Foundational Concepts and Issues Support a North American Wind Energy Academy

Wind as National Strategic Energy Provider

If wind is to become a contributor as a national strategic energy provider the "local wind farm" centric vision for wind technology development, deployment and operation is limiting and needs to expand. Achieving significant penetration levels (>30% of domestic generation) would move wind into a position requiring federal oversight to insure availability, reliability, and stability in order to achieve the same high level of service and performance expected from our existing power system.

Agency and Institutional Roles

Adopting a national "high penetration" vision and development strategy for renewables would require engagement and participation by several government agencies beyond DOE and FERC. DOC, DOI, DOD, et.al and their affiliated organizations (NOAA, NCAR, BOMER, Fish & Wildlife, et.al.) as well and other federal entities (FERC, NSF, NASA et.al.) would have stakeholder interests at a minimum and/or operational mission and regulatory responsibility; all would have an interest in the formulation of a vision and accompanying federal strategy. In most cases, existing roles, capabilities, and regulatory responsibilities would naturally extend to provide services and support with a national energy system based on renewable technologies; for example:

- Evolution and operation of a national transmission grid providing access, collection, dispatch balance and distribution of renewable power resources; FERC's existing mission.
- Strategic wind forecasts at a scale required to support the operation of a national grid system; similar services already provided by NOAA's NWS to the FAA, DOD, FEMA, et al.
- National wind resource weather conditions and resource monitoring from land based and satellite systems supporting forecast modeling and real time operation, distribution and dispatch strategies required to maintain a stable grid and power delivery; NOAA and NASA; industry partners.
- Development of advanced wind (and solar) forecast modeling tools that ranged from global circulation to mesoscale and at resolutions to support wind plant power production; NOAA, NSF, NCAR
- Climate change models capable of predicting long term wind resource variability to mitigate venture capital risks and performance concerns; DOE Office of Science; NOAA.
- Obtaining a fundamental understanding of wind as a strategic national resource including future availability, spatial and temporal characterization, effects of topography, etc., on and offshore to the same fidelity as fossil and nuclear resources; NOAA, NCAR, DOE/SC , et al.

- Quantifying and mitigating the potential adverse affects of high penetration on wildlife, the environment, competing land and sea use, and other socio-economic impacts through technology advances and regulatory policies; Fish and Wildlife, EPA, NOAA et al.
- Siting and permitting of transmission and wind plants; FERC, BOEMRE, FAA, DOD, Fish and Wild Life, Army Corps of Engineers, Coast Guard, NOAA, et.al.

This list is by no means inclusive of all potential agencies that would have a vested interest in a high penetration scenario. It also does not include the extensive investments by DOE/EERE to evolve innovative technology and address market barriers.

Environmental Constraints and Market Barriers

High penetrations of wind, solar and MHK resources face significant future hurdles as an variable weather driven resources attempting to displace a well-established power generation and delivery infrastructure based predominantly on fossil and nuclear fuels. Wind technology has rapidly matured and been demonstrated as technically and economically viable with over 40 GW of installed capacity. The constraints and barriers to deployment are numerous and significant in scope; transmission, distribution, socio-economic, environmental, wild life, regulatory, market, public policy, etc. In addition, unresolved technical challenges and concerns adversely impact achieving national deployment goals including:

- Creating a vision and operating paradigm that would support a national strategic dependence on renewables
- Technology innovation to lower LCOE compared to fossil generation – especially CCNG
- Intermittency and need for storage in operating a power collection and distribution system at nation scale
- Thoroughly understanding the potential short and long term benefits, impacts, risks and consequences of converting an existing robust energy system to dependency on a weather driven intermittent resource
- Would very high penetration scenarios result in unforeseen environmental consequences macro and micro climatology changes affecting weather, precipitation, temperature at a local and regional level?

In many respects, changing an established power infrastructure to renewables will be no less challenging from a political, socio-economic, environmental assessment and technology evolution perspective that any other endeavor attempted thus far by the nation. The breadth, depth, and scope of the challenge crosses numerous technical disciplines and will require public acceptance and supporting governmental policy in additional to technology to achieve the end goal. To be successful with an energy system transformation requiring a change of this magnitude must be done synergistically from the perspective of diverse stakeholders. Technology innovations and deployment must always be evaluated in the context of potential impacts. For example, a new floating turbine design offering 100% capacity factor at zero cost would never be deployed if an indigenous whale population were threatened.

Potential Roles for an Academy

Formation of a national academy is critical in providing a forum for government, academia, and industry to assemble the resources and expertise required to formulate a holistic vision and develop an integrated strategic plan that transforms the nation's electric power dependency from fossil fuels to renewables. There is no single agency, organization or entity that has sole mission and/or regulatory and statutory responsibility necessary to address the high renewables penetration challenge. An academy will provide the open and scholarly forum required to:

- Assemble the diverse stakeholder group needed to implement change on a national level
- Evolve a national vision and strategy to obtain our domestic electrical power from domestic renewable resources
- Identify and articulate the technical, socio-economic, environmental and political challenges and barriers
- Understand the synergies, interdependencies and codependencies in the missions and roles of government agencies and institutions
- Promote cross-discipline and synergistic discussions in developing recommendations for regulators and policy makers
- Become a central repository and archive of the intellectual knowledge base required to evolve and transform the electrical generation sector
- Disseminate information and knowledge through workshops and forums
- Provide an environment for the formulation of R&D collaboratives.

Areas where this collaboration will be beneficial are:

- Turbine and wind farm technology and engineering
- Forecasting and atmospheric science
- Turbine dynamics
- Micrositing and array effects
- Mesoscale processes
- Climate effects
- Grid integration for large scale deployment requiring grid expansion and enhancement, storage capabilities, dispatchable ancillary power, and demand side management
- Social acceptance
- Policy, law, and regulations
- Economics and business models
- Wind energy education

Turbine and Array Design, Performance, and Reliability Background

Utility concerns about the interoperability of wind as part of their generation portfolio remains a barrier to deployment. A much better understanding of the grid interconnection requires comprehensive systems level characterization based on field operating performance measures. Recent events in Texas and Hawaii continue to highlight the operational sensitivities and vulnerabilities in collecting energy from a stochastic resource. Geographic diversity, variance in wind resource, site-specific grid characteristics and interoperability concerns based on the portfolio mix raise questions about the level of dynamic control and the degree to which mitigation strategies are necessary for stability. Established and validated guidelines for ancillary service requirements including storage and VAR control limits are required to insure sufficient ride-through capability, system stability and a robust interconnection. Information collected from a number of operating wind plants with diverse geographic, resource and grid characteristics is required to develop the appropriate dynamic stability models. Documented field experience combined with validated analysis tools is necessary to assist utilities in assessing their unique configurations and overcoming their reluctance to utilize wind in high penetration and weak grid applications.

With the rapid deployment of large machines in various geographic and wind resource environments, existing commercial turbine designs are experiencing several problems affecting both performance and reliability. Drive trains, particularly gearboxes, are experiencing major component failures after 4-5 years, significantly less than the expected 20-year design life. Power production from large farms are 5-10% lower than expected based on local wind measurements. Blades and rotors require field service for cracks and other deficiencies. As a result, O&M costs are higher than expected raising concerns about long-term profitability as the deployed fleet exceeds the warranty period. These problems appear independent of turbine type, operator and geographic location; thus, generic to currently deployed architectures.

The root cause for these operational deficiencies is yet unknown, however, the breadth and impact on the existing fleet suggest a number of potential sources. Diverse geographic locations and specific topographies may produce higher that expected levels of turbulent inflow thereby increasing loads. Multiple array configurations in large farms will alter the inflow pattern, change the boundary layer shear characteristics and introduce additional turbulence on downwind machines. Complex terrain installations have been documented to produce extremely sharp shear gradients and additional coherent vertical flow that will adversely affect performance and loads. Hence, numerous sources to lower production, increase machine loading and thereby increased failure rates and the potential for underperformance.

Large machines aligned in multiple arrays also have been shown by the Europeans (Risoe) to affect inflow and surface boundary layer behavior. Questions on the microclimatology changes in and around large farms are raising environmental and agricultural concerns. Likewise, wind resource turbulence “quality” as well as downwind availability will eventually require quantification before licensing and permitting application awards. These analysis tools do not currently exist and require the development of new comprehensive atmospheric and inflow turbulence models in collaboration with leading world experts like NOAA and NCAR. High quality 3-D inflow measurements quantifying the spatial and spectral characteristics of the flow in and around wind farms will be required for both development and validation– the same information required for determining the underlying performance and reliability problems noted earlier. These data will be difficult to obtain, requiring participation by various international experts including Risoe as well as the Office of Science laboratories.