DNV KEMA ENERGY & SUSTAINABILITY

Knowledge Boosting Curriculum for New Wind Industry Professionals Final Technical Report

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EXECUTIVE SUMMARY

DNV Renewables (USA) Inc. (DNV KEMA) received a grant from the U.S. Department of Energy (DOE) to develop the curriculum for a series of short courses intended to address Topic Area 5 – Workforce Development, one of the focus areas to achieve the goals outlined in *20% Wind by 2030: Increasing Wind Energy's Contribution to Electricity Supply* [Ref. 1]. The aim of the curriculum development project was to provide material for instructors to use in a training program to help professionals transition into careers in wind energy.

Under this grant DNV KEMA established a "knowledge boosting" program for the wind energy industry with the following objectives:

- Develop technical training curricula and teaching materials for six key topic areas that can be implemented in a flexible format by a knowledgeable instructor. The topic areas form a foundation that can be leveraged for subsequent, more detailed learning modules (not developed in this program).
- Develop an implementation guidance document to accompany the curricula outlining key learning objectives, implementation methods, and guidance for utilizing the curricula.

This curriculum is intended to provide experienced trainers course material that can be used to provide course participants with a basic background in wind energy and wind project development. The curriculum addresses all aspects of developing a wind project, that when implemented can be put to use immediately, making the participant an asset to U.S. wind industry employers.

The curriculum is comprised of six short modules, together equivalent in level of content to a one-semester college-level course. The student who completes all six modules should be able to understand on a basic level what is required to develop a wind project, speak with a reasonable level of confidence about such topics as wind resource assessment, energy assessment, turbine technology and project economics, and contribute to the analysis and review of project information.

The content of the curriculum is based on DNV KEMA's extensive experience in consulting and falls under six general topics:

1. Introduction to wind energy
2. Wind resource and energy assessment
3. Wind turbine systems and components
4. Wind turbine installation, integration, and operation
5. Feasibility studies
6. Project economics

Each general topic (module) covers 10-15 sub-topics. Representatives from industry provided input on the design and content of the modules as they were developed.

DNV KEMA developed guidance documents to accompany the training curricula and materials in order to facilitate usage of the curricula in a manner consistent with industries requirements.

Internal and external pilot trainings using selections of the curriculum provided valuable feedback that was then used to modify and improve the material and make it more relevant to participants. The pilot trainings varied in their content and intensity, and each served as an opportunity for the trainers to better understand which techniques proved to be the most successful for accelerated learning. In addition, the varied length and content of the trainings, which were adjusted to suit the focus and budget for each particular situation, highlight the flexibility of the format.

The material developed under this program focused primarily on onshore wind project development. The course material could be extended in the future to address the unique aspects of offshore project development.

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1 INTRODUCTION

DNV KEMA received a grant from the U.S. Department of Energy (DOE) to develop the curriculum for a series of short courses intended to address Topic Area 5 – Workforce Development, one of the focus areas to achieve the goals outlined in *20% Wind by 2030: Increasing Wind Energy's Contribution to Electricity Supply* [Ref. 1]. The aim of the curriculum development project was to provide material for instructors to use in a training program to help professionals transition into careers in wind energy. This scope of work is governed by DOE award number DE-EE0000536 dated January 4, 2010.

As the leading U.S. wind energy engineering and risk management service organization and as a long time participant in the U.S. wind energy industry, DNV KEMA has a unique insight into the education and skills necessary for technical professionals to successfully enter and participate in the wind energy industry. DNV KEMA has also experienced significant growth over the past 6 years which has resulted in development of certain internal training materials and processes for new staff. Under this grant, DNV KEMA built on those materials, aided by guidance from our industry partners and utilizing the pedagogical framework of our parent organization Det Norske Veritas (DNV) Learning, to develop a "knowledge boosting" curriculum targeted toward recent graduates of engineering or science programs and technical professionals experienced in other industries who are interested in transitioning into the wind industry, as well as business, government, or policymakers whose functions require a better understanding of wind energy's background, technology, performance, risks, and future capabilities. This targeted group of learners is referred to throughout this report as "participants."

In addition to developing a "knowledge boosting" curriculum based in Microsoft PowerPoint, DNV KEMA created guidelines for implementing the curriculum. The guidelines are designed to accompany the presentation material. They provide the trainer with additional background and details, as well as suggestions for how to present each topic and the associated learning objectives.

As of 2012, the nation is on target to achieve the DOE's goal of 20% wind by 2030 [Ref 2]. However, one of the identified requirements to reach this goal is the need for a seven-fold increase in the workforce. Reaching 20% wind energy by 2030 will require a workforce of approximately 500,000, but today only about 70,000 people are working in the industry in the U.S. This increase cannot occur without bringing in professionals from other industries or recent graduates from university programs – candidates with perhaps relevant skills but no specific experience in the wind industry. The "Knowledge Booster Curriculum for New Wind Industry Professionals" is designed to help such professionals to obtain the knowledge necessary to productively contribute to the wind industry more quickly than simply learning on the job. The curriculum covers a broad range of topics relevant to wind energy, thereby giving participants context for the specific job they may be hired to do as well as the ability to think beyond their own assignments. We note that the knowledge boosting curriculum described herein was designed as a classroom course intended to be delivered by an instructor knowledgeable in wind energy topics.

This report presents the objectives, design, and results of our curriculum program, as well as some conclusions as to its application and efficacy, and recommendations for its implementation.

2 PROJECT DESCRIPTION AND OBJECTIVES

Growth of wind energy generation over the next few decades is projected to accelerate as industrialized and developing countries embrace the use of this zero emission technology to meet electricity demands, respond to renewable portfolio standards or other policy/market mechanisms, and combat global warming. This growth will demand more engineers, scientists, project managers, business people, and policymakers who are well versed in the unique aspects of wind generation technology and risk management. However, a lack of trained personnel is one of the industry's most pressing challenges to meet the expected growth.

At this point in modern wind energy's approximately 30-year existence, the majority of project work has been performed by people with prior experience in the industry combined with on-the-job training for new entrants into this emerging engineering field. College and university programs specific to wind energy have been in existence for many years and they have produced many of the leaders in the wind energy business today. Although these programs have been expanding in recent years, the number of graduates from these programs remains small compared to the total number of people engaged in wind energy related work. Expanding and adapting university programs to include wind energy alongside the more traditional engineering and science curricula are important steps; however, this takes time and resources. Therefore, an interim measure is necessary to improve the wind-energy-specific knowledge of people with more traditional education backgrounds.

There are significant numbers of people in other professional fields that could play a role in the wind industry; but the unique and technical nature of wind energy results in their previous knowledge being of limited use in their first few years in the industry. This period is often marked by on-the-job training which can be inefficient, error prone, and frustrating. For professional service companies, project developers like our industry partners EDP Renewables North America and Edison Mission Energy, utilities such as Puget Sound Energy, and many other industry stakeholders, reducing this initial learning period and increasing awareness of key industry knowledge will enable expansion while maintaining quality and performance.

Over the past few years, there has been (and remains) a significant focus on training programs for wind turbine technicians, retraining of the manufacturing labor force, and wind energy awareness curricula for elementary, secondary and high schools. In addition, knowledge sharing within the wind industry is often oriented around annual conferences, workshops, and business networking seminars. These knowledge sharing opportunities, while useful, have a tendency to be too general (and short) or too "industry insider" oriented to enable a deeper understanding of key industry knowledge. Therefore, DNV KEMA targeted this series of "knowledge boosting" technical and industry specific training curricula toward the participants described in Section 1.

In response to the topic goals set forth in the DOE 20% Wind Energy by 2030 Funding Opportunity, DNV KEMA has developed a “knowledge boosting” program for the wind energy industry with the following objectives:

- Develop technical training curricula and teaching materials for six key topic areas that can be implemented in a flexible format by a knowledgeable instructor. The topic areas form a foundation that can be leveraged for subsequent, more detailed learning modules (not developed in this program).
- Develop an implementation guidance document to accompany the curricula outlining key learning objectives, implementation methods, and guidance for utilizing the curricula.

This training is intended to make a difference to the participants by providing them with a basic background in wind energy and wind project development. The curriculum includes all aspects of developing a wind project, that when implemented can be put to use immediately, making the participant an asset to U.S. wind industry employers.

The curriculum is comprised of six short modules, together equivalent in level of content to a one-semester college-level course. The student who completes all six modules should be able to understand on a basic level what is required to develop a wind project, speak with a reasonable level of confidence about such topics as wind resource assessment, energy assessment, turbine technology and project economics, and contribute to the analysis and review of project information.

The target participants for this curriculum are professionals with technical, business or policy backgrounds, as well as recent graduates with math-oriented degrees such as engineering, mathematics, physics, business, or economics. Our expectation is that students who seek this type of wind energy training course are likely to have limited time to devote to training and a need to get up to speed quickly. Thus the program is designed to be modular and flexible to accommodate different schedules. We also expect the target participant to be highly motivated, eager to be involved in the industry and enthusiastic about learning. The curriculum is therefore designed to be interactive, engaging, and focused on issues deemed relevant and practical for today’s wind industry.

3 CURRICULUM DESIGN METHODOLOGY

Under this project, DNV KEMA utilized the curriculum development experience of DNV’s training department combined with DNV KEMA’s extensive wind energy experience and guidance from our industry partners to structure a training program, prepare technical learning materials, develop an accompanying guidance document, assemble hands-on learning examples, and include other accelerated learning techniques known to be effective.

We targeted a length of 2-3 days for each training module to enable sufficient time for hands-on learning with real-life examples and to facilitate group discussions and side conversations and time for reflection, all of which are important elements in acquiring and retaining deeper knowledge. A multi-day course also expands the time for students to have access to a technical expert, permitting questions and follow-up dialogue typically not possible in a one-day short course. We recognize that it can be difficult for a professional to devote more than a few days at a time to training, given other responsibilities. Therefore, delivery of these training classes can be distributed over the calendar year in a manner that allows students to apply their recent learning on the job as a means of reinforcing the knowledge gained. Other delivery schedules are certainly possible as well. The actual length of each module will vary depending on the specific implementation of the curriculum.

The content of the curriculum is based on DNV KEMA's extensive experience in consulting and falls under six general topics:

7. Introduction to wind energy
8. Wind resource and energy assessment
9. Wind turbine systems and components
10. Wind turbine installation, integration, and operation
11. Feasibility studies
12. Project economics

Each general topic (module) covers 10-15 sub-topics. Representatives from industry provided input on the design and content of the modules as they were developed.

The modular nature of the curriculum means that the material can be delivered in a number of formats. Possible delivery modes could include:

1. One module every two months over the course of a year
2. Three one-week sessions, each covering two modules
3. Six consecutive modules for an intensive 3-week program

4 GUIDANCE DOCUMENT DEVELOPMENT

DNV KEMA developed guidance documents to accompany the training curricula and materials in order to facilitate usage of the curricula in a manner consistent with industries requirements. The guidance documents for each module provide:

- Key learning objectives
- Background information for instructors
- Detailed implementation procedures for all presentation material
- Suggestions for quizzes, reflections, and discussions to help reinforce retention of the material

5 DETAILS OF CURRICULUM CONTENT

Development of the curriculum was a key activity of this project. This section describes the content in each of the six modules. Appendix A provides a more detailed outline of the sub-topics covered under each module as well as the content of each segment.

5.1 Module 1: Introduction to Wind Energy

Module M1 is an overall introduction to wind energy from the perspective of project development. The module begins with a brief review of the long history of wind energy and how the wind industry has arrived where it is today, as well as why most utility-scale wind turbine designs have evolved to the same overall topology. The rest of the module provides a review of some basics about wind resource and energy assessment, turbine technology, siting, environmental and political issues affecting wind projects, incentive programs, turbine technology, installation, operation and maintenance. These topics are covered within the framework of the project development cycle. This module lays the groundwork for each subsequent module, which expand on the introductory topics as well as broaden into other relevant subjects.

Module 1 topics include:

- The History: How we got here and why it matters
- The Market: capacity, growth rates, trends, 20% by 2030
- Where is the wind? Where are the wind projects? What drives the market?
- Phases of the development process:
  - Prospecting: where to begin?
  - Wind resource assessment
  - Energy assessment
  - Environmental impact and permitting
  - Transmission
  - Contracts and agreements
  - Engineering, procurement and construction
  - Financing
  - Operation and maintenance
- The Bottom Line: Cost of Energy (COE)
- Heading Offshore: challenges and potential
- Summary

5.2 Module 2: Wind Resource Meteorology and Energy Assessment

Module M2 presents wind as the power source – including variations in time and space, turbulence, shear, wind resource estimation, and other related material. Participants who complete this module will be able to evaluate, understand and carry out simple validation of measured wind data. Participants will also understand the components involved in conducting an energy assessment.

Module 2 topics include:

- The Driving Forces: atmospheric processes, power in the wind
- Wind variation in time and space
- Wind speed and direction
- Shear and turbulence
- Site conditions and suitability
- Wind measurements
- Wind data collection and validation
- Summarizing wind characteristics at measurement locations
- Long term adjustments
- Wind flow basics

Energy Assessment topics include:

- Wind to energy conversion
- Wake effect basics
- Losses and uncertainties
- Energy assessment criteria
- Summary

5.3 Module 3: Wind Turbine Systems and Components

Module M3: Wind Turbine Systems and Components begins by examining the power in the wind from a loading perspective as well as some basic rotor and aerodynamic concepts for converting wind power into mechanical power, then into electrical power. This module looks in detail at the overall technology involved in producing wind energy. This course will enable participants to understand manufacturers' technical specifications. In addition, participants with an engineering background taking this course will be able to review a basic technical due diligence study and, with assistance, conduct a due diligence technical review. The business or economics professional taking this course will understand to a greater degree a technical due diligence report and basic turbine operation.

Module 3 topics include:

- The big picture
  - Power in the wind, C_P
  - Basic rotor and aerodynamics concepts
- Converting wind power to mechanical power
  - Blades – Airfoils, blade construction

  - Rotors – Blade number, shapes, tip speed, C_P -λ curves, pitch mechanisms
- Converting mechanical power to electricity
  - Gearboxes and mechanical systems
  - Wind turbine electrical systems
- Putting it all together
  - Turbine models
  - Towers, yaw systems, control systems
  - Power curves
  - Balance of plant (BOP)
- Design drivers and turbine dynamics
- Operation and maintenance
- Technology advances

5.4 Module 4: Wind Turbine Installation, Integration and Operation

Module M4 introduces participants to the basic elements of a wind farm, including issues related to site suitability, grid compatibility (including grid penetration and low-voltage ride-through), availability, operations and maintenance (O&M), roads and general site preparation, supervisory control and data acquisition (SCADA) systems, electrical distribution, and offshore wind project issues. The student will understand the turbine-related technical issues associated with development.

Module 4 topics include:

- Wind farm siting and design
- Turbines for wind farms
- Design standards – Turbine classes
- Installation and Construction – Transportation, foundation loads, BOP, wind farm infrastructure
- Operations and maintenance
- Electricity and Grid operation
  - Interconnection equipment
  - Real and reactive power, power factor
  - Grid operation and control
  - Meeting needs of grid operators
  - Penetration issues
- Offshore Projects
  - Offshore design - Waves and wave loading, offshore turbines
  - Offshore foundations and construction
  - Offshore O&M

5.5 Module 5: Project Feasibility Considerations

Module M5 introduces participants to all aspects that must be considered when evaluating the feasibility of a potential project. It describes what a site assessment includes – what kind and quality of information (data) is needed, what experts to hire for environmental or other reviews. Participants who complete this module will understand the issues affecting wind turbine siting as well as how those issues are addressed technically, financially, and politically.

Module 5 topics include:

- Siting overview – issues to consider when evaluating site feasibility
- Local wind speed data; estimating uncertainty
- Setbacks
- Environmental issues
- Airspace issues and conflicts
- Turbine layouts
- Measurement tower siting
- Community impacts
- Sound basics: sound power, sound pressure, measurement, turbine levels, standards
- Shadow flicker
- Transportation/site access
- Foundation design – soil issues
- Preliminary energy estimates
- Project Economics – plant costs, O&M, COE, analysis methods
- Geographic information system (GIS) methods

5.6 Module 6: Wind Project Economics

Module M6 presents the basics of economic projection over the life of a project for the purpose of evaluating project viability or obtaining financing. The course begins by establishing where wind energy currently sits in the overall energy market, including where to find reliable up-to-date wind market reports. The course then goes into some detail about how investment risk evolves as a project approaches commercial operation date (COD) and after a project is in operation. Economic terms are defined and used in simple cash-flow models that students use to carry out hypothetical scenarios. A significant portion of the course is focused on case studies to help participants gain a solid understanding of how economic factors (e.g., inflation, interest rates, incentives, debt/equity ratio, etc.) as well as uncertainty in the wind can influence the financial performance of a project. The course winds up by discussing trends in the wind energy market. Participants who complete this module will understand some of the complexities surrounding wind project economics as well as the sensitivity of economic projections to factors such as wind resource, inflation and energy price.

Topics include:

- Introduction
- Wind Market Position
- Project timelines: Evolution of money at risk, both pre and post COD
- Project costs: Pre-construction development costs, capital and operating costs
- Project revenue: Incentives, retail sales of energy, sale of project
- Project finance: Equity partners, commercial lending, self-funding
- Metrics of interest
- Case studies: Example cash-flow analyses, sensitivities to production, capital expenditures (CAPEX), etc.
- Special considerations: Variants, priorities, incentives, timing
- Impact of wind resource
- Impact of turbine technology
- Market trends

6 PILOT TRAINING EXPERIENCE

The scope of work for this project covered curriculum development but did not include budget for delivering training. However, over the course of developing the program several opportunities arose to test out elements of the curriculum. The list below highlights a number of pilot DNV KEMA trainings that incorporated elements of the Knowledge Boosting curriculum:

- A one-day in-house overview of onshore wind energy topics delivered to new DNV KEMA employees (Seattle)
- Two-day overview of onshore wind energy project development delivered to external clients interested in learning more about wind energy in an emerging market (Brazil)
- Two 2-week internal training sessions covering onshore and offshore wind energy topics (Seattle and Hamburg)
- A 3-day training on wind resource and energy assessment delivered to external clients interested in learning how to do their own energy assessments (Argentina)
- A 3-hour seminar of onshore wind project development and wind resource assessment delivered internally to a group evaluating Clean Development Mechanism (CDM) projects for the United Nations. This training used two-way high-definition video conferencing (Seattle to Oslo)

The trainings were both internal and external and each one provided valuable feedback that was then used to modify and improve the material and make it more relevant to participants. The pilot trainings varied in their content and intensity, and each served as an opportunity for the trainers to better understand which techniques proved to be the most successful for accelerated learning. In addition, the varied length and content of the trainings, which were adjusted to suit the focus and budget for each particular situation, highlight the flexibility of the format.

7 SUMMARY AND CONCLUSIONS

The growth of wind energy generation over the next few decades is projected to accelerate, even in spite of the recent economic challenges facing the world economies. As the use of wind energy grows the industry will demand more engineers, scientists, project managers, business people, and policymakers who are well versed in the unique aspects of wind generation technology and risk management. Many of these professionals, as well as recent graduates from general engineering, science or business programs, will need to pursue accelerated learning if they wish to move rapidly up the wind energy learning curve.

In response to a growing need to retrain professionals interested in moving into the wind industry, DNV KEMA developed curriculum for a series of Knowledge Boosting wind energy short courses. The curriculum covers the full range of onshore wind energy topics plus a few aspects of offshore wind energy. The curriculum covers six general topics related to wind energy and wind project development:

- M1: Introduction to Wind Energy
- M2: Wind Resource and Energy Assessment
- M3: Wind Turbine Systems and Components
- M4: Wind Turbine Installation, Integration and Operations
- M5: Wind Project Feasibility
- M6: Wind Project Economics

Pilot trainings conducted both internally and externally using elements of the Knowledge Boosting curriculum demonstrated the utility and flexibility of the program to address a variety of training needs, from 3-hour seminars to a two-week intensive training program. The feedback from participants was used to improve the curriculum. The final product is curriculum material in the form of Microsoft PowerPoint slides and accompanying guidelines that may be used in whole or in part by knowledgeable trainers as part of a wind training program for professionals looking to move into the wind industry.

8 RECOMMENDATIONS

The curriculum developed under this program focused on six specific topics related to wind project development. For the most part, the topics explored were related primarily to onshore wind turbines. This work could be expanded in several ways.

Suggestions for extensions of the current work

- Customize the curriculum for specific market sectors
- Expand the curriculum to include 1-day short-courses

- Develop online and/or video versions of each module

Suggestions for future curriculum development

- Develop an offshore module (3-day curriculum) that includes additional aspects of offshore issues including installation challenges, offshore construction, vessels, offshore foundations, project certification, and HSE
- Expand focus into other big markets besides the U.S. such as China, Europe, Brazil, India or Australia

9 REFERENCES

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2. 2011 Wind Technologies Market Report, U.S. Department of Energy, August 2012, Figure 41. (Available electronically at: http://www1.eere.energy.gov/wind/pdfs/2011_wind_technologies_market_report.pdf).

APPENDIX A

Wind Energy Knowledge Booster Curriculum Details

A detailed summary of the sub-topics and content included in each of the six curriculum modules is provided in Table A-1 through Table A-6.

Table A-1. Module 1: Introduction to Wind Energy

Module Number	Topics Include	Sub-topics	Content Description
M1.1	Introduction	**What are we doing?** **Introduce each other** **What will you get from this module?** **The big picture**	Overview of what we will be doing Have students get to know each other and instructor Basic understanding of wind industry, its history, the market and all phases of wind project development. What are we talking about? Origins and context of modern wind industry and current markets. Development of a hypothetical project to highlight all phases of development, and places where the other courses will provide more detail.
M1.2	History: How did we get here and why does it matter?	How did we get here and why does it matter? Evolution from vertical to horizontal, from drag to lift • Early wind turbines • Vertical and horizontal axis • Lift vs. drag – efficiency	• First use of wind energy: 10th-century Persia • Earliest: vertical axis (Persia, China) • First European windmill horizontal axis! • Lift replaces drag - so much more efficient. • American windmill • Windmills to wind turbines: 1888-1940
M1.3	History: Modern wind turbines - design overview	How and why? Modern wind turbines - design overview • Modern wind turbines • Design overview • Turbine technology overview	• Modern wind turbines • Some designs that did not pan out • The "Danish" model • The case for 3-bladed, upwind, tubular tower, VS
M1.4A	The Market: Overview	Overview of the U.S. wind industry; capacity, growth	Lecture focus: Big picture of wind energy market in

Module Number	Topics Include	Sub-topics	Content Description
	of the U.S. Wind Industry	rates, trends, 20% by 2030, differences among markets; utility-scale; community wind; mention small wind • Capacity in the U.S. • U.S. market growth rates • Trends • Market to achieve 20% by 2030 • Comparing different regions in the U.S.	U.S. - the trends over the last 10+ years, and why the rates of development vary so much (tax incentive history). Potential for wind; what will it take to reach 20%, etc. - give overviews. Main point: The industry is still in "prospecting" stage; still "greenfield" opportunities; but once wind resource areas are established they can be continuously redeveloped. Contrast with conventional energy that runs dry. Hands-on: Point out where to find additional background and details of market and trend info. Have them use the background data to determine potential market in a specific region of the U.S.
M1.4B	The Market: Overview of the Worldwide Wind Industry	Overview of the international wind industry; capacity, growth rates, differences among markets; utility-scale • Sources of good online resources • Capacity worldwide • International market growth rates • Trends • Policies/incentives around the globe • Comparing U.S. and foreign markets • Future direction	Big picture of global wind energy market - the trends over the last 10+ years, and why the rates of development vary so much (tax incentive history). Potential for wind; what will it take to reach 20% Main point: The industry is still in the "prospecting" stage; there are still "greenfield" opportunities; but once wind resource areas are established they can be continuously redeveloped. This is in contrast with conventional energy that can run out.
M1.5A	Where is the wind? Where are the wind projects?	Overview of wind maps – sources Overview of wind projects (public domain) Brief review of meteorology (wind resource analysis)	Discuss NREL wind maps Wind Powering America web site - animated map of wind power capacity from 1999-2011 AWEA has a map of wind energy projects by state

Module Number	Topics Include	Sub-topics	Content Description
M1.5B	What are the market drivers? What makes a good prospect for development?	What makes a good opportunity? • Market drivers • Policies that affect development • Policies that affect access to grid/market • Training/workforce development • Institutions (universities, government agencies, NREL, DOE)	Review of what factors are most important in driving the market forward
M1.6	Developing a project: Where do I begin? Prospecting and Site Control	Players involved: Developer, Landowners, Wind Consultants, Lawyers • Appropriate site: siting overview, sufficient resource, land issues • Does the developer have experience? Does he need expert assistance? • Brief review of feasibility	Introduce the role of each player. How do these players interact? At what point is each involved in a wind project? What must be considered at the outset of a project? This segment reviews project feasibility issues.
M1.7	Developing a project: How much energy can I produce? Wind resource and energy assessment Wind resource and energy assessment	Players involved: Developer, Consultants • Wind basics – variation in time and space, and wind characteristics • Brief review of wind resource and energy assessment	Introduce each new player by continuing the story of project development. In this segment, discuss prospecting measurement tower(s), data collection, and energy analysis that occurs during this phase of a project.
M1.8	Developing a project: Where can we place turbines? Environmental studies and permitting	Players: Developer, Government agencies, policy makers, Permitting agencies, Consultants, Public • Regulations overview • Environmental and community impacts • Carbon regulation	How do each of these players participate in the permitting and environmental studies phase of a project? What government agencies are involved, what information does the developer need to provide? Determining environmental, cultural and other restrictions.
M1.9	Developing a Project: Getting electricity to the grid. Transmission interconnection	Players: Developer, Utility agencies, Grid operators (transmission & grid integration) • Grid integration, transmission • Brief review of Turbine Integration and Operations	What does being “grid-connected” mean? What are some of the issues (technical, policy, etc.) involved in bringing wind energy to the grid?

Module Number	Topics Include	Sub-topics	Content Description
M1.10	Developing a Project: How do I select turbines? Contracts and procurement.	Players: Developer, Equipment suppliers (manufacturers), Lawyers, Due Diligence Consultants • Turbine technology overview • Available turbine models • Component suppliers • Brief overview of M3: Turbine Operation and Components	Overview of turbine technology and available models in the market today. Who are the major component suppliers? Brief overview of Turbine operation and components. Describes how a developer selects turbines, what sort of due-diligence they must carry out. Also, what is involved in a turbine supply agreement?
M1.11	Developing a Project: What is the plan? Engineering design	Players: Developer, Electrical and Civil Engineers, Wind Consultants • Engineering-Procurement-Construction (EPC) process • Project construction timeline • Turbine installation plan • Road building • Performance verification (power curve, noise and loads testing)	This segment presents what goes into the engineering design of the wind turbine site, including road building, grading and electrical infrastructure, as well as turbine staging areas, crane pads, substations, etc. Performance verification (testing) is also described.
M1.12	Developing a Project: Show me the $$! Financing	Players: Developer, Financial Institutions (banks), Investors, Due Diligence Consultants, Customers (power purchase agreements [PPA]/Offtake agreements) • PPA or spot market pricing • Tax appetite • Financial strength • Sufficient documentation	This segment covers many aspects of obtaining financing for developing a wind project, including identifying sources of investment or debt.
M1.13	Developing a Project: Keeping the project running. Operations and maintenance.	Players: Owner, Operator, Service Provider/Maintenance, Turbine Supplier, Consultants, Customers • Skilled O&M provider	
M1.14	The Bottom Line: Economics overview, key drivers, COE, comparison with other forms of generation. Simple COE model	Overview of project economics • General overview of what is in COE • Brief preview of M6: Energy Assessment • Key drivers: cost, energy, investment $$, incentives • PPAs/offtake • Comparison of wind COE with cost of other generation.	Compare wind COE with hydro, national gas, oil, coal, nuclear, etc.
M1.15	Heading Offshore: challenges and	• Added factors with offshore turbines • Advantages/disadvantages of offshore wind	Brief overview of offshore wind. Technical issues with offshore - foundation, wave loads, O&M, grid

Module Number	Topics Include	Sub-topics	Content Description
	potential	• Where are offshore opportunities in the U.S.? • Offshore activity in Europe	connections Where are offshore opportunities in the U.S.? Factors influencing offshore development both in the U.S. and in Europe.
M1.16	Closing	Q&A and summary	

Table A-2. Module 2: Wind Resource and Energy Assessment

Module Number	Topics Include	Subtopics	Content Description
1 - Characteristics of the Wind Resource			
M2.1	Introduction and Power in the wind	**What are we doing?**	The student will understand the wind resource as well as components involved in conducting an energy assessment, and be able to conduct a basic energy assessment (not a "bankable" EA). Student will be able to read and critique others' energy assessments.
		Introduce each other	Getting to know instructor and other students, Overview of what we will be doing. What can the information in this module be used for? What will you get from this module?
		What will you get from this module?	Accurately assessing wind resource and energy production are arguably most critical elements of a wind project. This module will help the student understand best practices for doing an EA.
		The big picture	Atmospheric processes, energy in the wind Useful concepts - pressure, temperature, ideal gas law, buoyancy, air density The big picture - solar energy drives winds, kW vs. human consumption. Large scale forces on wind: Pressure gradients, Coriolis force, surface friction, gradient wind, greater solar insolation at equator, atmospheric boundary layer (ABL) - height, characteristics
M2.2	Wind variation in time and space	• Temporal patterns: (Seasonal changes - global and local, solar insolation, temperature) • Stability, adiabatic lapse constant • Spatial effects: Local effects - terrain, flow separation, thermal effects, mountains, Drainage flows, land/sea breezes, complex terrain	Lecture: scales of temporal variation, scales of spatial variation, power density and wind power classes, case studies

Module Number	Topics Include	Subtopics	Content Description
		• Useful concepts - power, energy, KE, power in moving fluids • Power density & Wind power classes • Raw harvestable global and national wind resource vs. Net wind resource (with land use, etc. constraints)	
M2.3	Wind speed and direction	• Average wind speed (Long-term mean, annual mean, 1-hour/10-minute mean) • Wind speed distribution – histograms, Rayleigh and Weibull distributions • Temporal patterns - Van der Hoven spectrum • Daily, monthly, annual and interannual variability • Consequences of wind speeds on wind turbines - power, lower limiting, cut-in, cut-out • Wind direction: Measuring wind direction, wind roses, Wind direction sectors • Consequences of direction changes for wind turbines - yaw adjustments, turbine spacing, wake losses (mention), direction sector management, different conditions in different direction sectors	Lecture: Wind speed and direction Hands on: use public wind data from tall-tower measurements. Compare histogram with Weibull dist. using derived parameters., derive a wind rose and interpret
M2.4	Shear and turbulence	• Shear – cause, stability effects • Characterizing shear - Power law and log law shear models, Applicability of shear models • Turbulence - causes and effects, including stability effects • Characterizing turbulence - fluctuating wind component, turbulent length scale, TI (mean, speed distribution, Iref) • Consequences of shear and turbulence on wind turbines - turbine loading, hub height WS, fatigue, control actions	Lecture: Examine wind shear and turbulence including what causes them, stability effects, and how each is characterized mathematically. Discuss the consequences of shear and turbulence on energy production and turbine loading. Hands on: Calculate shear from 30m and 60m wind data; predict 80m wind and compare with measured data
M2.5	Site conditions and suitability	• Site suitability assessments • IEC Standard 61400-1; IEC design class • Site conditions, turbine layout and sector management	Lecture: What is a site-suitability assessment and what are the key wind characteristics of importance in turbine design and suitability studies? What is an IEC design class? How do site conditions impact turbine selection and layout design?
2 - Measurement of the wind resource			

Module Number	Topics Include	Subtopics	Content Description
M2.6	Wind measurements	• Wind maps, including how generated and associated uncertainties (modeling uncertainties, spatial resolution, scaling based on local data) • Examples: Available wind resource in the U.S. and other countries • Technologies - towers, remote sensing • Characteristics: Measurement biases and uncertainties, Sensor reliability	Lecture: Intro - how do we assess the wind resource? Begin with wind maps, turn then to measurement campaigns Hands on: Examine NREL wind maps ,show sensor examples with logger; web sites to see wind turbine web site data
M2.7	Wind data collection and validation	• Sensors • Loggers • Data Validation - tower data • Data Validation - remote sensing • Sources of errors: Icing, sensor/logger failure, bearing friction + vibration, Tower shadow	Lecture: Hands on: Validate some data - look for tower effects, malfunctioning data, tower icing. Validate some data that has problems; try to identify when problem occurred and what it is.
M2.8	Wind Summary at Measurement Locations	• Same period of record • Steps involved in Measure-Correlate-Predict • Obtaining hub-height frequency distributions or time series • Getting the most out of limited data records	Lecture: Why bring all met towers to the same period of record? What are the steps involved in MCP? Translating from a mast-height frequency distribution or time series to a hub-height frequency distribution or time series. Working with limited data sets (one year of data or less).
M2.9	Long-term adjustments	• Purpose of long-term adjustments and data types • To adjust or not to adjust? • Calculating statistics • Methods of making LT adjustments	Lecture: Why would you make a long-term adjustment? What are some data sources for making an adjustment? What are the major risks and considerations in making an adjustment, and how can these be managed? Why would you not make a long-term adjustment, and what would be the consequence? Hands on: Screen reference data set to determine if it is good enough quality to use for making a long-term adjustment. Select a method and calculate a long-term adjustment.
M2.10	Wind flow basics	• Calculating wind flow • Examples of wind flow software • Combining outputs from multiple met towers	Lecture: Review of wind flow Examples of wind flow software (WindFarm, Jack Kline models, WAsP (from RISØ), others?)

Module Number	Topics Include	Subtopics	Content Description
			Terrain effects: estimating wind at turbine sites and wind flow basics: wind flow modeling and other techniques for determining site-specific wind resource.
3 - Estimating energy resource from the wind/Converting wind to energy			
M2.11	Wind to energy conversion	• Sensitivity of power to wind speed • Converting wind to power: efficiency (Betz limit) • Power curve (energy) • Mechanical and electrical losses at the turbine • Calculating site air density • Adjusting power curves for air density (if density-adjusted PC's not available), • Applying wind speed to energy relationships • Calculating 12x24s and related time series • What does a real power curve look like? How much scatter is plausible?	Lecture: Intro: Given measurements of the wind resource, how do we convert them to energy estimates? Wind Power basics: power conversion efficiency, power curve including density adjustments to power curve and energy calculations, Betz limit. Wind Energy basics: AEP calculation, 12x24s Hands on: Worksheet to calculate gross energy from a power curve and frequency distribution
M2.12	Wake effect basics	• What are turbine wakes? • Calculating wakes • Using wake calculations to adjust energy predictions • Iterating on turbine layout - to minimize wake losses	Lecture: Calculating wake effects on other turbines in a wind farm; difficulty in validating wake models; using wakes to adjust energy predictions Hands-on Excel worksheet
M2.13	Losses and uncertainties	• Loss categories: availability, wake effects, turbine performance, electrical losses, environmental losses, curtailment • What are P50, P90, etc.? • Sources of uncertainty: site-wide wind speed estimates, turbine availability, electrical losses, topographic and other effects • Most effective strategy for reducing uncertainties	Lecture: Review of the many sources of losses and uncertainties in the energy estimate (remember site suitability and sector management); review of the many sources of variability in the energy estimate. Hands-on: Apply losses to energy estimates from previous lessons (worksheet)
M2.14	Developing an	• How to verify that a turbine is suitable for a site. • What does a good wind measurement campaign look like?	Lecture: Is the energy assessment good? Assess the turbine design and site parameters to check for

Module Number	Topics Include	Subtopics	Content Description
	Energy Assessment	• Overview of the energy analysis work • Application of losses and uncertainties	site suitability. Review the content and procedure of the wind resource measurements and validation. Describe uncertainty analysis and how that relates to energy. Hands-on: Worksheet (Excel) to explore different scenarios.
M2.15	Closing	Closing FAQs and summary – tie back to project economics	

Table A-3. Module 3: Wind Turbine Systems and Components

Module Number	Topics Include	Sub-topics	Content Description
M3.1	Introduction	**What are we doing?** **Introduce each other** **What will you get from this module?** **The big picture**	Overview of what we will be doing. Have students get to know each other and instructor How can the information in this module be used? Due-diligence report contents, turbine selection, site suitability, understanding turbine spec sheets. Basic horizontal axis turbine topology, turbine size, and components. Power from a constant or variable speed rotor is transformed to constant frequency power.
M3.2	Power in the wind and basic rotor concepts	Power in the wind • Energy, power, units of measurement • Power in the wind • Rated power • Mechanical(rotational) power Power curves, Cp • Power curves • Power coefficient Rotor and airfoils concepts • Lift and drag coefficients • Tip speed ratio Betz limit • Factors which reduce Cp below theoretical limit Constant speed vs. variable speed	Lecture: Discuss power in the wind, definition and characteristics of the power curve, basic rotor aerodynamics (lift and drag), the Betz limit and optimal blade shape Hands-on: Calculate Cp of modern wind turbines, Betz blade shape spreadsheet
M3.3	Wind Turbine Blades	Blade sizes and properties Blade shapes and airfoil choices	Lecture: From blade design to manufacturing and transporting; Operating loads on wind turbine

Module Number	Topics Include	Sub-topics	Content Description
		Blade construction and materials Blade operating loads Blade standards and testing Manufacturers Costs	blades; Blade standards and testing; Major blade manufacturers and blade cost. Hands-on: Research blade manufacturers online.
M3.4	Gearboxes and Mechanical Systems	Drive train configurations Drive train components Gearboxes Gear ratio, types, fluid drives, issues, cooling system, lubrication system	Lecture: Discuss different types of drive train configurations and their advantages and disadvantages. Review manufacturer's descriptions of drive train components. Overview of gearbox designs and issues.
M3.5	Wind Turbine Electrical Systems	Electrical power Electrical power, energy, force, units Electrical basics (DC, 3-phase AC, VAr) Generators Types of generators: induction, synchronous, doubly-fed induction, permanent magnet, cooling systems, efficiency, power factor (PF) Converters Transformers	Electrical power, energy, force, units Electrical basics (DC, 3-phase AC, VAr) Types of generators: induction, synchronous, doubly-fed permanent magnet, cooling systems, efficiency, PF Understanding turbine electrical specifications and advantages/disadvantages of the generator/converter choices made by a manufacturer
M3.6	Towers, BOP and Control	Tower and foundation Yaw system components Control System Turbine Operation	Tower (size, weight, materials) Foundation (typical designs, materials) Yaw gear, yaw drive motors Controller (role of controllers, SCADA (supervisory) vs. dynamic controllers, pitch, torque, yaw control) Power limiting Stall regulation Pitch regulation

Module Number	Topics Include	Sub-topics	Content Description
			Constant speed operation Variable speed operation
M3.7	Turbine models	Design choices Rotor speed, pitch, number and type of generators, others Historical view Current examples of turbine models Multiple generators, optislip, others	Lecture: Explain pitch and stall-regulated wind turbines, and the required features of variable speed wind turbines. Review current turbine manufacturers and describe the range of turbine models in the market place. Also show where up-to-date information on turbines can be found online.
M3.8	Turbine dynamics and fatigue	Vibration: basics, natural frequency, mode shapes; tower, blade and drive train natural frequencies Inputs: turbulence, rotational sampling, cyclic loads: shear, imbalance Dynamic responses: gyroscopic loads, dynamic responses Consequences: Material fatigue, rain flow counting	Lecture: Explain what natural frequencies are and describe three sources of excitation of turbine component vibrations. Describe what a Campbell diagram is, and how component fatigue life is evaluated. Describe some of the consequences of turbine vibrations
M3.9	Wind Turbine design standards and testing	Type certification, project certification Requirements of design safety standards Other standards: power curve testing, noise testing, loads testing Blade testing	Lecture: Summarize the different categories of type and project certification. Explain the major design basis considerations in the certification process. Discuss the safety standards that govern U.S. wind project development. Describe the important steps in a power performance test, or a static or fatigue blade test.
M3.10	Operation and Maintenance	Common wind turbine failure modes Difference between preventative and reactive maintenance Explain “asset management” and “condition monitoring” Describe details of condition monitoring systems	Lecture: Describe wind turbine failure modes seen in the field today. Summarize the differences between preventive and reactive maintenance. Hands on: Have students pair up and discuss the distinction between “asset management” and “condition monitoring”.
M3.11	Technology Advances	Advanced generators and drive trains Advanced rotor blades and aerodynamic controls	Lecture: Some advances in wind turbine technology are presented here, including the difference between a direct drive permanent

Module Number	Topics Include	Sub-topics	Content Description
		Evaluating and comparing different technologies	magnet generator and a superconducting generator, passive and active aerodynamic devices, bend-twist coupling and smart rotor technologies. Hands on: Have students develop a proposal for applying new technologies
M3.12	Closing	Q&A and Summary	

Table A-4. Module 4: Wind Turbine Installation, Integration, and Operation

Module Number	Topics Include	Sub-topics	Content Details
M4.1	Introduction	Getting to know instructor and other students Overview of what we will be doing. How can the information in this module be used?	Overview of what we will be doing. Have students get to know each other and instructor. How can the information in this module be used? Due-diligence report contents, turbine selection, site suitability, understanding turbine spec sheets.
M4.2	Wind Farm Siting and Design	Main considerations for siting a project Micro siting Airspace, environmental and cultural siting constraints Difference between power and energy Effect of terrain on wind speed	Lecture: Discuss main issues for siting wind turbines from the perspective of structural integrity and ease-of-maintenance. What is micro siting? What is the difference between power and energy? What effect does terrain have on wind speed?
M4.3	Turbines for Wind Farms	Main components of a wind turbine IEC classes for wind turbines Selecting a turbine for a project Differences among turbine designs	Lecture: Describe the main components of a wind turbine, and what is different about the different IEC class designations. Explain how turbine manufacturers determine which turbine is suitable for a given site. Hands on: Turbines in North American projects; Explore manufacturer's brochures
M4.4	Construction of Wind Farms	Planning construction of a wind project Constructing a wind project Equipment needed for wind project construction Review of foundation designs	Lecture: What are the most important steps to consider when planning and constructing a wind project? What types and sizes of equipment will be needed? What factors must be considered in the design of the foundation? Hands on: Select a turbine model for your project and calculate staging area needed for construction. Write down all your assumptions and present to the class.
M4.5	Operation and maintenance	Monitoring operation - SCADA systems Common failure modes for wind turbines	Lecture: Describe SCADA system and other systems used for monitoring wind turbine

Module Number	Topics Include	Sub-topics	Content Details
		Maintenance O&M costs	operation. Discuss common wind turbine failure modes. Describe the difference between preventive and reactive maintenance. Explain “asset management” and “condition monitoring”. Describe details of condition monitoring systems. Hands on: Asset Management System
M4.6	Electricity and grid operation	Overview of the electrical grid Basic grid operation 3-phase AC power High-voltage DC power transmission Grid control areas - what are they?	Lecture: Explain the basic operation of the grid and the various grid control areas. Also explain 3-phase AC power and DC power transmission. Hands on: Power, energy, current, voltage exercise.
M4.7	Connecting to the Grid	Explain the technical requirements for interconnection of a wind farm What is low-voltage ride-through? Basic components in the wind farm electrical collection system and grid interconnection	Lecture: Discuss three technical requirements for interconnection of a wind farm. Explain that most grid operators insist on LVRT capability for grid conditioning. Hands on: Power quality and connecting to the grid
M4.8	Offshore wind farms	Overview Components of an offshore wind project Types of offshore foundations Challenges going offshore Construction of offshore wind projects	Lecture: Describe the main components of an offshore wind project, including offshore foundation technology. Explain some of the challenges offshore wind projects face during both development and operation. Describe the main steps in constructing an offshore wind farm. Hands on: Offshore challenges group exercise.
M4.9	Closing	Q&A and summary	

Table A-5. Module 5: Introduction to Project Feasibility

Module Number	Topics Include	Sub-topics	Content Description
M5.1	Introduction	**What are we doing?** Overview of what we will be doing. **Introduce each other** Have students get to know each other and instructor **What will you get from this module?** The student will know what a site assessment includes – what kind and quality of information is required to evaluate a site.	Lecture: Introduce "Strong Winds Mountain" case study which will be used in exercises throughout this module. Hands on: Various exercises and activities throughout this module.
M5.2	Siting overview-issues to consider when evaluating site feasibility	• Indications of wind resource • Compatibility: Federal Aviation Administration, communications, environment, public acceptance • Land/Terrain: ownership, accessibility, constructability • Transmission: distance, voltage, capacity, availability • Electrical Market: RPS, market structure, pricing	Lecture: Summarize siting considerations and what makes or breaks a wind project. Hands on: Critical thinking - assessing industry needs
M5.3	Local wind speed data: estimating uncertainty	• Various sources of wind data; different levels of quality/accuracy • Estimating the uncertainty of different sources of wind data: wind maps, nearby met towers, local met tower, less than 1-year of data, multiple met towers, multiple years of data	Lecture: Sources of wind data and their associated uncertainty Hands on: Estimating wind resource and uncertainty from a wind map
M5.4	Setback requirements	• Why we have setbacks • How setbacks are defined: maximum tip height (MTH) • Features that warrant a setback • Purpose of setbacks (safety) • Where to look for setback regulations	Lecture: Discuss where to look for setbacks, examples of setback regulations. Hands On: Calculating MTH, brainstorming what requires setbacks and why, researching setback regulations
M5.5	Environmental & cultural issues	• Wetlands • Endangered species, birds, bats, etc. • Permitting	Lecture: Discuss the major environmental restrictions on wind development, and where the most recent are updates found. Finding GIS map layers of environmental exclusions and sensitive areas, and how to make use of them. Hands on: Go to EPA or Audubon or RETI site to see shape files, if available.

Module Number	Topics Include	Sub-topics	Content Description
M5.6	Airspace issues and conflicts	• NEXRAD (weather radar) • FAA obstruction process and online • Tools • Telecommunication conflicts (electro-magnetic, line of sight)	Lecture: Discuss impact turbines can have on airspace, how to evaluate and how to mitigate. Hands on: Visit AirNav; DoD screening tool, etc.
M5.7	Turbine layouts	• Preliminary turbine layouts • Setback requirements/exclusion zones • Wind rose • Turbine spacing • Terrain/constructability	Lecture: Discuss why layouts are needed (met tower siting), establishing exclusions, applying wind direction, examining terrain for constructability Hands-on: Google Earth mapping exercise
M5.8	Measurement tower siting	• Wind monitoring • Zoning/permitting • Met tower placement • Number of towers/MW - general guide	Lecture: What to consider when designing measurement campaign and why to perform a site visit. Hands on: Google Earth mapping exercise
M5.9	Community Impacts	• Visual effects • Cultural and historic sites • Subjective sound impacts - noise perception and annoyance	Lecture: Review community impacts; how these are determined; how visual simulations are used. Hands on: Case study (provide sample results for a generic site, and have students determine whether turbines must be moved/removed)
M5.10	Sound basics	• Sound power vs. sound pressure • Decibels and A-weighting • Propagation/attenuation • Noise regulations • Noise assessments	Lecture: Discuss sound basics, how it is regulated, how noise assessments are performed. Hands on: adding decibels, you tube videos with turbine noise, researching regulations
M5.11	Shadow flicker	• What is shadow flicker from wind turbines? • Frequency? When does it occur? • How to predict? • Software tools: WindFarm, Wind Pro	Lecture: Review shadow flicker; what is it, what influences it, how it is determined. Hands on: you tube video with shadow flicker.
M5.12	Transportation/site access	• Levels of detail in feasibility - when to use • Modes of transport - advantages/disadvantages • How to determine height/length restrictions on transport routes	Lecture: Overview of component sizes for transport; methods of transport (roads, train, boat); road/highway restrictions - how to determine site construction maps with transportation plans,

Module Number	Topics Include	Sub-topics	Content Description
		• Staging for turbine erection	estimating required staging area for turbine erection Hands on: you tube video
M5.13	Foundation design - soil issues	• Geotechnical issues • Bore samples - geologic surveys • Types of foundations for different soil types • Foundation stiffness - structural dynamics	Lecture: Brief overview of geotech - bore samples, soil types Brief overview of foundation types; discuss foundation stiffness and its influence on turbine dynamics
M5.14	Preliminary energy estimates	• Wind frequency distribution • Turbine power curves • Energy losses • Capacity Factor	Lecture: Binning time series of wind data to get wind histogram; Review turbine power curves; calculating energy; applying losses. Hands on: Excel worksheet to calculate energy
M5.15	Economics - plant costs, O&M, COE, analysis methods	• Capital costs - turbine hardware • BOP costs • O&M costs • Incentives - where to find latest info • COE • Pro Forma	Lecture: Covers the basics of wind energy economics: sources of capital investment (equity investors or debt investors), sources of revenue and energy production and Patty Paul Hands on: develop generic COE model in excel
M5.16	GIS methods	• What is GIS? • Uses of GIS • General GIS tools/ mapping tools • Sources of GIS data	Lecture: Discuss how GIS mapping tools are used to assist in a feasibility study. Hands on: Google Earth, viewing various layers
	Closing	Q&A and summary	

Table A-6. Module 6: Wind Project Economics

Module Number	Topics Include	Sub-topics	Content Description
How money flows into and out of an individual project			
M6.1	Introduction	**What are we doing?** **Introduce each other**	Overview of what we will be doing. Have students get to know each other and instructor

Module Number	Topics Include	Sub-topics	Content Description
		What will you get from this module? **The big picture**	Basic understanding of wind project economics What are we talking about? Review of market conditions and policy, all aspects of project economics including capital and operational costs, sources of revenue, financing, metrics of interest, and how to model financial performance over the life of a project. Will examine the impact of major economic drivers: market conditions, policy, wind resource, technology, and costs.
M6.2	Wind market position	1. Comparison with other methods of generation 2. Policy affecting wind energy	1. Comparison with other methods of generation a. Where does wind sit in the energy marketplace? b. How do different generation methods compare in price? How does national gas pricing affect wind development? i. National gas volatility risk ii. Carbon risk for fossil fuels c. Differences in when money is spent: i. All up front - typical of wind and other renewable projects ii. Higher ongoing costs - typical of "fuel based" projects, where upfront costs are lower d. Environmental impacts (land and water use) e. Dispatchability - firm or non-firm resource i. different value to utility or grid operator ii. firming and shaping costs for wind 2. Policy associated with wind energy generation Incentives (PTC, REC, FIT) Environmental regulation Curtailment
M6.3	Project Timeline	Evolution of money at risk What happens as a project "matures" towards COD? What happens beyond COD?	Lecture: Project timeline must begin with assessing RISK. Why? Understanding and mitigating risk can make or break a project. This must be considered. Discuss the decrease in reward on capital as project progresses and

Module Number	Topics Include	Sub-topics	Content Description
			risks are "put to bed" (that is, for projects that survive…) Review things that happen between Point A (estimated NPF at early development stage) and Point B (NPV derived before major construction starts -- the big investment decision).
M6.4	Project Costs	What kinds of costs are incurred in a wind project and when? • Pre-construction development costs • Capital costs • Operating costs • Onshore/Offshore comparison • Trends in these costs over time (COE, changes in DSCR) • Brief comparison to other forms of generation	Lecture: Discuss pre-construction development costs such as land surveying and lease options, grid access costs, insurance/legal, WRA, EA, TSA deposits. Discuss what capital costs include and what percentage of overall COE is capital cost. Discuss which costs are fixed at COD and which vary. Compare onshore and offshore costs. Explore trends in these costs over time.
M6.5	Project Revenue	How does a project make money? • Revenues to the project • Revenues to other parties	Lecture: Discuss sources of revenues to the project such as PPAs, and market pricing (including FIT), federal incentives such as PTC, ITC and cash grant, state and local incentives (including FIT), the voluntary carbon market, RECs, retail sales (for utilities), and sale of an entire project. Discuss revenues to other parties (costs to the project) such as land owners, tax revenue, transmission providers, insurance/ legal/ consultants.
Methods and considerations in economic analysis			
M6.6	Sources of financing	What to do when you do not have the capital needed to build a project? • Equity partners (regular and tax) • Commercial lending (DOE Loan guarantee, project level or portfolio debt) • CREBS • Self-funding	Equity partners (regular and tax) Regular equity "Tax" equity Commercial lending (DOE loan guarantee, project level or portfolio debt) DOE loan guarantee program Project-level or portfolio debt Clean Renewable Energy Bonds (CREBs) Self-funding

Module Number	Topics Include	Sub-topics	Content Description
M6.7	Metrics of Interest and Basic Economic Analysis	Finance Speak 101 • Financial terms defined • Economics overview • Simple economic analysis • Levelized cost of energy (LCOE)	Lecture: Define various economic terms, pointing out purpose of each: Nameplate vs. expected production, net capacity factor (NCF), cost of energy (COE), Specific power, debt service coverage ratio (DSCR), net present value (NPV), Risk-adjusted internal rate of return (IRR). Discuss difference between cost of energy and value of energy. Hands on: Exercise - Levelized cost of energy
M6.8	Case Studies	What is a pro forma? What is IN a pro forma? Example pro forma Key performance drivers	Lecture: Discuss the concept of a pro forma - a method of calculating financial results to evaluate projected figures. Review inputs to the pro forma, pro forma models, and outputs. Present an example pro forma and discuss how the class will use it for several case studies. Finally, review four key performance drivers: capital cost, energy/PPA price, energy production, O&M costs Hands on: Analyze several example situations using a Pro Forma to assess economic impact. How much variation in production and O&M costs can your project withstand, especially in early years? Revisit key performance drivers: production, energy price, capital costs, O&M costs (which of these costs become fixed over time as we move towards COD?)
Connecting to earlier modules			
M6.9	Impact of wind resource and turbine technology	How sensitive are project economics to variations in wind resource? How are project economics affected by changes in project parameters? What influence does turbine technology and turbine operation have on project economics?	Run sensitivity cases using the sample pro forma • Low production scenarios (P99 vs. P50) • Inaccurate EA scenarios (incorrect P99 and P50s) • Impact of terrain on turbine layouts / project costs / wind energy economics Run sensitivity cases and discuss impacts of: • Siting • Turbine size

Module Number	Topics Include	Sub-topics	Content Description
			• Spacing • Terrain complexity Run sensitivity cases and discuss impacts of • Serial failures • Variation in O&M costs • Maintenance strategy • Choices among turbines
M6.10	Special considerations and market trends	Variants of developing and operating a wind project Technology trends Financing trends Other trends	Variants of developing and operating a wind project • When else is a project sold or bought? • Differences in priorities (e.g. utilities vs. IPPs) • Deciding among incentives • How to optimize among options for project scale and timing? • Impact of scale/maturity/"pocket depth" of organization on perspective Technology trends • - BRIEF summary of emerging technologies • - potential of emerging technologies to impact COE • Financing trends • Evaluation of trends' impacts on production, capital costs, operating costs, and revenue. • Other trends • Utility competition with independent power producers (IPPs) and pure play developers
M6.11	Closing	Q&A and summary	

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