussions will be detailed enough to serve as examples that readers can use to help identify opportunities on specific distribution systems.

PERI will also develop a checklist of generic utility system characteristics and wind resource requirements designed to allow use of the information described above to identify potential high value opportunities in any state. In developing a generic checklist, PERI will provide a step-by-step process by which analysts can methodically evaluate potential opportunities using a complete set of criteria developed in step 2 of this task. If requested by the NWCC or NREL, PERI will demonstrate use of the checklist through use of a hypothetical example.

In addition to the checklist, the PERI Team will prepare a case study that evaluates a range of distributed values for an installed project located in the Midwest. PERI will work with the NWCC and NREL to finalize the case study scope, based on the level of information that is accessible. PERI will also include a discussion of the key factors associated with utility valuation of potential distributed benefits from wind, including an assessment of capacity value. PERI will include insight gained from literature or its European consultants on how systems in Europe have handled high penetration situations and how utilities have
valued capacity and various distributed benefits. PERI will also explore implications of utility restructuring on the valuation of distributed benefits, including new value that may be captured and changes in the parties that recognize or capture value. Opportunities for potential value from provision of auxiliary services will be listed, but not analyzed.

**Task 4. Identify Technical Opportunities for Enhancing Distributed Benefits**

**Objectives:** Evaluate the technical capabilities of current wind turbine technologies to understand their strengths and limitations in delivering distributed benefits. Discuss opportunities for enhancing distributed benefits with improvements to wind technology or addition of storage or other capabilities.

**Summary of Task Steps**

1. Formulate/characterize 2 representative distributed utility systems *(report)*
2. Develop matrix of benefits and limitations for different wind turbine designs. *(report)*
3. Discuss technical capabilities and opportunities that will enhance distributed benefits. *(report)*

PERI will first develop specific technical descriptions of two [delete: wind turbine] [distributed utility] systems as a precursor to assessing the ability of wind turbines to deliver distributed benefits. These representative system applications will likely include a strong, thermally-limited system, and a weak, voltage-limited system. These applications represent two basic sets of distribution system characteristics that dictate the requirements for a large number of potential wind project opportunities. These characteristics also affect potential benefits and limitations for different types of wind technology. Therefore, establishing these representative descriptions will allow analysts to make proper matches of technology and utility systems when evaluating potential opportunities.

Next, PERI will develop a matrix of wind project benefits and limitations for different wind turbine designs using the classifications developed in the first step of this task. For example, on weak distribution systems, wind penetration limits due to voltage fluctuations are expected to vary significantly for induction and variable speed designs, the latter of which can supply voltage support. Whereas, in strong distribution systems, voltage fluctuations may not be significant. PERI will summarize the strengths and limitations of these two types of wind turbines for the two representative distribution system application classifications. PERI will recommend potential approaches to enhancing distributed utility benefits for both types of wind turbines [and will broadly characterize the value of these approaches]. Potential approaches include addition of stand-by generation, small amounts of storage, wind project output controls, and others. PERI will include the following in its discussion:

* An overview of the issues associated with interconnection requirements and impacts of various approaches on a generalized level, not a system-specific level.
* An overview of the favorable conditions for realizing these added benefits and the potential extent of their value
* A summary of intermittency-related issues, requirements, or impacts specific only to distributed connections, i.e., not to the broader electricity system.
* A high-level overview of potential benefits of adding small amounts (seconds or minutes) of storage as a potential enhancing/mitigating factor, i.e., identify qualitatively which benefits would be increased by storage and which would not. PERI may include generic,
or example calculations to demonstrate potential value, but will not portray specific
distribution systems or wind turbines.

• An outline of other technical characteristics differentiating distributed installations from
large, transmission-level wind farms.

PERI will work with the NWCC and NREL to identify experts for review of an interim draft of this task.
PERI will solicit comments on approach and content from the reviewers. PERI will integrate reviewer
comments into its draft final report.

Work for this task will draw exclusively from the PERI Team's in house knowledge and existing studies in
this area that others have performed for DOE and its laboratories, EPRI, utilities, or other entities. PERI
will coordinate work on this section with Task 1 so that issues pertaining to this task may be included in
interviews with utilities conducted under Task 1. For example, an anticipated area of investigation during
the Task 1 interviews is the value to utilities of shifting a short period of energy production with storage.

Task 5. Evaluate European Distributed Wind Market Characteristics and Infrastructure

Objectives: Provide detailed information from European experiences with distributed wind market models
to understand how to enhance opportunities for distributed applications in the U.S. and reduce barriers.

Summary of Task Steps:

1. Interpret and summarize findings from interviews and literature review (report)

PERI will summarize findings from its information collection in Task 1 to provide the following.

1. A description of the economic conditions, utility or government policies, social characteristics, or
   factors that led to the establishment of the infrastructure that currently supports the distributed wind
   market segment in Europe.
2. A description of the wind industry capability and infrastructure serving the distributed wind market.
3. A characterization of the market conditions and infrastructure that existed when distributed deployment
   was beginning.
4. An overview of key developments that facilitated the distributed deployment method.
5. A characterization of market share for distributed applications.
6. A listing of different types of project owners and development characteristics and associated
demographics of the load area.
7. An examination of differences between Denmark, Germany, and the U.K. markets as a tool to evaluate
   what conditions may help or hinder adoption of distributed systems.

PERI's focus on European policies will be to identify those which impacted decisions to install distributed
projects. However, PERI will take a descriptive approach rather than an advocacy position relative to its
discussion of policies. PERI will identify when the impact of various policies is not clear and will provide
the necessary data for readers to debate and infer the impacts for themselves. PERI anticipates that it will
characterize project financial conditions on a general level if it can not easily obtain detailed project
financial data.

Objectives: Evaluate (1) factors or circumstances that need to be present in a local or regional wind market in order to support distributed wind development; and (2) the necessary roles of various business stakeholders.

Summary of Task Steps:

1. Evaluate essential factors, circumstances, & precursors for distributed project proliferation (report)
2. Evaluate required roles of market participants (report)
3. Discuss policy options that do and do not encourage the distributed model (report)

Based on its summary of the factors that supported development of distributed wind projects in Europe, PERI will identify differences and similarities between the European and the current U.S. market infrastructures and requirements. A description of the types of current U.S. project owners will be included. PERI will then use these findings to describe policy options that may encourage distributed project deployment in the U.S.

Task 7. Detail Local Economic Impacts of Distributed Wind

Objectives: Assess the role that the wind development plays in the local economies where distributed projects are common. Compare economic benefits from distributed installations to large wind farm development.

Summary of Task Steps:

1. Summarize findings (report)

PERI will utilize existing literature, and results of its discussions with European contacts for this task to produce a summary of all work performed in this area to date. PERI will summarize and compare economic impacts on as disaggregated a level as the data will allow. PERI will identify limitations of the current data, and will indicate the extent to which data is site-dependent or can be generalized to broader applicability.

Task 8. Local Identity (Social) Implications

Objectives: Assess the social implications of distributed projects on the localities in which they are constructed.

Summary of Task Steps:

1. Summarize findings from information collected in Task 1 (report)

PERI will use three primary sources for U.S. data on social implications associated with distributed projects: literature, conversations with NWCC members, and interviews. Using these sources, PERI will summarize the current state of knowledge in this area and will also identify considerations for which there is no current information. PERI will investigate literature developed for other renewable energy-related purposes, e.g., studies of implications and benefits of increasing adoption of solar technologies as part of recently-proposed or adopted renewable portfolio standard legislation. An analysis of public perceptions of wind power before and after projects have been installed will be included.
PERI will summarize findings relating to local perceptions and problems, approaches for resolution of problems, and other implications. PERI will coordinate closely with current NWCC research efforts in the green power area to highlight potential opportunities created by links between green market programs and local social implications. PERI will include a reference to NWCC research and corresponding publications in its final report. PERI will also utilize current literature to tie state policy efforts in this area to potential opportunities for distributed wind applications.

Task 9. Conclusions, Recommendations, and Report

Summary of Task Steps:

1. Compile/Edit Draft Report
2. Present Draft Findings To NWCC Steering Committee and Obtain Comments
3. Produce Draft Final Report
4. Obtain Final NWCC Review
5. Produce Final Report
Project Report Draft Outline

Executive Summary

Introduction

1 Interconnection Requirements
   1.1 Characterization of interconnection requirements
      1.1.1 Generic list of requirements
      1.1.2 Detailed findings
   1.2 Assessment of turbine manufacturer ability to meet interconnection requirements of local utilities

2 Cost analysis of distributed projects
   2.1 Cost differentials, tradeoffs, and sensitivities of project cost elements due to project scale, number and size of turbines, and development schedule
   2.2 Impact of project scale, number and size of turbines, and development schedule on project valuation

3 Distributed Benefits
   3.1 Detailed discussion of potential distributed benefits from wind
   3.2 Characteristics and conditions necessary for benefits to occur
   3.3 Challenges influencing opportunities for wind
   3.4 Impacts on system operating parameters
   3.5 Case study: evaluation of distributed benefits
   3.6 Utility Quantification of Benefits: capacity value and other factors

4 Identifying Market Opportunities: Technical and Valuation Issues
   4.1 Representative distributed utility systems characteristics
   4.2 Feasibility checklist for evaluating potential opportunities
   4.3 Wind technology capabilities and opportunities for enhancing value

5 Economic and Social Impacts
   5.1 Local economic impacts
      5.1.1 Current state of knowledge and issues
   5.2 Social Implications
      5.2.1 Local identity, perceptions, concerns, and solutions
      5.2.2 Green power

6 Analysis of Economic and Market Infrastructure and Policy Drivers
   6.1 Review and Analysis of European experience and current conditions
      6.1.1 Industry Infrastructure and market characteristics
      6.1.2 Financial characteristics and conditions
      6.1.3 Utility and government policy drivers
   6.2 Review and Analysis of U.S. market
      6.2.1 Essential factors, circumstances, or precursors for distributed wind project proliferation in the U.S.
      6.2.2 Required roles of U.S. market participants
      6.2.3 Policy options to encourage the distributed model

Issues and themes to be addressed in the report
1. Consideration of benefits under a new utility structure
2. Emphasize that new market paradigm implies new opportunities, whose emergence will be dependent on restructuring developments and are difficult to predict