

PROJECT DESCRIPTION

1. List of Participants

Name	Role	Dept./Univ.	IGERT Thrust	Specific Expertise	prv. igit?
Erin Baker	PI	MIE/UMA	Eng & SER	OR/Econ/Energy Technology Policy	
Curtice Griffin	Co-PI	ECO/UMA	Env	Wildlife Ecology/Birds	
Elisabeth Hamin	Co-PI	LARP/UMA	SER	Regional Planning & Policy	
Francis Juanes	Co-PI	ECO/UMA	Env	Fisheries Ecology	
Jon McGowan	Co-PI	MIE/UMA	Eng	Mechanical Engineering/Wind	
Geoffrey Allen	Faculty	Res. Econ, UMA	SER	Resource Economics	
Sanjay Arwade	Faculty	CEE/UMA	Eng	Civil Engineering/Structures	
Donald Degroot	Faculty	CEE/UMA	Eng	Civil Engineering/Soil	
Elizabeth Dumont	Faculty	Biology/UMA	Env	Biology/Bats	
Donald Fisher	Faculty	MIE/UMA	SER	Psychology	
Stephen Frasier	Faculty	ECE/UMA	Eng	Electrical Engineering/Radar	
Matthew Lackner	Faculty	MIE/UMA	Eng	Mechanical Engineering/Wind	
James Manwell	Faculty	MIE/UMA	Eng	Mechanical Engineering/Wind	
Yahya Modarres-Sadeghi	Faculty	MIE/UMA	Eng	ME/Fluid Structure Interaction	
Timothy Randhir	Faculty	ECO/UMA	SER & Env	Ecological Econ and Policy	
Henry Renski	Faculty	LARP/UMA	SER	Regional Planning/Economics	
Robert Ryan	Faculty	LARP/UMA	SER	Landscape Architecture	
James Boyce	Faculty	Econ/UMA	SER	Policy/Economics/Environmental Justice	
Jan Servases	Faculty	Comm/UMA	SER	Communications/Policy	
Paul Sievert	Faculty	ECO/UMA	Env	Conservation Biology	

CEE=Civil & Environmental Eng.; Comm = Communications; ECE=Electrical & Computer Eng.; ECO= Environmental Conservation; LARP=Landscape Architecture & Regional Planning; MIE=Mechanical & Industrial Eng.; OR=Operations Research; SER=Social, Economic, Regulatory Policy; UMA=UMass Amherst

International Participants

Name	Role	Dept./Univ.	IGERT Thrust	Specific Expertise	Country
Gijs van Kuik	Intl	Tech. Univ. of Delft	All	Mechanical Engineering/Wind	The Netherlands
Farrokh Nadim	Intl	Norwegian Geotech Inst	All	Civil Engineering/Geotechnical	Norway

2. Vision, Goals, and Thematic Basis

Wind energy is now in the forefront of national energy policy, both politically and in research funding opportunities. It is the only renewable energy source that is cost competitive with traditional sources like gas, coal, oil, and nuclear. As a result, over the past decade wind has become the fastest growing energy source in the world. Installed capacity in the U.S. has increased from 2.5 GW in 2000 to over 35 GW in 2009. Despite these gains, significant advances are essential to achieving the national goal of generating 20% of the total electricity from wind by 2030 (U.S. Department of Energy, 2008). Unlike in Europe, U.S. wind generation currently comes exclusively from onshore resources, despite the fact that offshore wind energy offers large continuous areas suitable for major installations, proximity to major load centers, higher quality winds and wind speeds, and lower turbulence. The National Renewable Energy Laboratory

(NREL) estimates that winds offshore of the United States within 50 nautical miles of the coast have the potential to generate an average power of approximately 1,000 GW (Musial, 2007), compared to the average electricity consumption of the United States, which was 436 GW in 2005 (U.S. Energy Information Administration, 2006). The offshore wind resource is also located near major population centers, including the Northeast, the Gulf coast, the Great Lakes, and the West coast.

Wind energy technology has advanced significantly over the last thirty years, to the point where it is often cost competitive with electricity from conventional sources. The cost of energy from land based wind turbines has dropped from about \$0.50/kWh in the 1970's to approximately 1/10th that today, depending on site conditions (Wiser & Bolinger, 2008). With only 1% of the electricity in the U.S. provided by wind energy and no offshore wind farms in operation, there remains tremendous opportunity for growth.

The challenges of increasing wind energy market penetration are complex, and involve technological, environmental, and policy/regulatory issues. Experience with proposed offshore wind farms in the U.S. to date demonstrates that environmental and policy issues are just as important as solving the engineering challenges. The decade-long delay of the proposed Cape Wind project in Massachusetts, the first offshore wind project proposed in the U.S., underscores the critical need for an integrated, cohesive, multidisciplinary approach to offshore wind energy development that achieves technical excellence while reaching out to the public early in the process. Multidisciplinary communication among experts, and from experts to and from the public is an essential, but currently under-researched, component of the design and approval process. We believe that a better understanding of technological and environmental constraints as well as public concerns will enable wind farm designs that have a greater likelihood of successful approval and construction (see text box on Lobster to the right for an example).

We propose an IGERT that will train the next generation of researchers to take on these challenges. This IGERT will create a coherent community of researchers who will understand the technological challenges, the environmental implications, and the social/economic/regulatory (SER) challenges, and be willing to work with stakeholders in an environment of participatory communication, encouraging equity as well as increasing approval. This will allow the trainees to design wind energy systems that better address the environmental and SER challenges; to design policies and regulations that enable wind energy technology and development while addressing legitimate public concerns; and to help bridge communication gaps between different stakeholder groups and the academy. In the standard process for wind farm development traditional "silos" of expertise are integrated at a late stage, and public engagement is limited and late. This late engagement can create a high-risk situation, where early feedback is not received from multiple disciplines and the public, and so there is more uncertainty at the time of review and permitting. In contrast, in our IGERT method the innovative multidisciplinary process provides more feedback opportunities, and so reduces uncertainty for all stakeholders. Currently, there is no graduate program in wind energy, or even in renewable energy, at any university in the U.S. that is giving students the set of skills that they need to solve such complex technological, environmental, social, and regulatory problems.

The University of Massachusetts Amherst (UMass Amherst) is home to the Wind Energy Center (WEC), founded in 1972, and recognized nationally and internationally as a leader in wind energy education and research. Its faculty authored the well known text book *Wind Energy Explained* (Manwell, McGowan, & Rogers, 2002), and currently teach two wind energy courses, with a third course under development. The WEC boasts over 200 graduates, and a long track record of cutting edge research. The WEC faculty have also been leaders in working with local governments to actually get wind turbines

Lobster, lobstermen, and wind farms

In offshore wind farms, environmental assessment, engineering, and public support are interdependent. For example, offshore wind turbines have the potential to create artificial reef environments, which could improve habitat for fish and lobsters. Lobstermen and fisherpeople from New England who know that a project will improve their livelihoods are more likely to become supporters of offshore wind farms even if large landowners oppose such an installation. But research is needed into the criteria a turbine must meet to serve as an effective artificial reef, how that changes the engineering specifications, and whether and how this will really make a difference to residents. These sorts of interacting, complex phenomena require the transformative training and research this IGERT proposes.

installed and in overcoming the significant technical, environmental, social, and regulatory barriers. Recently, the WEC was involved in a site visit for an NSF Engineering Research Center (ERC), as part of a team led by the University of Houston. This team is aggressively pursuing the ERC, and tremendous opportunities for synergies between the ERC and this IGERT exists. The goals of the ERC are similar to ours – to integrate engineering, environmental science, and policy. However, the ERC is focusing primarily on research and primarily on cross-university integration. Our IGERT is focused on training and on a cross-disciplinary integration within a single university. Thus, the IGERT students will benefit from the research going on across the ERC, and the ERC will benefit by having our IGERT as a model of an integrative educational program. Also, the WEC is in the process of submitting a full proposal for an NSF Industry/University Cooperative Research Center (I/UCRC). Combined with the ERC industrial partnership program, these two programs offer outstanding opportunities for internships and interaction with industry for our trainees. We plan to leverage these complementary programs to further develop our leadership in research and teaching in wind energy.

The overarching goal of this IGERT is to educate a new generation of researchers able to integrate engineering, environmental science, and social science to better position the U.S. in global competitiveness in wind energy. Specifically the overall program goals are to:

1. Encourage and motivate students, particularly those from underrepresented groups, to pursue research careers in renewable energy.
2. Create an environment in which students and faculty engage in transformative interdisciplinary research.
3. Provide students with a curriculum that achieves both deep knowledge in their chosen field and inter-disciplinary knowledge across fields related to wind energy including exposure to state-of-the-art topics through an innovative real-time case study (on a proposed wind installation in Hull, MA), international exchanges, and training in participatory communication.
4. Provide students with skills and strategies for professional success including mentoring and activities centered on career guidance and ethics.

UMass Amherst supports minority student recruiting and retention through the NSF-funded Northeast Alliance for Graduate Education and the Professoriate (NEAGEP), a program initiated nine years ago, co-lead by **Fisher** and participated in by PI **Baker**. IGERT-associated faculty and students will collaborate with NEAGEP and take advantage of well-established relationships with minority-serving institutions to recruit top minority and majority students working in engineering, environmental science, and SER disciplines. We aim to mirror the NEAGEP program's increases in minority applicants (71%) and enrollees (171%) over the past four years, for students working on wind energy research. NEAGEP's letter of support (included as a supplemental document) further details this collaboration.

Our proposed program distinguishes itself in multiple ways: **a novel unifying real-time case study that all students will participate in; application of studio pedagogy to SER, engineering, and environment teaching; association with the WEC and exposure to its industrial partners; strong institutional commitment; international and national exchange opportunities at top research institutions; a focus on participatory communication; and dedication to underrepresented student populations**, as described throughout the proposal.

3. Education and Training

The proposed doctoral program will financially support students for 2-3 years, starting in their first or second year, although students will participate in a range of activities throughout their academic career. The UMass Amherst Graduate School will provide an additional year of support for SER students in their third or fourth year, as described in the letter of support attached, while students from Engineering and Environmental Sciences will be supported by their departments or other outside funding. Students will obtain degrees from one of the 9 departments listed in Section 1. They will be supervised by the IGERT faculty, with additional faculty joining as appropriate. The Doctoral program will be administered by the WEC, but students are granted their degrees from their home department. The pedagogical goals of the training program are:

- A. Core competency in wind power engineering and its environmental and societal impacts
- B. In-depth knowledge in individual field of study.
- C. Promoting creativity within a multidisciplinary and international research environment.

- D. Ability to engage in effective two-way communication across disciplines and with a wide range of stakeholders.
- E. Professional skill development including an appreciation for the ethical nature of scientific research, particularly in relation to renewable energy and its impacts.

To achieve these goals, we will develop several innovative pedagogic approaches, as well as follow well-proven routes. Innovative aspects include: integration of a real-time case study across multiple classes; an interdisciplinary studio in which teams of IGERT and other students will address a community need; and ladder-mentoring. Equally important are well-established modes: a weekly seminar series, international travel, internships, and rigorous course work both in their home disciplines and in IGERT-focused classes. These are discussed below (international travel is in Section 9), followed by an integrative discussion of how each of these contributes to the five pedagogical goals.

Real-time Case Study An innovative “real-time” case study focused on the proposed offshore wind farm in Hull, MA will be utilized to expose students to an actual wind farm project, as it is happening. See text box below for more details. This key element of the project will integrate research with training, and will encourage investigation of the interconnections across technology, design, communities, and ecology. This allows a service-learning component for the students and the overall IGERT project by bringing benefits to a specific community through our active participation in the design and planning. This case study will combine aspects of a teaching-focused case study as commonly used in business schools (Miles et al., 1986), with a research-focused case study. The students will work on aspects of the case in each of their core classes as described in more detail below. The output of each class will include a team report on the case study. These three reports will be a key part of each student’s portfolio, discussed in Section 6. Additionally, the seminar series, described in more detail below, will focus half of its sessions on the case study. Each year, one seminar will be devoted to introducing the case and reviewing its current state. Other sessions will have group discussions on current developments, speakers who are involved in the different aspects of the Hull project, and student groups presenting their findings. We envision that most of the IGERT students will incorporate the case study into their theses. We will not require it as it may not fit the thesis topic well; or some students may want to work on the other two cases (Cape Wind and Block Island) we will be closely involved in, or on research initiated during our international visits. For any students who do not specifically incorporate the case study into their thesis, we will require a short written work to be included in their portfolio, which will provide an integration of the reports from the three different classes, as well as a discussion of how the student’s work can be viewed in conjunction with the case study.

The IGERT students will actively participate in all parts of the Hull development process, including but not limited to: estimating the long-term wind resource; analyzing measured wind, wave, and current data for loading analyses; analyzing soil sample data for determining promising foundation designs and locations; developing layout options to maximize energy capture, minimize capital costs, and achieve social acceptance; analyzing potential environmental impacts; interacting with regulatory agencies at the local, state, and federal levels; studying public acceptance issues and survey data; and conducting economic analyses and projections to assess the benefit to the local economy.

As interesting and promising as Hull is, Massachusetts and New England are extremely active in locating potential offshore wind farms, and the entire eastern coastal area could provide case studies as needed. We are collaborating with the Massachusetts Executive Office of Energy and Environmental Affairs (see letter of support included as a supplemental document) to assure that we have access to other case study sites, and also that research and design results will be policy relevant. IGERT faculty

**The Case Study:
Hull, Massachusetts**

The WEC has a long history with wind energy provision in Hull, and has conducted feasibility studies for the two onshore turbines currently operating in the town. The town of Hull has recently proposed a 15 MW offshore wind farm, and once again the WEC is participating in the process. The project to date has included preliminary offshore studies and preparing and filing an environmental notification form. Considerable additional work is envisaged to actually obtain the required permits, to ensure public acceptance, to continue monitoring wind and wave data, and to determine the most appropriate turbines, support structures, and layout. Thus, this is a unique opportunity for students to participate in the technical assessment and planning of the wind farm, the environmental impact assessment, and the policy, regulatory, and outreach process.

have relationships with the Cape Wind (see letter of support included as a supplemental document) and Block Island (Rhode Island) projects. Finally, our international partners are active in ongoing offshore projects, providing more opportunities. This flexibility provides assurance that if Hull gets stuck in a particular development phase, we have other cases to use for pedagogy and research.

Studio Instruction The studio mode of instruction, as widely practiced in architecture and planning programs, is highly effective at engendering student creativity and collaborative work, yet is rarely applied to engineering or multidisciplinary education (Schön, 1984). It also provides value to communities, as the projects undertaken are of pressing need to the clients. By nature and design, studio courses vary significantly from seminars. Studios stress professional competencies and responsibilities demonstrated through project work. Success in the studio is defined by: thoughtful, useful and integrative knowledge the students develop and apply; how well they cooperate within a team; and how well they communicate with clients and the public. Promoting creativity within a multidisciplinary research environment is a core objective of the IGERT, and will be achieved in part by having students work intensively in a dedicated common space (the studio room), and in teams composed of a member from each thrust area. The studio process closely mirrors the professional consulting experience, where multi-disciplinary teams work together to resolve complex problems within discrete time periods for a client. Core faculty plus invited specialists will work with the student teams during class time, using a method commonly called “desk crits” in which they review the work so far and make comments and suggestions for improving it. The studio approach will be implemented in the *Wind Energy and Society* course described below. This approach immerses students into problem solving, discovery, and content delivery, and builds strong analytical and conceptual skills through active, experiential learning.

Ladder Mentoring In this project we will implement a concept developed by **DeGroot** in an NSF-funded PIRE (OISE #0530151) called “Ladder Mentoring”, in which individuals have intensive exposure and interaction with those at the next educational/career stage. We will implement formal mentoring relationships between graduate students at different stages of the program, as well as between senior and junior faculty and IGERT alumni as the project progresses. We will build on materials developed in the PIRE project to assure that the students have mentoring skills. This will benefit both the mentors and mentees, and will help the trainees to establish long-lasting collaborative relationships resulting from their IGERT experiences.

Seminar Series We will hold a weekly seminar series that will be required for all IGERT students and core IGERT faculty, but also open to the general UMass Amherst audience to allow for impacts far beyond the core IGERT group. The seminar series will play three roles. First is in-depth learning about the real-time case study: about half of the sessions will be devoted to Hull or other regional wind farms. Second is exposure to issues that, while focused on wind energy, may be outside the scope of the project. For this, we will bring in top researchers and members of industry relevant to wind or renewable energy. In particular, we will work closely with ISO-NE, the local Independent System Operator (the entity that keeps the lights on in New England) to bring in speakers on issues of wind integration with the grid, as well as other issues of importance to the electricity system (see letter of support included as a supplemental document). We will target external speakers representing diversity in gender, race and ethnicity, to provide diverse IGERT student populations with role models in research careers. Finally, the seminar series will bring all the IGERT students, associates, and faculty together on a regular basis. In support of this role, the seminar will include a time for informal networking with refreshments.

Additionally, we will encourage the students to run their own informal seminar series where they can discuss topics in the absence of faculty. This has proven to be very popular and successful in the other two IGERTS on campus and really helps the students to build a community.

Internships We will work to place students into appropriate internships, including with industry, the Department of Energy’s National Wind Technology Center (NWTC; see letter of support included as a supplemental document), ISO-NE, Fish and Wildlife, regional permitting agencies, and others. ISO-NE, for example, has established interest in our trainees, and has an extremely well developed existing internship program which IGERT interns could join (see letter of support). PhD exchange opportunities will also be available for students to collaborate with researchers at the NWTC. The NWTC covers a diverse range of expertise including offshore wind energy technology, education, grid integration, environmental impacts, and planning. The NWTC also houses many UMass Amherst WEC graduates.

Coursework In their first fall, the students will take our current class in wind engineering, *MIE 573: Engineering Wind Power Systems* taught by **Manwell** and **McGowan**, which covers a broad range of

wind energy engineering topics, including the wind resource, basic rotor aerodynamics, wind turbine structures and materials, and the basic wind turbine design process. It also briefly covers wind turbine economics and offshore-specific issues. At the end of the course, IGERT students will prepare a supplemental team report that applies class principles to the Hull project, allowing them to undertake original calculations that will train them in the specifics of offshore analysis. This class has been taken successfully by students from diverse departments, including the school of management.

In the spring of their first and second years students will take the two new courses we are developing, *Wind Energy: Environmental Effects, Monitoring and Regulatory Requirements* and *Wind Energy and Society Studio*. These classes will be offered every other year. In the early summer of their first year the students will take the International travel course, described in Section 9 below. Students will take all four of these courses with their cohorts to build community. We describe the two new courses here.

Wind Energy: Environmental Effects, Monitoring and Regulatory Requirements. This course is designed for the Wind Energy IGERT students and graduate students throughout the University. The goals of this course are to provide students with an in-depth understanding of the array of potential environmental impacts of onshore and offshore wind energy facilities, and the regulatory requirements for monitoring and mitigating these impacts. Faculty and students will review the technical literature on the environmental impacts of on- and offshore wind farms; study environmental impact statement reports; and review major laws, regulations and policies of federal and state environmental agencies. The second half of the course is dedicated to understanding wind farm effects on terrestrial, avian, and marine mammals, fish, and humans. The extensive environmental reviews conducted for the Cape Wind Project in Nantucket Sound and the W.E.S.T. Project on the Texas Gulf Coast as well as the Hull project will provide relevant, contemporary case studies. This course will provide critical professional and theoretical knowledge for engineers, scientists, planners and policy analysts working in the wind energy field. We anticipate an enrollment level that will allow for extensive discussion among students, utilizing a graduate seminar approach. This course will be team-taught by **Dumont, Griffin, Juanes**, and **Sievert** with guest presentations by staff from regulatory agencies and environmental consulting firms directly involved with environmental impact assessment of wind energy facilities. An edited syllabus is below on page 8.

Wind Energy and Society Studio. This class will use a studio-style of team learning centered on the case study. It will be open to students from any major. This course will have three overarching objectives:

1. Place wind energy and renewables within broader social and policy goals (climate change, environmental justice, economics, federal and state policies);
2. Encourage cross-disciplinary problem solving through team-based active learning;
3. Practice skills in one-way communication (presenting science to the public), and two-way communication (engaging the public in workshops and other public engagement techniques).

The course will be planned with the seminar series in mind to avoid redundancy and ensure maximum impact. The course will be sponsored by the LARP department. It will be team-taught by **Baker, Randhir, Renski**, and **Hamin**, who will lead the course. The course will meet twice a week for 3 hours each meeting, in a room dedicated to the studio, so that students can leave materials in place and use the space as a meeting place between classes. The first three weeks will be dedicated to intensive work on public engagement principles and interconnections between engineering, environment, and equity; and will consist of lectures and small-group assignments. The topics covered will include:

- Framing renewable energy within climate change, with Baker and Hamin.
- Economics of renewable energy, with Baker, Renski and Randhir.
- Planning and environmental justice, with Hamin.
- Communicating science, with Servaes and other faculty from the Center for Communication of Sustainable Social Change, a center of excellence at UMass Amherst. This will address reasons for public opposition to wind farms, and methods for better communicating the outcomes of wind energy and renewables in general.
- Project management and team work skills with Hamin.

The remaining weeks of the class will be focused on the case study and will use project-based team learning, following a studio style of instruction. Prior to the semester, instructors will meet with representatives from the real-time case study to identify relevant current project and community needs. These might include research on possibilities for redesign based on visual preferences of the public and technical requirements; preparation of public presentations and documents that are technically accurate but also accessible and informative; engagement of lobster fishermen or other stakeholders in monitoring environmental effects of the wind farm; and training schoolchildren on the project's science and engineering. Student teams will be cross disciplinary so as to fertilize engineering, environmental, and planning communication and problem solving. The projects will be designed to be of genuine assistance to Hull, and thus provide experience in service learning for the students, and will increase the relevance of the IGERT project as a whole. The projects will also tie into the social science/participatory action research thrust. See condensed syllabus below on page 8.

Summer Travel Course. All students will travel to International wind farm research sites in the early summer of their first year. Please see Section 9 for details.

1 Credit Courses. **Ethics of Engineering and Society** will be required for students in their 2nd year. The seminar will be offered by the College of Engineering and will be based on the successful course offered by the Chemistry-Biology Interface Program on campus. It will be designed to provide graduate students working at the interface of engineering and society with a solid background in research ethics. It will be made up of four 2-hour sessions, using case studies to study topics related to research misconduct, science and society, and intellectual property. Each session will be structured as follows: (1) introduction/background for the topics to be discussed; (2) discussion groups and analysis of relevant case studies illustrating ethical dilemmas encountered by laboratory researchers; and (3) concluding summary and wrap-up. Case studies will be distributed to students in advance and students are expected to read assigned material before the beginning of each session. During each session, discussion groups will be asked to come to a consensus for each case study on the ethical issue at hand and to suggest an appropriate course of action to address the situation. Each group will present their case study followed by a class-wide discussion.

We will offer a course on **Written Communication of Science**, including preparation of Curriculum Vitae, a letter of application for employment, a research abstract, and a bibliography. It will include discussion of the structure of a scientific paper, a professional poster, and the publishing process. Note that this course may be waived for students entering the program with strong public speaking and writing skills.

The courses and programs identified above all work together to meet the project's five main goals:
Goal A: Core Competency Each IGERT student will take the three core classes enumerated above, one each in engineering, environmental science, and social science. The three core classes will be taught in three different styles – lecture, graduate seminar, studio – in order to appeal to a diversity of students and build skills in multiple learning styles (Felder & Brent, 2005). Additionally, students will take a two-week international travel course, described below (described in Section 9), and the one-credit courses. Each

IGERT coursework Year 1

- MIE 573 *Engineering Wind Power Systems* (3 credits)
- Either ECO 697W *Wind Energy: Environmental Effects, Monitoring and Regulatory Requirements* or LARP 591 *Wind Energy and Society* (3 credits each)
- *IGERT Seminar*
- Written Communication of Science recommended (1 credit)
- Summer Travel Course
- Home discipline courses to sum to 18 – 24 total credits for academic year

Year 2

- Either ECO 697W or LARP 591 (3 credits each)
- *IGERT Seminar*
- *IGERT* electives
- *Ethics in Engineering and Society* (1 credit)
- Home discipline courses to total to 18 – 24 credits
- Comprehensive Exams & Proposal Preparation

Years 3 and 4

- Dissertation research and writing.

core course will result in a written project. These projects will form the basis for the students' further in-depth research with an IGERT faculty member, and will be the key part of their portfolio.

ECO 697W Wind Energy: Environmental Assessment, Monitoring & Regulatory Requirements	
Section I – Wind Resources & Wind Power Facilities	
1	Course Introduction & Expectations
2	Global wind resources
3	U.S. wind resources
4	Wind turbine designs & operation
5	On-shore and off-shore wind energy projects
6	Distribution grids
7	Overview of off-shore case study projects (Cape Wind, Block Is., Hull)
Section II – Environmental Regulations	
8	Permitting and review authorities
9	Federal environmental regulations
10	Environmental Impact Statement (EIS) process & requirements
11	State environmental regulations & the MEPA process in Massachusetts
12	Court rulings & wind power
13	Cape Wind EIS case study
Section III – Environmental Aspects	
14	Avian species
15	Bat species
16	Marine mammals
17	Fish species
18	Benthic infauna & shellfish resources
19	Commercial & recreational fisheries
20	Air & water quality and sediment transport patterns
21	Visual impacts
22	Noise assessment
23	Air & sea navigation
24	Archaeological & cultural resources
25	Final Group Presentations
26	Final Group Presentations

RP 692X: Wind Energy and Society Studio	
Wk	<i>Teams/Key Activities (Instructors)</i>
1	Introduction to course and to the planning process
2	Renewables, Climate Change, and Communities (Baker and Hamin)
3	Economics of renewable energy; (Baker, Renski and Randhir)
4	Environment and environmental justice; (Juanes/Griffin and Hamin)
5	Divide into teams; Get training from SSEC on working with communities; (Servases)
6	Teams develop and present their work plans, begin data gathering
7	Data analysis, present findings to date
8	Teams plan workshop; Continue data analysis & develop recommendations
9	Workshop planning; Outline of report and recommendations due
10	Workshop training from SSC, continue report preparations
11	Conduct community workshop presenting recommendation, get feedback from community
12	Incorporate community feedback into findings and recommendations
13	Finalize recommendations, write report
14	Draft final report due, prepare presentations
15	Final report revisions, presentations

Goal B: In depth knowledge in individual field of study Students receive their degrees from their home departments, and meet the core requirements of their home department. To establish in-depth knowledge on wind energy, students will be required to take two courses from appropriate courses within their major fields, and which satisfy core disciplinary requirements. Some examples are: *Wind Turbine Design* and *Offshore Wind Energy Systems Engineering* for engineers; *Marine Conservation* for environmental science students; and *Multi-criteria Decision Making* and *Ecological Economics and Sustainability* for social scientists. It is important to stress that this proposed curriculum, including the core competency and the classes in the major fields, will not increase the time to graduation of the IGERT students. The IGERT classes (both these electives and the three core IGERT courses) satisfy electives in each program, and thus are not an additional burden. Each student's elective courses will be selected in discussion with their

primary advisor and a secondary IGERT advisor (i.e. the person that will oversee one of the chapters in their thesis) to be sure that the subject matter is well integrated with the research focus.

Goal C: Promoting creativity within a multidisciplinary and international research environment This goal will be supported in a variety of ways and is woven throughout the program, including: participation in the seminar throughout the student's residency, shared international travel, a common discussion point (the case studies), the interdisciplinary teams in *Wind Energy & Society Studio*, and specific training on interdisciplinary communication. Each doctoral student will have a member of their dissertation committee who is from the IGERT and who is outside their home department. This outside member will direct the work on one chapter of the student's thesis. Ideally, this will result in a paper to be co-authored by the student and the outside member. This requirement will formalize interdisciplinary research. A key method to encourage interdisciplinarity is to model it. The research projects presented below all require intercommunication, and many of them build on the results of other IGERT research to create a more coherent, relevant finding. Engaging students in this sort of collaborative work is, we believe, the best way to encourage such behavior from them in the future.

Goal D: Ability to communicate effectively across disciplines and with a wide range of stakeholders and with the public We will work with **Servaes** and the Center for Communication for Sustainable Social Change (CSSC) to facilitate communication across the disciplines and with a range of stakeholders. We will focus on three levels of communication: between disciplines (discussed in Goal C above), one-way communication of science to the media and public, and participatory "two-way" communication. For "one-way" communication, we will prepare the students for better communication of science to the public, through one lecture in the *Wind Energy & Society Studio*, as well as exercises such as preparing a news release or a visual representation of their work, which will be incorporated into the other core classes. A particularly helpful component is that the IGERT faculty already offer a related course that provides the necessary skills, and the University has a center dedicated to the communication of science and sustainability. As described above, students will take the 1-unit elective offered by **Griffin** on Written Communication of Science (see attached syllabus), and participate in workshops by the CSSC.

What differentiates this project from others is that the concept of participatory communication is crucial to this project. Participatory communication is used to involve people in decision-making and is characterized by a horizontal flow of communication based primarily on dialogue. We will incorporate the basic aspects of participatory communication in all phases of the case study. The participation of the CSSC will help assure that all participants – students and faculty – keep a participatory perspective and don't default into strictly one-way, top-down communication mode.

Goal E: Professional skill development including an appreciation for the ethical nature of scientific research, particularly in relation to renewable energy We achieve this goal through several mechanisms, including mentoring, connections and networking, internships, and training in ethics. In particular, the ladder mentoring has proven to be an effective method of helping students develop professional skills and networks. The case study project will expose the students to the full spectrum of stakeholders involved in the siting, evaluation, and operation of a wind farm, including city engineers, municipal policy makers, state regulatory bodies, environmental groups, offshore foundation engineers, ocean monitoring engineers, and interested citizens. Additionally, we will work to place students into appropriate internships, including with industry, the NWTC, ISO-NE, Fish and Wildlife, and others. PhD exchange opportunities will also be available for students to collaborate with researchers at our international partners.

To advance students' ethical awareness, we use two approaches. First, in the case study the students will face a spectrum of values and tradeoffs related to implementing renewable energy projects, and these subjects will be addressed in the seminar and the *Wind Energy and Society Studio* with a particular focus on environmental justice and the impacts on diverse stakeholders. Second, we will work with the College of Engineering to offer a 1-unit ethics seminar on Engineering and Society, to be taken by trainees in their 2nd year (see above).

Additionally, students will be exposed to entrepreneurship and translational research through a seminar facilitated by the UMass Amherst Commercial Ventures and Intellectual Property Office. The recently funded Nanoscale Device IGERT has a significant innovation component. This is an ideal opportunity for interacting with the existing IGERT including trainee participation in technical challenge projects and enrollment in both business and innovation courses.

Typical Student Pathways and Time to Degree We will have multiple student pathways depending on the program and specifics of the student. The typical student will be admitted as an IGERT student or associate when they are admitted to a UMass Amherst PhD program. However, we will allow current students to apply during their first year. Some students will be admitted as associates and be funded by other sources for their first year, such as a graduate TA or NEAGEP funding. These students will follow the same path as those who are admitted as IGERT students. All IGERT students and associates will take one IGERT course in each of their first two semesters, and one course in their second year. Additionally, they will attend the seminar throughout their IGERT association, and will take the 1-credit ethics course during their second year as an IGERT student (see course schedule above). Some students will be funded for a third year depending on timing, available funding, and the specifics of the student. Students selected for a third year of funding will either be undertaking extensive field work for their IGERT-related dissertation or will take on project management responsibilities such as coordinating ladder mentors, TAing for the IGERT courses, helping with recruiting, or other similar activities. Students' fourth years of study will be funded by departments, the graduate school, or outside sources. For Year 5 entrants, the second year of the stipend will be supported either by the IGERT Program renewal, primary graduate advisor, or NEAGEP Program. Advisors will be asked to agree to this arrangement before the fellowship will be awarded for Year 5 entrants. All these requirements fit well within the current graduate degree requirements of the participating departments, thus we do not expect the proposed education and training requirements to impact the time to degree. We will track time-to-degree as part of our evaluation, with four years of matriculation as our goal.

Undergraduate Involvement We will work with the existing College of Engineering REU (NSF EEC0850424) to recruit undergraduate students to work on projects in conjunction with IGERT faculty and students. In particular, the Hull case study will provide an excellent opportunity for REU students. We will also work with the REU program in general to recruit outstanding students for the IGERT. This has proven to be an excellent recruiting tool for the other IGERTs on campus. Such REU students will also participate in the ladder mentoring program.

4. Major Research Efforts

UMass Amherst is a leading center of public higher education in the Northeast and a world center for research. The campus is ranked fourth in sponsored research support and is the fourth largest producer of PhDs in Massachusetts. During 2006, research expenditures topped \$113M, with approximately 12% allocated to clean energy-related research. The initial research thrusts for the proposed IGERT are: Engineering Offshore Wind Energy Systems; Mitigating Environmental Impacts; and Design for Public Acceptance. These thrusts are closely aligned with the University's focus on Advanced Energy Research. Thus, our proposed doctoral training program is an integral part of the campus' unified multidisciplinary approach to energy science, engineering, and policy, and one that will reinforce and continue the quality of the research taking place at our university. The research will be integrated with the student training by using the Hull case study as an application for many of the projects, having many of the projects build on the class projects, and having the curriculum provide the basis for the research.

Some of the research projects will fit within one of the thrusts. We will describe these first. But some of the research projects will cut across the thrusts. We will touch on these within the thrust descriptions when appropriate, but will emphasize them in a section on cross-cutting projects at the end. The actual research projects will be informed by the process and findings at Hull, the interests and ideas of the IGERT students, and through discussions and cross-fertilization at the seminar and other meetings. These aspects will affect the overall work as it progresses through the IGERT years and beyond.

Engineering Offshore Wind Energy Systems Thrust

As noted above, the U.S. Department of Energy (DOE) has established the goal of wind power supplying 20% of the nation's electricity by 2030 (U.S. Department of Energy, 2008). Much of this will come from offshore turbines.

While wind energy technology has advanced significantly, and onshore wind energy is approaching a state of maturity, offshore wind energy presents an extremely complex technical challenge. New scientific knowledge and technology advancement are much needed for offshore wind energy systems, to increase rotor efficiency, improve turbine reliability, and reduce system costs (U.S. Department of Energy, 2008). The transformative research proposed here will significantly impact offshore wind energy technology, and will result in more efficient, reliable, and cost effective wind energy systems. Four specific research topics are presented (Figure 1), ranging from the wind resource itself, to the turbine, the support structure, and the overall wind farm configuration. This range of topics reflects our systems level view of wind energy. Moreover, this research will have cross-disciplinary interaction and collaboration both within this thrust, and between the other thrusts. Below, we note these opportunities.

1 – Microwave Remote Sensing of Offshore Winds, Waves, and Currents (Frasier, Manwell, McGowan) Measuring the external conditions (wind, wave, current) for potential offshore wind farm sites currently are often prohibitively expensive and unreliable, as the offshore environment is an extremely challenging location for a monitoring campaign. The ability to sense these external conditions from a single onshore location would revolutionize the wind energy site assessment process for offshore sites, by being less expensive, quicker, and more reliable, and eventually leading to increased offshore wind energy development.

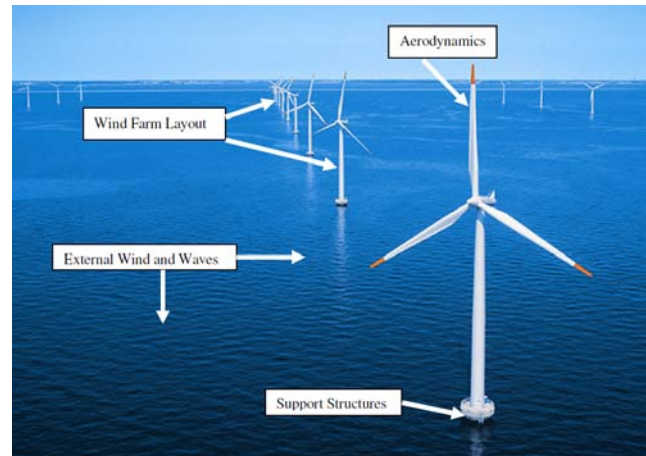


Figure 1: Engineering research topics.

Frasier will collaborate with **Manwell** and **McGowan**, and a doctoral student, on utilizing microwave radar observations of the sea-surface to estimate winds, surface waves (i.e. wave length, wave height, wave period, direction), and surface currents. Microwave radar scatterometers are routinely used to estimate sea surface winds from space or from aircraft (Carswell et al., 1994; Esteban-Fernandez et al., 2006). These techniques have not been used for wind monitoring in more localized regions, which would represent a significant advancement in the state of the art.

This project will assess the adaptability of these techniques for localized wind speed and direction measurements. Experimental investigations will be performed using anemometer and wind vane data from meteorological (met) towers located on a small island along the Mass. coast, operated by the WEC. These met tower data will be used to calibrate and then validate the radar techniques, with the radar positioned near the met tower.

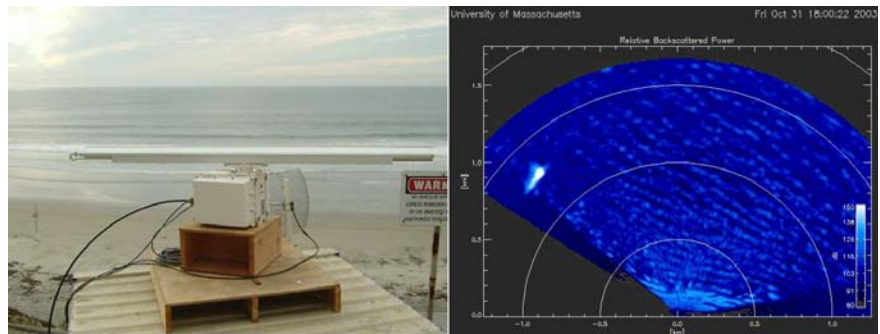


Figure 2: A modified high-seas navigation radar (left) is used to map surface wave fields (right). Observed patterns provide information on wind speed, wave spectra, and near-surface currents.

Radar measurements can also be used to estimate wave direction, wave length/period, significant wave height, and near-surface currents (Frasier & McIntosh, 1996; Perkovic et al., 2008). Such quantities are critical for determining forces on the wind turbine support structure, as discussed later in this thrust. An example system and observations are shown in Figure 2.

Once the method for utilizing radar measurements to assess wind, waves, and current has been validated, it will be applied to the proposed Hull offshore wind farm project. This measurement campaign will demonstrate the new technology, and provide valuable data for estimating power and loads in a proposed offshore wind farm.

This topic will also interact with proposed research in the environmental science thrust related to monitoring bird migratory paths in real time using radar based measurement, and using this information for selective turbine braking during certain critical time periods. See the “Crosscutting projects and themes” below for more details.

2 – Aerodynamic and Aero-elastic Analysis Tools and Advanced Rotor Designs (Perot, Modarres-Sadeghi, Lackner)

2.1 – Computational Fluid Dynamics development for Smart Wind turbine Blades. Smart rotor concepts employ Active Aerodynamic Load Control Devices (AALCDs, see Figure 3), which are actively controlled to respond to disturbances and reduce blade loading (Lackner & van Kuik, 2009; 2010). These advanced rotors have not been implemented in practice, but would be capable of substantially advancing wind turbine technology, leading to more efficient, reliable, and cost effective turbines.

Computational fluid dynamics (CFD) has the potential to accurately predict the steady and dynamic loads on turbine blades. However, this potential will not be realized until significant advances in the state of the art are achieved. The primary bottleneck is that the equations of motion are highly dependent on the state of the fluid turbulence, and standard turbulence models are insufficient for the complex turbulence physics occurring on a blade (Leishman, 2002).

Perot and Lackner will demonstrate that the turbulent potential model (Perot, 1999; Wang & Perot, 2002) and the universal modeling approach (Perot & Gadebusch, 2009) contain sufficient physics in the turbulence model to produce computations that are far more predictive than standard two-equation models. They will demonstrate the ability to calculate the detailed flow behavior over airfoils and AALCDs and predict the resulting loads. The project will demonstrate three key technologies:

- A low cost, advanced turbulence model that can predict transition to turbulence, three-dimensional boundary layers (due to blade twist and rotor rotation), rotating turbulence, hub/tip losses, and boundary layer separation. An example of predictions with this model is shown in Figure 4.
- An adaptive moving-mesh numerical scheme that can accurately deal with moving blade surfaces as well as small scale and dynamic flow structures such as trailing vortices and separated shear layers.
- An open source CFD framework (OpenFoam) that will aid the rapid dissemination of this technology.

These advances will provide a critically useful tool for wind turbine and smart rotor blade design. This technology will eventually allow for the assessment and design of various AALCDs, the evaluation of their load reduction performance potential, and the ability to develop new correlations and improve the simpler models currently employed for analysis of smart rotors.

2.2 – Flutter Limits for Wind Turbine Blades. For offshore wind turbines, there is a powerful motivation to utilize longer blades thus leading to increased energy capture. One of the factors that may limit the length of blades is their possible instability. When a blade becomes unstable, it fails, and possibly results in the failure of the neighboring turbines in a wind farm. **Modarres-Sadeghi** and a doctoral student will investigate the extent to which the blades can become longer and therefore more flexible without undergoing any instability, in order to give guidelines for designing

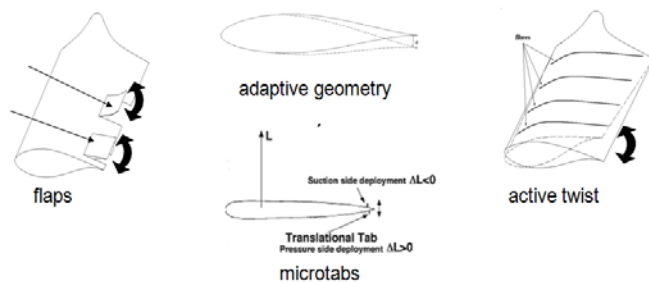


Figure 3: Example active aerodynamic load control devices.

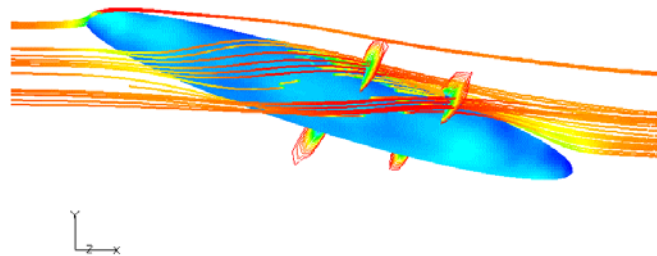


Figure 4: Predictions of the flow over a prolate spheroid at an angle of attack using the turbulent potential model (Perot, 1999). The figure shows some streamlines colored by streamwise velocity and contours of the pressure at two streamwise locations.

revolutionary generations of blades. The major possible instability for pitch-regulated variable-speed wind turbine blades is flutter (Lobitz, 2004, Hansen, 2007), which is a violent instability and may result in failure of the blade very quickly.

In this project, the flutter instability of wind turbine blades will be studied using a nonlinear model and also by conducting a series of experiments in a water tunnel and a wind tunnel at UMass Amherst. See Modarres-Sadeghi et al. (2005, 2008) for details of this procedure applied to a similar system. The onset of flutter for various system parameters will be pinpointed, and the post-critical behavior of the system including the possibility of quasiperiodic and chaotic motions will be investigated. Also, the influence of instability on the near wake will be studied.

The results of this project will help us understand the influence of geometric nonlinearities of long slender blades as well as other system parameters on the onset of instability, and come up with methods to avoid failures due to such instabilities, while being able to use larger blades in current as well as future innovative designs.

3 – A Stochastic Multiphysics Simulation Environment for Offshore Wind Turbine Support Structures

(Arwade, DeGroot, Lackner) Offshore wind turbine (OWT) support structures account for one quarter of the total lifecycle cost (Figure 5; Musial et al., 2006) so that increasing their efficiency and reliability can make a major impact on the cost of energy generated from offshore wind resources. Analyzing and designing support structures for OWTs, however, presents challenges unlike those associated with any other engineered structure, even offshore oil/gas exploration/extraction facilities. Current state-of-the-art design and analysis methods give insufficient consideration to: (1) soil property uncertainty; (2) long term degradation of soil properties due to cyclic loading. The OWT support structure problem also involves extreme loads (storm driven wind and waves), the coupling of distinct physical mechanisms (aerodynamics, hydrodynamics, solid mechanics), and strong nonlinearities (large soil deformations, soil inelasticity), such that the problem involves the following disciplines: turbine aero- and hydrodynamics (Lackner: Lackner, 2009; Lackner & Rotea, 2010), probabilistic structural mechanics (Arwade: Arwade et al., 2010; Louhghalam & Arwade, 2009; Arwade et al., 2010), and soil characterization and mechanics (DeGroot: DeGroot et al. 2010, DeJong et al. 2010, DeGroot et al. 2007).

To advance the state-of-the-art in OWT support structure analysis and design, Arwade, DeGroot, and Lackner with a team of doctoral students, will develop a stochastic multiphysics simulation environment for the long-term dynamic response of OWT support structures (Figure 6). This simulation environment will leverage existing computational tools where possible (FAST for turbine aerodynamic loads (Jonkman & Buhl, 2006), NESSUS for uncertainty quantification) but will also require fundamental research on the interaction of very large diameter piles and soils with highly nonlinear properties, probability models for the natural frequencies of OWT support structures resulting from soil property uncertainty, and the effect of long term cyclic degradation of soil properties on OWT support structure dynamics and deformations. The existing body of knowledge for offshore structure design (API, 2000) provides a strong base for the work, but must be extended to consider the substantially different dynamics of OWTs compared to other offshore structures resulting from their much smaller size, mass

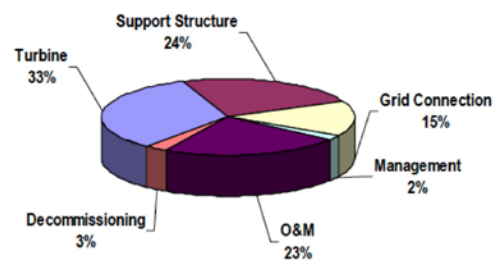


Figure 56: Typical costs of offshore wind turbines (Musial et al., 2006)

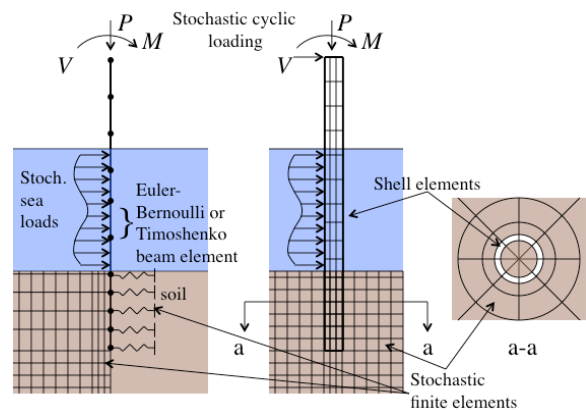


Figure 6: Two and three dimensional idealizations of the turbine tower and monopile foundation. In the 2D idealization beam elements are used for the tower whereas shell elements are used in the 3D idealization. Tower top loads are the moment (M) shear (V) and axial force (P). For the 2D model a choice of solid or spring elements for the soil model is shown.

and stiffness. As one specific example, resonance with wave and wind loads is a likely catastrophic failure mode for OWT support structures, but is not a substantial risk for oil and gas platforms.

Once this simulation environment has been developed, it will be applied to the Hull wind farm. Using the measured soil properties at the proposed wind farm location, simulations will be carried out to assess the long term reliability of wind turbines at the site, and the potential risk of cyclic soil degradation and catastrophic resonance.

This topic will interact with proposed research in the environmental science thrust related to the impact of offshore structures on marine life populations. Life-cycle cost analysis of various support structure designs integrates with the environmental science and policy thrusts, in that the support structure alternatives may have different initial costs, life-cycle costs, and impacts on the marine environment (see “Crosscutting projects and themes” below for more details and text box on Lobster in Section 2). The aerodynamics topic provides quantification of the loads delivered by turbines with new designs or control mechanisms. Structural reliability is a key component of system lifecycle cost and therefore affects wind farm design and layout.

4 – Wind Farm Multidisciplinary Design Optimization (Manwell, McGowan) The performance of the wind farm is a highly interdependent system, due to the wakes generated by upstream turbines that interact with downstream turbines (Barthelmie & Kuhn, 2009). The planning and operation of a wind farm must be cognizant of this interdependence, to produce an optimal operating wind farm, not just a collection of operating units.

Manwell, McGowan, and DeGroot will build on the above projects and collaborate with **Baker and Randhir**, and a team of doctoral students, to develop a multidisciplinary design optimization (MDO) methodology for wind farm layout. The optimization problem is typically summarized as: where should each turbine in the array be positioned so as to minimize overall cost of energy (COE)? This objective implies multiple technical criteria including maximizing energy capture, and minimizing costs (capital and O&M) (Elkinton, et al., 2008). There are also a number of constraints that must be considered, including environmental and logistical (e.g. shipping lanes). Finally the design must achieve public acceptance to be viable. An example utilizing the state of the art optimization methodology is shown in Figure 7.

Our approach will significantly advance the state of the art in wind turbine layout optimization in two ways. First, it will incorporate the impact of rotor wakes on downstream turbines resulting in increased fatigue damage and lower reliabilities. The increase in the wake turbulence intensity and loads on downstream turbines has been noted previously (Vermeer et al., 2003). But, this effect has never been incorporated into layout optimization.

Second, this methodology will incorporate uncertainty to give probabilistic estimates of the cost of energy. Uncertainty arises from a number of sources including wake models, spatial variability of soil properties (DeGroot & Baecher, 1993; DeGroot, 1996), and turbine reliability. This uncertainty will be modeled, and then will be utilized in a probabilistic optimization process. An example approach is summarized using the equation to the right, which shows that the objective is to minimize the expected value of COE, subject to a 90% confidence that the constraints are satisfied (other confidence intervals and approaches may be used).

Once this methodology is complete, it can be re-applied to the Hull offshore wind farm, to improve the layout and quantitatively assess the robustness and risk associated with the solutions. The resulting methodology and software will represent a significant advance in the state of the art of wind turbine layout optimization, and will result in lower costs of energy for future operating wind farms. This research will

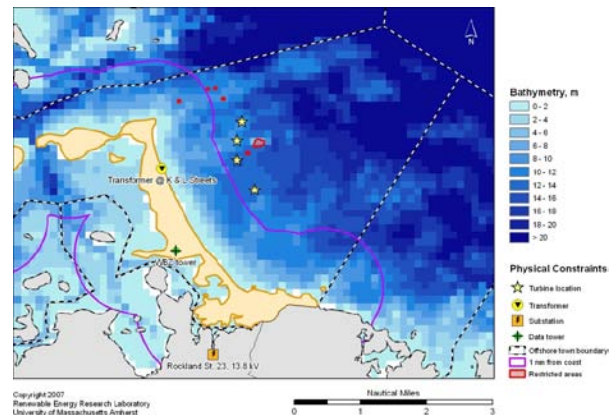


Figure 7: An example layout optimization for a hypothetical offshore wind farm in Hull, MA. Optimal turbine locations are the yellow stars. This approach is deterministic and does not consider the effect of the layout on reliability.

$$\begin{aligned} & \min_{\mathbf{X}} E[COE(\mathbf{X})] \\ & \text{subject to} \\ & P\{C(\mathbf{X}) \leq 0\} > 90\% \end{aligned}$$

then be extended to include broader economic and environmental concerns. See the “Crosscutting projects and themes” below for more details.

Ecological Assessment and Environmental Monitoring Thrust

The goal of this thrust is to obtain a sound science base on coastal and marine organisms and the supporting aquatic habitats associated with off shore wind turbines, using the proposed Hull offshore wind energy facility as a test bed. Such information is critical to ensure the stewardship of healthy and sustainable ecosystems while providing important human and community benefits, and is tightly integrated with the regulatory review process. This thrust focuses on three primary issues critical for development and operation of offshore wind energy facilities. These are (1) ecological assessment of the positive and negative impacts of offshore wind facilities on birds and bats, fish and other marine species; (2) development and evaluation of technologies and protocols for monitoring responses of marine organisms to offshore wind facilities; and (3) potential to enhance habitats for marine organisms at offshore wind facilities. Using a unique blend of monitoring equipment, including radar, sonar, and underwater video and audio, combined with at-sea surveys and spatial modeling, we will identify the spatial and temporal patterns of marine organisms and their critical habitats. With no offshore wind farms developed in the U.S., there is much uncertainty about the effects of offshore wind farms on the population dynamics, behaviors and habitats of marine organisms. This research will investigate the extent of ecological impacts of wind farms to the marine biota by monitoring marine resources and responses of organisms during all phases of the project, and assess a variety of technologies and protocols for monitoring responses of marine organisms to offshore wind energy facilities. Additionally, this project affords unique opportunities to develop novel interdisciplinary approaches not previously used at existing offshore wind facilities. The first would utilize radar surveillance of bird concentrations in combination with environmental data to develop innovative strategies to minimize collisions by stopping rotors when specific environmental and avian and bat behaviors exist. The second focuses on conducting field experiments to quantify the responses of marine organisms to development of artificial reefs at turbine structures. These are described under Cross-cutting Projects and Themes below.

Offshore wind energy has both positive and negative environmental consequences. Aside from the global positive effects of wind power displacing other forms of electricity generation, the other environmental consequences are primarily local in scale (Snyder & Kaiser, 2009). Yet, primary concerns for offshore wind farms are risks they pose to birds and other marine species (Fig. 8). Assessing the potential ecological risks of an offshore wind power facility to birds and other marine organisms requires much information on their distribution, abundance and behaviors. Here we discuss two research directions, one concerning negative effects both in the air and in the water, and the other potential benefits to fish and marine invertebrates. We then outline the benefits of the Hull location for both research directions.



Figure 8: Birds flying through wind farm in southeast Asia (John Tsai)

1 – Negative Effects of wind farms

1.1 – Birds & Bats. A primary concern surrounding wind farms is the risk they pose to excessive avian mortality through collisions with turbines (Drewitt & Langston, 2006) especially at night (Mabee et al., 2006), and especially for shorebirds, seabirds and waterfowl at offshore facilities. To reduce mortality, wind farms need to be sited away from sensitive bird nesting, roosting and foraging areas (Snyder & Kaiser, 2009). Radar observations and at-sea surveys will be used to monitor movements of birds and to identify important habitats for birds near and within the proposed Hull wind farm site. Radar systems are especially useful for collecting information on nocturnal flight behaviors, including flight direction, speed, and altitude, essential for assessing vulnerability to collision or displacement. At-sea surveys will be used to determine the diurnal spatial distribution and behaviors of birds. Using data from radar and at-sea survey observations and mapped locations of nesting colonies, sensitive bird areas will be mapped using GIS and kernel density analysis used to assess vulnerability. **Griffin** and **Sievert** bring much experience with coastal and marine bird ecology and behavior, spatial modeling, and vulnerability assessment.

Dumont provides expertise in bat ecology and behaviors. Note that while there may be relatively few bats at the coastal Hull site, we include bats for three reasons: 1) there are, in fact, very little data on the presence or absence of bats in coastal and offshore regions but they are known to fly over the water at night (Ahlen et al., 2009; Cryan & Brown, 2007); 2) bat mortality at on-shore wind farms (Baerwald & Barclay, 2009) may be an important consideration when choosing an offshore versus onshore site; and 3) preventing bat mortality is an important issue, particularly given other current threats to bat ecology in the Northeast (Frick et al., 2010). Although radar technology provides the ability to detect the approach of birds and bats in the vicinity of wind farms, there is a critical need to link real-time bird/bat radar observations with environmental measures so that rotors could potentially be stopped to minimize bird/bat collisions. See the “Crosscutting projects and themes” below for more details.

1.2 – *Marine Fish, Mammals & Invertebrates*. Wind farms have the potential to affect marine fish, mammals and invertebrates by habitat (physical and biological) changes due to wind farm construction, as well as noise levels in the construction phase and during operation. A major concern is the barrier that wind farms may pose to movements of marine organisms, thereby reducing their foraging efficiency (Snyder & Kaiser, 2009). There is also concern for marine mammals, such as seals and whales, especially during the construction phase when sound pressure can modify behaviors (Carstensen et al., 2006). Similarly, sound associated with construction and operational chronic noise exposure can cause direct mortality or behavioral changes in fish and invertebrates. Further, the electromagnetic fields caused by buried underwater cables can retard migration, affecting catch rate for several economically important fish (Ohman et al., 2007). Pre-construction monitoring will examine bottom types and distribution of benthic and demersal organisms by using a combination of underwater video, diving surveys, and traps (see for example, Rountree & Juanes, 2010). Pelagic fish distributions can be assessed with mobile nets such as trawls, and with fixed gear such as gill nets. Marine mammal presence and behavior can be monitored with human observers on at-sea surveys. Background sound levels will be monitored during construction and compared with pre- and post-construction levels using hydrophones. The range of audibility for fish and marine mammals can be calculated based on noise levels, hearing ability, and assumptions about transmission loss (based on wind speed, water depth, bottom type, etc) to estimate area of noise impact (Tougaard et al., 2009; Wahlberg & Westerberg, 2005).

2 – Potential benefits of wind farms Most marine fishes and invertebrates are dependent on refuge for cover especially early in their life history (Juanes, 2007). Such cover is often a limiting factor and with continued habitat destruction can be a factor in the decline of fish and invertebrate populations (Nitschke et al., 2002; Marino et al., 2007). Artificial reefs and protected areas are a response to such limits. Turbine foundations may serve as a source of refuge for local demersal marine species (Wilhelmsson et al., 2006). Refuge requirements (size and shape) vary with ontogeny and across species (Manderson et al., 2006). Similarly, floating objects serve as aggregating devices for many pelagic fish species and in turn attract their predators, often large pelagics of commercial importance (e.g. tunas, sharks) (Hanrahan & Juanes, 2001). Part of the monitoring will focus on large pelagic fishes and whales to assess whether the turbine structures act as aggregating devices, which could potentially reduce the beneficial habitat effects for smaller fish. The Hull case study affords the opportunity to *design an array of refuges and track long-term responses of coastal species never before attempted at off-shore wind farms*. Additional underwater structures could be placed on the bottom as part of the construction of the wind farm. The effects of structures and artificial habitats on fish aggregation, especially juvenile stages of demersal fish species (e.g. cod, haddock) and invertebrates (lobster, crab), will be monitored using underwater video and audio with periodic diving censuses around the structures and nearby ‘control’ regions. **Juanes** brings much experience with fish ecology and habitats, and the use of passive acoustics to identify and locate soniferous fishes.

This topic also interacts directly with engineering project 3 (**Arwade, DeGroot and Lackner**) related to offshore turbine support structures. Further, **Frasier** and **Juanes** are currently collaborating on developing new oceanographic instruments for passive acoustic recording and underwater video to examine anthropogenic impacts on sound production by marine animals. This research also interacts with the social thrust initiatives, as designs that improve underwater species viability will likely achieve more community and faster regulatory approval. See the “Crosscutting projects and themes” below.

The choice of Hull, MA as a real-time case study for this project provides unique opportunities for working within the Greater Boston shoreline with its dense human population and wide variety of coastal and marine habitats. Boston Harbor and Massachusetts Bay provide important areas for coastal and marine birds, marine mammals such as whales and seals, pelagic fish such as striped bass and bluefish, demersal fish such as cod, and invertebrates such as blue crab and lobster. Surrounding the Hull project site is the Boston Harbor Islands National Park Area (BOHA), a unit of the National Park Service that includes 34 islands and peninsulas (Fig. 9). The BOHA was designated as a Massachusetts Important Bird Area, providing habitats for a significant number of colonial-nesting birds, of which several species are state-listed and of high conservation concern. The lobster fishery is also critically important to the town of Hull, as are other fisheries for scallop, cod, squid, and monkfish. The number of fishing vessels with Hull as a homeport has varied from 16-26 over the last 15 years. Recreational fishing is also an important part of the community and includes catches of striped bass, bluefish, cod and lobster.



Figure 9: Boston Harbor Islands National Park and community of Hull (red star)

Design for Public Acceptance

Understanding the intersection of public acceptance and technological effectiveness is a critical research need for proposed wind farms. There is a complex relationship between designs of facilities the public will accept, and the economic outcomes and technological feasibility of those designs. Costs and benefits are not evenly distributed. As a result, feasible design is an outcome of a negotiated process. To contribute toward better scientific understanding of this process and the boundaries it sets on technical possibilities, the Design for Public Acceptance thrust begins with nuanced qualitative analysis of reasons for public support and opposition to wind farms, utilizes visual and Web 2.0 participatory analysis of design possibilities, and then uses that base of knowledge to develop a multivariate analysis that will be widely helpful in predicting important factors toward siting and design success of future projects.

Several points here are innovative and unique. The team utilizes a wide variety of research approaches as ‘lenses’ on the same problem, meaning we can get a deep and wide understanding of the issues at hand. Many of the projects use the case study or studies as a data point, and this will tie into the studio and seminar classes of the IGERT. The use of Web 2.0 is an exciting innovation, and will allow us to test the different outcomes from more traditional photo-simulation analysis and newer technological approaches. Bringing these together with economic analysis engages a new level of input in the wind farm siting process. Public policy, economic, planning, and design researchers will be working with engineers and environmentalists; as a result, the outcomes will be grounded both in feasible design and in feasible policy.

1 – Public narratives of renewable energy siting A first research goal is to develop understanding of the positions of the affected communities toward wind power. The East Coast provides three very different community responses to wind power proposals. Hull has embraced municipal power generation as part of its community character; Block Island has developed a modest level of community support for a commercial project that will reduce local electrical costs; Cape Wind has met huge resistance as its local benefits and connections are much weaker. The social, environmental, and engineering similarities and differences of these case studies provides an outstanding opportunity to develop a grounded theory of key variables in social acceptance of wind designs. To undertake this, **Hamin** will utilize narrative analysis of siting discourses and interpretive planning techniques (Hamin, 2003) for the three case study sites. The result will indicate the important factors designers and engineers can engage to encourage public acceptance, and what factors are external to the process.

2 – Visual Preferences **Ryan** and **Kumble** will perform preliminary visual preference testing via surveys with photo-simulation of wind turbine projects to identify the visual parameters of public acceptance, including distance, pattern, height and spacing of turbines (Ryan, 2002). The surveys will be conducted

via the internet with stakeholder groups using methodology developed by Ryan (Ryan, 2007). Visual preference research has been found to be an effective technique for gathering public input on a range of planning issues, as well as communicating to the public about these alternatives (Kaplan & Kaplan, 1989). Since little work to date has been conducted on the cumulative visual impacts of wind turbines or other energy facilities (Council on Environmental Quality, 1997; McCold & Saulsbury, 1996; Germond, 2009), these photo-simulations will study how the addition of more turbines affect public acceptance. In some of our case study communities, such as Hull, the initial installation of wind turbines has been followed by more turbines. Thus, it is important to know if there is a threshold to public acceptance in local communities as more turbines are added. With these bases established, the entire team (engineers, physical scientists, social scientists) will collaborate to identify a range of technically and politically feasible designs for case study sites. From this, Schreyer and Schweik will develop a Web 2.0 Content Management System with Google Sketch-up-based images of what various technologically feasible designs would look like; GIS and 3-D visualization and animations will allow stakeholders and the public to look at various proposal options and provide feedback (Schweik et al., forthcoming). **Fisher** will translate these simulations to his Human Performance Lab, letting people drive, walk, fly, or sail through the simulated environment, using the eye tracker to determine which aspects of the designs are drawing the most attention (Hurwitz et al., in press), then using this work to better understand visual preferences. This research altogether will provide us with a much more complete view of the role of visual preferences and how they interact with specific designs and layouts.

3 – Multi-Attribute Decision Making **Randhir** and **Baker** will design a set of multi-attribute decision tools that will include the preference outcomes discovered through above work, engineering criteria as in the layout optimization model described in the engineering thrust above, plus detailed preference information from focus groups (Randhir & Shriver, 2009; Ewing & Baker, 2009). The specific frames for the tools are described in the cross-cutting work below. Here we describe the methods for gathering and analyzing preferences into a multi-attribute framework including economic, ecological, and social factors.

We will organize multiple, diverse focus groups, each including a range of stakeholders from Hull. Using preference elicitation methods we will define the set of strategic values that the stakeholders find relevant for wind-farm related decisions, and then develop a set of rankings over those values for each participant. We will then use the Deliberative Attribute Prioritization Process (Randhir & Shriver, 2009) to help the group come to a consensus which can then be used to systematically model preferences in a way amenable to implementing into a multi-attribute decision tool.

Two aspects of this research are particularly innovative. First, we will do an analysis across multiple focus groups, paying particular attention to the dynamics of the groups, in order to ascertain how robust the results are from a single group, and how portable these results may be to other situations. By the dynamics of the group, we mean we will analyze how the group changes on a consensus scale, which individuals were most influential, and which individuals were most compromising. Second, we will work on methods that are robust across a wide variety of decision makers and in the case of little consensus among stakeholders. We will develop concepts of “non-dominated alternatives.” This concept is well defined in decisions that have multiple criteria (Dyer et al., 1992) and in decisions that have uncertainty (Baker, 2009); however, it is not well defined in decisions that have both multiple criteria AND uncertainty. We will build on our work in this field to define useful concepts and ways of representing the alternatives to stakeholders.

Finally, these models will be specifically linked with engineering criteria in order to evaluate technical designs on a wide range of attributes, and to help lead to technological innovation. See Cross-cutting research.

4 – Employment, equity and innovation from wind power facilities **Renski** and **Boyce** will investigate the employment and equity effects of wind power installations, including initial construction jobs and on-going employment, tax base, and other local/regional/state benefits. Extending the analysis beyond traditional upstream economic multiplier effects, this research thrust will also consider a broader spectrum of prospective economic development impacts through the lens of industry cluster analysis (Feser et al., 2009). This involves understanding the key technologies, equipment and assemblies, materials and labor needs required for the construction and on-going operations of wind-power facilities and the inter-connections among them. It also requires identifying which of these key inputs might be acquired from regional suppliers as well as the potential role of university researchers and economic/workforce development institutions in serving this emerging industry. Lastly, it will examine downstream economic

development opportunities that arise from increasing the regional supply of renewable energy such as additional opportunities for regional businesses to serve the growing local and international market for renewable wind-power technologies. An outcome of this inquiry will be a set of guidelines for state, regional and local economic developers and planners on how to leverage existing regional assets in order to maximize the potential economic benefits from new wind power projects.

5 – Non-market costs and benefits of wind power installations **Allen** and **Boyce** will build on all of the above work to estimate the overall costs and benefits (Timmons et al., 2007) of wind farms in different locations, especially the non-market values (Murphy et al., 2005) such as aesthetic impacts and environmental impact, positive and negative. Benefits include direct employment for construction and operation, indirect employment through the multiplier effect, and increase in local taxes through additions to the tax base. The value of the multiplier will be based on the research project described above. An additional economic benefit or cost is the change in tourism (e.g., beach-goers, recreational fishers). There may be aesthetic benefits where wind-power development substitutes for conventional fossil-fueled electricity generators and there are likely to be environmental benefits in air-quality improvement and reduced carbon footprint relative to substitute power sources. Economic costs are the direct subsidy provided to wind-power generator construction and operation (for example through the Internal Revenue Code) and indirectly the higher unit power cost of wind power compared with alternative generation sources. Such indirect costs may be incurred as a result of legislation that mandates a percentage of generation from non-conventional sources. Non-market costs are the aesthetic degradation and environmental damage that will occur. These will need to be described and quantified in other parts of the study, as will the number of affected residents. Standard willingness-to-pay or willingness-to-accept-compensation survey methods will be used to monetize non-market benefits and costs. While making efforts to include all benefits and costs we will need to be careful to include only marginal impacts and to avoid double counting. Finally, different technologies and different sizes of operation represent a set of trade-offs in benefit-cost space that will be represented as such. We should not expect a unique, socially optimum solution to exist.

Crosscutting Projects and Themes

Finally, the most novel contributions of the research agenda are likely to arise from the projects that cut across our thrusts. These potential projects can be gathered under three themes. First, in collaborations between the environmental scientists and the engineers, we will develop and apply new technologies for environmental assessment of the marine environment, and develop new methods for reducing bird/bat collisions at wind farms. Second, in collaborations between environmental and social scientist we will integrate the environmental assessment with public preferences, attitudes and socio-economic concerns. Third, in collaborations between the engineers and the rest of the team, we will develop data and methods for evaluating engineering designs in terms of environmental and social issues. Here we provide a few examples of the kinds of projects we will pursue.

Theme 1 As an example of the first theme, **Griffin, Sievert, Dumont, Frasier, Lackner, and Baker** will collaborate on a process aimed at using radar surveillance to detect vulnerabilities in real time, and then communicating with the wind farm to induce automatic responses such as stopping rotors. This project will require the environmental science team to collect and analyze data that determines what *measurable* data, such as the presence of leading animals or meteorological conditions, correlates with *population* danger. They will then collaborate with Frasier to develop methods for collecting this data in real time – an innovation that will require considerable advance over the state of the art. The current state-of-the-art in avian radar detection is limited in determining the height of birds in addition to range and bearing. We will prototype and test new radar height-finding configurations and sampling strategies to enable real-time warning of avian and bat encounters. Additionally we will examine the use of acoustical monitoring. Lackner and Frasier will collaborate on methods for communicating the necessary data in real time and implementing control strategies. Baker, Lackner, and the environmental science team will develop a quantified set of tradeoffs, for instance expected profits lost versus expected decrease in avian and bat mortality for a given strategy (such as stop all turbines when a particular condition exists). The Social Science team will then work on ways of communicating these tradeoffs, assessing preferences, and determine optimal strategies.

Theme 2 As an example of the second theme, we will focus particularly on the context of the lobster fishery, an important financial and cultural part of the Hull community. Monitoring effects of the wind farm on lobster population dynamics and distribution will be closely linked with efforts to assess public attitudes

and acceptance of the wind farm. **Juanes, Hamin, Kumble, Randhir, Renski, and Ryan** will collaborate to understand the attitudes and preferences of the lobster fishers and at the same time assess the economics of the fishery. Similarly, impacts on the recreational fishery can be monitored by quantifying changes in important recreational fisheries (bluefish, striped bass), and by measuring impacts on the local fishers.

Theme 3 The third theme will involve the integration of a number of projects, including evaluating the impacts of noise, support structures, and layout. A common tool in these projects will be the use of multi-attribute decision tools that will account for technical parameters and objectives and environmental impacts and social preferences. We describe two potential projects here. **Perot** will collaborate with **Juanes** and **Hamin** in a project aimed at assessing the noise impact of turbines on both marine organisms and humans. The CFD created as part of Engineering project 2 will be extended to do aero-acoustic investigations that can be used to estimate noise levels from turbines. Information about noise levels will be used to estimate potential consequences to wildlife and social reactions and preferences. The environmental and social information will then feedback into sensitivity analysis using the CFD to derive tradeoff measurements for noise and other parameters, which will be used by **Baker** and **Randhir** to design a multi-attribute decision model. We will use a multi-model approach, going back and forth between the CFD – which analyzes one particular design at a time – and a multi-objective decision model, which analyzes tradeoffs between designs. Baker has successfully used a multi-model research design before, combining large technologically-detailed Integrated Assessment Models with technology-focused R&D portfolio models (Baker & Solak 2010).

In a similar manner, **Arwade, DeGroot, Lackner** and **Juanes** will collaborate on experiments leading to evaluations of different support structures, such as the traditional monopoles, but also such possibilities as gravity bases, jackets, and tripods (See Fig. 10). The engineering team will further their stochastic multi-physics model to simulate a range of support structures. **Juanes** will collect and analyze data on reef structures to estimate the impact of feasible alternative support structures to ecosystems. Together this group can build a set of explicit tradeoffs, which can then be used in a multi-objective decision analysis.



Figure 10: Example support structure options for offshore wind turbines.

5. Organization, Management and Institutional Commitment

5.1 Organization and Management The proposed IGERT requires a carefully conceived and conscientiously executed management plan to achieve success in meeting its project objectives. The most important elements of such a plan are: a well-defined, logical organizational structure, including adequate internal and external management oversight; effective methods for communication, cross-pollination of ideas and information, and other team-strengthening tools; adequate controls on the use of project resources (human, material and financial); realistic timelines and mechanisms for adjustment; and an assessment/evaluation system to provide feedback for improvement of the project impact. These are met through the rigorous administrative structure and evaluations described below. In addition, the interaction of the thrusts and the integration of their respective efforts are vitally important to the success of this project. To this end, we have designed mechanisms to promote direct interactions between all researchers. These include the seminar series, monthly meetings of the thrust leaders and Co-PI's; thrice-yearly meetings of the steering committee; an annual advisory board meeting; and an annual retreat of the whole IGERT instructional team. Note that these meetings may include members using teleconferencing, and will use appropriate technology at the university to make this feasible.

The primary structure of the project consists of the Thrust team leaders, who report to the Project PI and director, **Dr. Baker**. She has been PI on a DOE-funded project that involved a total of 5 other senior researchers, all at different institutions; an EPA-funded project involving collaboration across campus as well as with the local planning commission and a wide variety of community activists; and two NSF-funded proposals, including a collaborative proposal involving another campus. She has been active in NEAGEP, and has worked to increase participation by under-represented minorities and women in her

professional organization through her roles as cluster chair, student paper chair, and Council member. The Co-PIs will act as thrust leaders: **McGowan** for Engineering, **Juanes & Griffin** for Environment, and **Hamin** for SER. Baker will be guided by two bodies: 1) a steering committee to advise on the management, resource allocation, and progress of the project; and 2) an advisory board to advise on the overall strategy of the project. Additionally, there will be a project coordinator to assist in the day-to-day running of the project.

The **Steering Committee** will be established with representation from diverse departments, research areas, and campus leadership positions, with composition of:

- PI **Baker** (IGERT Program Director);
- Senior IGERT personnel **Griffin**, **Hamin**, **Juanes**, and **McGowan** as well as **DeGroot**, **Fisher**, and **Servaes**. **Griffin** is currently Co-Director of the multi-departmental Environmental Science Program, former STEM faculty for two NSF-funded STEM programs, and former fellow with the National Academy of Sciences and Fulbright programs in Romania and South Africa. **Hamin** has served as the program director for the PhD in Regional Planning for eight years, and has been successful in attracting and graduating minority students. **Juanes** was a co-PI on an NSF funded UMEB program focused on preparing under-represented students for careers in environmental biology. He has also been Graduate Program Director of the Wildlife and Fisheries Graduate Program and is presently Director of the Five College Coastal and Marine Science Program, and campus representative and Graduate Program Director of the UMass Amherst School of Marine Science. **McGowan** is Co-Director of the Wind Energy Center. **DeGroot** is the director of PIRE (described in more detail in Section 8 below). **Fisher** is co-PI on NEAGEP and is the department head of MIE. **Servaes** is the director of the Communication for Sustainable Social Change center and is an expert on international and development communication, intercultural communication and language, and participation and social change.
- Assessment Directors Drs. Martha Stassen and Marilyn Blaustein (see Section 6).
- IGERT Program Coordinator (full time, to be hired).
- Graduate Program Directors from the Electrical Engineering, Economics, and Resource Economics departments.

This committee will meet at least three times per year (September, January, and May) to evaluate program progress. The Steering Committee will elicit assistance from all IGERT faculty and students, particularly in planning mentoring activities, professional development seminars, and recruiting trips.

Specific roles of the committee include:

- Coordinate recruitment efforts aimed at both minority and majority students on and off campus.
- Review student applications and recommend new trainees, to ensure selection of outstanding candidates representing a spectrum of the different thrusts and departments.
- Review assessment data (collected as described in Section 6) annually and develop an implementation plan for program improvements.
- Review the progress of the real-time case study and suggest new directions.
- Review IGERT curriculum to assure coverage and suggest new courses to be added.
- Provide input to IGERT Director on any additional program issues that may arise.
- Review expenditures from Program's prior year and suggest any needed changes to future allocations.

We will also develop an IGERT **Advisory Board** that will convene annually. Their role is executive oversight. This board will be composed of both UMass Amherst members and external members from policy, industrial, and academic communities, and may include:

- UMass Amherst Dean of the Graduate School (John Mullin) and Vice Provost for Research (Mike Malone).
- State Representative Stan Rosenberg.
- A representative from the town of Hull, such as the Town Manager.
- A leading researcher from academia or a research institute such as the NWTTC.
- A representative of the state of Mass, such as from the Executive Office of Environmental Affairs.
- A representative from a WEC industrial partner.

At the annual Advisory board meeting, the IGERT Program Director (PI Baker) will provide a written report and presentation on the prior year activities, accomplishments and assessment data, as well as planned project activities for the coming year. The board will provide guidance on the technical work being carried out and will use the assessment data to make recommendations on improving student experiences, enriching collaborative interactions among the partners, making resource allocations, and overall project management. This external panel is intended to be an effective quality control structure to ensure that the project attains the highest possible achievements in both technical advancements and in the development of its participants. The IGERT instructional team will have an annual retreat in January to review the feedback received from the Steering, Advisory, and Evaluation committees, discuss current status and expectations, and make plans for the next academic year.

A full-time IGERT **Program Coordinator** will be hired to supervise daily operations, manage the seminars, coordinate assessment activities and liaise with industrial and case-study partner connections. The Program Coordinator will also organize travel and other recruiting activities, while IGERT faculty will attend the actual recruitment events. The **Program Coordinator** will be housed in the WEC offices and report to the IGERT Program Director.

In order to enable collaboration conferencing, we will purchase one dedicated laptop/monitor/video and analog system as outlined in the RFP to be compatible with Access Grid freeware and enable collaboration with NSF and other IGERT sites. This system will be available 24/7 in the WEC facilities for the IGERT team. Additionally, we have free access to multiple rooms on campus configured for video conferencing, described in more detail below.

5.2 Institutional Commitment All necessary resources for successful implementation of this project are present at UMass Amherst. We will utilize campus facilities in both training and completion of interdisciplinary research activities. Industrial and policy connections will be facilitated through **WEC**, **ECO**, **LARP**, and the Center for Public Policy and Administration, which have extensive networks of industrial partners, and local, state, and federal policy makers. We will work with the Center for Teaching and Learning, as described below. UMass Amherst has two existing IGERTs: (DGE0504485) entitled, “**Research and Innovation in Nanoscale Device Development**”; and (DGE0504485) entitled “**Interdisciplinary Research Training in Cellular Engineering**”. There is no overlap in research areas between either of the proposed IGERTs and the existing IGERT.

UMass Amherst is committed to expanding research and training opportunities in diverse fields related to energy and the proposed IGERT is supported at all levels of University administration. UMass Amherst and the UMass President’s Office have provided \$155K in seed funding to **WEC** to help establish novel interdisciplinary research and training activities in renewable engineering. For this IGERT the UMass Amherst administration has worked with the participating departments and colleges to get several specific agreements. First, the College of Engineering will sponsor an ethics course with a theme of technology and society. Second, the LARP department has agreed to sponsor the interdisciplinary course on Wind Energy and Society and provide them with a dedicated studio, thus assuring that the class will be sustainable. Third, UMass Amherst will waive any educational or health fees that are not covered by the IGERT educational expenses. Fourth, the campus is committed to supporting cyber-enabled conferencing ability. UMass Amherst’s video conferencing facilities are equipped with state-of-the-art Tandberg video conferencing equipment and allow real-time exchange of voice, video, and data with other facilities around the world. The facilities include rooms that seat 2 – 20 people and a portable system.

Finally, the Graduate School has pledged to fund up to 8 additional graduate half-time RA positions during the academic year, dedicated to students in LARP, Resource Economics, Economics, and Environmental Conservation, to be used to extend funding for their students beyond the 2-years support expected from the IGERT NSF funding. This additional support will help alleviate potential continuity in funding concerns for students and their faculty advisors.

There are two other groups on campus preparing full IGERT proposals this year. One, Materials-based Immunological Engineering, has no overlap with our IGERT. The other, entitled Societal Interaction with and Response to Complex Engineered Systems (SIRCES), does share some faculty with our IGERT, and has a related theme. It proposes to train students in the innovation and design of complex engineered systems, in particular addressing the integration of societal and technical elements of such systems. The proposed research projects do not overlap. In particular, in SIRCES, Frasier and McGowan will be looking at estimating the over-land wind, primarily related to weather rather than energy. This uses very different technologies and techniques than off-shore wind sensing for wind farm siting. The general

theme of SIRCES, however, is quite complementary with our IGERT. They are taking a broad, top-down approach to thinking about society interactions with engineered systems; we will be taking a bottom-up approach, focusing in great detail on one particular and important technology.

6. Performance Assessment and Project Evaluation

Project evaluation and improvement is a central organizing component of the project. We will use an external team and other external resources to provide annual program and teaching evaluations, and then use our management structure to implement changes rapidly so as to make the project highly successful. Project evaluation will involve both formative and summative activities, designed to provide feedback to the **Steering Committee** and to assist in project improvement. Our methods will include: long term tracking with comparative data; formative data while the program elements are in process (including focus groups, and individual interviews from multiple types of participants in the project); statistical tracking of student participation beyond specified IGERT students; individual course evaluations; and student portfolios. Below we introduce our evaluation team, list each objective and discuss the methods we will use in assessing success in achieving the objectives.

Project Evaluation Team This project will be evaluated through collaboration between the Office of Institutional Research, the Office of Academic Planning and Assessment (as external evaluators) and the faculty and program administrators of this IGERT. **Dr. Martha Stassen**, Director of Assessment and **Dr. Marilyn Blaustein**, Director of the Office of Institutional Research (OIR) at UMass Amherst will be responsible for formative evaluations of each IGERT program element or course, as well as evaluation of recruitment and retention activities. Dr. Blaustein has worked in the field of institutional research for over 20 years and has been the Director of OIR at UMass Amherst for over 15 years. Under her direction, the OIR has supported many evaluation initiatives of grant-supported projects. Much of this work has focused on developing tracking systems, both at the undergraduate and graduate level, to monitor the progress of students towards the degree. Her office also maintains extensive data about the characteristics of students on campus and is responsible for detailed analysis and reporting. She holds a PhD from Iowa State University in Research and Evaluation and is an active participant in the Association for Institutional Research and the Northeast Association for Institutional Research. Dr. Stassen has worked in the field of assessment and evaluation for 15 years, both on the UMass Amherst campus and as an evaluator for grant-funded projects at other higher education institutions. In addition to her extensive work assessing the success of institutional initiatives related to diversity, Dr. Stassen has expertise in developing course- and program-based assessment activities in collaboration with faculty members and department chairs. She is well-versed in a variety of evaluation and assessment methods, including survey design, direct assessment of student performance, and interview and focus group methodology. She holds a PhD in Higher Education from the University of Michigan and is active in regional assessment activities as the President of the New England Educational Assessment Network. Drs. Blaustein and Stassen have worked collaboratively, most recently on the evaluation of the NEAGEP project and have many years of experience working together on a variety of institutionally based program evaluations.

Teaching Evaluations UMass Amherst has an excellent Center for Teaching (CFT), and we will utilize their services to assure quality teaching in our IGERT courses. Each instructor will invite the CFT to do a mid-semester formative evaluation, which provides the ability to improve courses while they are still in session. Instructors will also be encouraged to invite CFT personnel to observe classes and provide advice on teaching improvement.

Assessment Strategies for Project Goals

Goal 1: encourage and motivate students, particularly those from underrepresented groups, to pursue research careers in renewable energy. We will assess this throughout the program by using **focus groups** and **individual interviews** that will collect information on topics such as what informed the participants' decision to attend UMass Amherst, their experiences with the program structure and how they see this impacting their choice of career, the impact the program has on their ability to perform interdisciplinary research, and questions about program climate, faculty support, and overall program benefits. This goal will also be assessed using **numerical data** on applications, admission, and enrollment of students in the program using the same database system developed to evaluate success of the NEAGEP program. We will use a recently developed milestone-based tracking system that follows the progress of individuals from admission through graduation to monitor retention and time to degree. We will monitor time required for advancement to candidacy, acceptance of dissertation proposal, as well as program-specific requirements. Additionally, we will track the wider impact of the IGERT, such as non-

IGERT students attending our classes and seminars, and community or industry internal goals achieved through the studio or student projects.

Goal 2: **create an environment in which students and faculty engage in transformative interdisciplinary research.** This will be assessed using student portfolios, an IGERT faculty annual survey, and a count of collaborative papers published or presented, or grants applied for or received. Each IGERT student will put together a **portfolio** of their interdisciplinary work that will be presented by the trainees in their final year of their PhD program as part of the seminar. The portfolio will contain the reports from each of the three core courses as well as an integrating project. We will work with the UMass Amherst Assessment office, the Center for Teaching, and the ICE IGERT on effective ways to use portfolios as learning and evaluation methods. We will focus on evaluating the particular aspects of this program that are critical and unique. For this goal we will evaluate to what degree each student integrates the three perspectives – engineering, environmental, and social – in their work. Portfolios provide a direct assessment of student’s achievement. To evaluate these portfolio artifacts, the faculty will develop a set of scoring rubrics, based upon the identified student learning goals. A subset of the IGERT steering committee will review each student’s portfolio when they complete their coursework and schedule their comprehensive examinations. The goal of the review will be to determine ways to improve the overall project, rather than as a criteria for evaluating the individual student. We distribute a brief survey to faculty in September (corresponding with the timing of the University faculty annual reports) that asks IGERT faculty to list collaborative activities from the prior year, and we will track these numbers and their trends. We will also assess effectiveness of the research program by determining the number of papers coauthored, as well as the number of collaborative grants received by IGERT members from different disciplines.

Goal 3: **Provide students with a curriculum that achieves both deep knowledge in their chosen field and inter-disciplinary knowledge across fields related to wind energy including exposure to state-of-the-art topics through an innovative real-time case study (on a proposed wind installation in Hull, MA) and international exchanges and training in participatory communication.** This goal will be assessed using student portfolios, quantitative data, and course evaluations. For this goal, we will use the **portfolios** to evaluate the quality of the student’s work, in a similar manner that one would evaluate a set of journal papers. We will track the students with **data** on their grades and breadth of classes. We will use multiple methods to assess and improve the **individual core courses** and the ethics course. These methods include specialized end-of-course student evaluation forms that we will design in conjunction with Dr. Stassen, along with mid-semester evaluations that include both surveys and focus group discussion of how well the course is meeting its objectives. For this goal, the individual course evaluations will include specific questions on the effectiveness of the case study. Additionally, we will monitor success of trainees by determining the number of presentations at national meetings, peer-reviewed papers authored, and grants received annually.

Additionally, we will focus particularly on the role of communication, assessed using focus groups, course evaluations, and student portfolios. The **focus groups** aimed at assessing this goal will not only include the IGERT students, but a variety of other people touched by this project, including faculty participants, and contacts from the town of Hull to assess how the case study projects and other research projects have responded to the town’s needs. The **course evaluations** will include specific questions on the effectiveness of interdisciplinary communication. For this goal we will also evaluate the degree to which participatory communication is evident in the student **portfolios**.

Goal 4: **provide students with skills and strategies for professional success including activities centered on career guidance and ethics.** We will assess this goal using focus groups, course evaluation(s), and follow-up surveys. The focus groups will be scaffolded, changing topics and objectives as the program evolves. As the project matures, we will focus on topics related to career development and ethics, such as how students view the program as directly contributing to their career achievements, and their reflective understandings of themselves as practitioners of scientific ethics. We will use in-depth course evaluation of the ethics course, including a mid-semester qualitative evaluation. We will track students through a web-based survey during the five years after each student completes the program, in which we will collect extensive information, modeled on the successful UMass Amherst ICE IGERT surveys. These evaluation results will be summarized in the Program Director’s annual report, and at the annual IGERT faculty retreat, the team will review assessment results and discuss program changes.

7. Recruitment, Mentoring, and Retention

Diversity and Recruitment The leadership of this IGERT includes two females and one under-represented minority. UMass Amherst has particular strength in minority student recruiting and retention through the NSF-funded Northeast Alliance for Graduate Education and the Professoriate (NEAGEP). **Fisher** is a co-PI of NEAGEP and will take the lead in integrating the IGERT and the NEAGAP, which includes formal collaborations among ten research-extensive and five minority-serving Partner Institutions and informal connections to 26 other partner institutions. We will leverage the successes of this program in promoting both faculty and student diversity in this IGERT. Many of the IGERT faculty are active in the NEAGEP program. Our goal is for each IGERT faculty member and trainee to be involved in NEAGEP-funded activities including: (1) mentoring in the Summer Program for Undergraduate Research (SPUR), an 8-week summer program for talented U.S. underrepresented minority (URM) students; (2) attending NEAGEP Partner Days (held twice a year at Partner Institutions); (3) attending NEAGEP Science Days (held annually at Alliance Institutions) for recruiting URM postdoctoral fellows and faculty members; (4) participating in NEAGEP-sponsored on-campus recruiting event to bring in 35-50 URM undergraduate students interested in academic careers in renewable energy; (5) mentoring URM graduate students for whom NEAGEP will fund first and final-year fellowships; (6) participating in social and professional development meetings held monthly for all URM STEM graduate students; and (7) hosting a recruiting program wherein groups of URM senior graduate students and postdoctoral fellows will be brought to UMass Amherst annually to learn about faculty opportunities. Finally, we intend to actively recruit faculty members from our partner institutions to visit UMass Amherst for a semester or a summer to encourage research collaborations between institutions and to aid recruitment of students. We will collaborate with the other two IGERTs on campus, who have been successful at working together to improve URM enrollment in their programs.

Domestic Students and Broad Participation The departments participating in the IGERT have strong records of recruiting domestic students. In the WEC, 13 out of 15 funded graduate students are U.S. students, in the NSF PIRE project thus far 46 out of 54 funded students are U.S. citizens, and similarly in the ECO department approximately 80% of graduate students are domestic.

This IGERT will benefit the broader UMass Amherst community by encouraging broad participation from students beyond the specific IGERT students. The introductory wind energy class, *MIE 573: Engineering Wind Power Systems*, had over 70 enrollees in 2009, with a mixture of undergraduates and graduates. This is double the amount from 4 years ago, as wind energy has become extremely popular among undergraduates and graduate students at UMass Amherst. It is anticipated that undergraduates and graduate students in many of the departments will participate in some of the IGERT activities. Many professional masters' students in the CPPA are interested in renewable energy and are likely to participate in many of our offerings. LARP is currently establishing environmental planning dual degree programs with universities in China and Brazil, and has a number of students researching climate change planning. Students from each will be interested in the IGERT course offerings and will encourage a broader international consideration of policy. Thus, this program will have benefits to a much broader community than just the IGERT students.

8. Recent Traineeship Experience

Fisher is co-PI on the NEAGEP Program (HRD0450339), aimed at increasing minority participation in STEM disciplines. NEAGEP piloted a number of successful recruiting and retention activities and established strong ties with over 30 minority-serving institutions, as well as diversity coordinators in 10 research universities in the northeast. As a result, UMass Amherst doubled the number of applications and tripled the number of URM students enrolled in STEM doctoral programs. The retention rate has increased from approximately 29% to a current rate of 85%. This year we anticipate that 10 NEAGEP scholars will be graduating with PhD degrees, a number representing a 5-fold increase over the graduation rate during the period before NEAGEP. **DeGroot** is PI on "PIRE I: Developing International Protocols for Offshore Sediments and their Role in Geohazards: Characterization, Assessment, and Mitigation (0530151)." The PIRE project has thus far involved 60 participants from all career levels (28 UG, 12 MS, 12 PhD, 2 Postdoc, 6 Faculty). Of these participants, 52 are US citizens and 27 are from underrepresented groups. The extent of training, mentoring (peer and ladder), collaboration, and technology transfer involving the numerous participants across multiple US and International institutions (e.g., Research I, PUI, Public, Private) indicates the significant level of human resource development occurring in this project.

9. International Collaboration

We will provide for significant interaction with international research centers. The international component will have two main parts. First, all students will participate in a two week travel class. They will visit the Netherlands, including the Technical University of Delft (TUD), with two professors from two different thrusts. This site was chosen because it has a university at the forefront of wind energy academic research, the region has substantial wind energy development, and participating faculty have strong ties to TUD. The students will visit onshore and/or offshore wind farms in the region, meet engineers and planners/policymakers for these wind farms, see the laboratories, and interact with a wide variety of researchers and stakeholders. Upon their return students will each prepare a report summarizing what they have learned including a short review of a particular topic of interest. To prepare the students, the seminar series will devote a number of meetings in the semester before the trip to reading the research papers from the labs, and to familiarizing themselves with the policy organization of wind energy in the EU and individual countries, as well as the general history of the region visited. This will provide all students with an international perspective, prepare students who will conduct research at the international Institutions (see below), provide a different perspective than the Hull case study, integrate social, engineering, and environmental aspects, and provide a shared experience for each cohort. Co-PIs Griffin, and Juanes as well as Kumble all have extensive experience leading international travel classes. The research field trip will occur at no cost to the students as we have budgeted for this expense as part of our International Allocation.

Second, we will partner with two leading institutions in wind energy research, the TUD, and the Norwegian Geotechnical Institute (NGI) in Norway, to provide opportunities for 4 students (per year) to spend an extended time at one of the international laboratories. The PhD exchange opportunities will be available to those students who have complementary research interests to researchers at the international partner institutions. Students will be selected based on their plan of study by the steering committee and monitored by the students' advisor and international collaborator. Upon their return students will give a presentation summarizing their international research project as part of the seminar series. This will serve as a chance for students to gain communication skills and for new students to learn about the international internships. Our strong ties to these international institutions include **Lackner** who did postdoctoral research at TUD, and still collaborates with researchers there on aerodynamic research topics. Likewise **DeGroot** did a sabbatical at NGI in 1997 and has an ongoing collaborative research program, which has included several UMass Amherst PhD students, on characterization of offshore seabed sediments. Thus IGERT PhD students working on these and other relevant topics – including the environmental and policy topics – could benefit from the expertise at TUD and NGI, as well as their state-of-the-art experimental facilities.

10. Recruitment and Retention History

Department of Biology

Department of Biology	2007-2008				2008-2009				2009-2010			
	Woman	Minorities	Other	Total	Woman	Minorities	Other	Total	Woman	Minorities	Other	Total
No. applicants to PhD program	14	1	8	22	20	1	13	33	20	4	10	33
No. applicants accepted by program	7	1	1	8	3	0	4	7	2	2	2	6
No. that matriculated	3	1	1	4	2	0	3	5	1	1	1	3
No. PhD awarded	2	0	2	4	2	0	2	4	3	0	2	5
No. currently enrolled	16	1	13	29	15	0	14	29	11	1	11	23

Department of Civil Engineering

Department of Civil Engineering	2007-2008				2008-2009				2009-2010			
	Woman	Minorities	Other	Total	Woman	Minorities	Other	Total	Woman	Minorities	Other	Total
No. applicants to PhD program	2	0	1	3	2	0	3	5	2	1	2	4
No. applicants accepted by program	1	0	0	1	1	0	2	3	2	1	1	3
No. that matriculated	1	0	0	1	0	0	2	2	0	0	1	1
No. PhD awarded	1	1	0	1	0	0	1	1	2	0	3	5
No. currently enrolled	4	1	4	8	3	0	4	7	3	0	3	6

Department of Communication

Department of Communication	2007-2008				2008-2009				2009-2010			
	Woman	Minorities	Other	Total	Woman	Minorities	Other	Total	Woman	Minorities	Other	Total
No. applicants to PhD program	27	10	23	55	32	2	13	46	34	5	22	57
No. applicants accepted by program	8	2	8	17	7	0	6	13	5	3	2	7
No. that matriculated	4	2	3	8	3	0	2	5	2	2	0	2
No. PhD awarded	2	1	3	5	1	0	1	2	2	0	1	3
No. currently enrolled	26	7	14	42	25	6	15	42	26	8	15	43

Department of Electrical & Computer Engineering

Department of Electrical & Computer Engineering	2007-2008				2008-2009				2009-2010			
	Woman	Minorities	Other	Total	Woman	Minorities	Other	Total	Woman	Minorities	Other	Total
No. applicants to PhD program	2	2	10	13	4	3	6	12	2	5	7	12
No. applicants accepted by program	2	1	8	10	2	2	4	7	1	2	3	5
No. that matriculated	0	0	1	1	1	1	3	4	1	2	1	3
No. PhD awarded	0	0	5	5	0	0	0	0	0	0	1	1
No. currently enrolled	1	4	11	15	3	6	9	16	4	8	9	18

Department of Economics

Department of Economics	2007-2008				2008-2009				2009-2010			
	Woman	Minorities	Other	Total	Woman	Minorities	Other	Total	Woman	Minorities	Other	Total
No. applicants to PhD program	14	5	33	50	17	3	17	36	12	8	31	49
No. applicants accepted by program	5	1	6	11	4	0	2	6	4	1	5	10
No. that matriculated	2	0	2	4	3	0	1	4	2	1	2	5
No. PhD awarded	1	0	2	3	1	0	0	1	2	0	1	3
No. currently enrolled	20	6	16	41	25	6	16	46	24	7	17	47

Department of Environmental Conservation

Department of Environmental Conservation	2007-2008				2008-2009				2009-2010			
	Woman	Minorities	Other	Total	Woman	Minorities	Other	Total	Woman	Minorities	Other	Total
No. applicants to PhD program	9	0	8	17	5	1	4	9	6	0	3	9
No. applicants accepted by program	2	0	5	7	0	0	2	2	0	0	3	3
No. that matriculated	2	0	5	7	0	0	2	2	0	0	2	2
No. PhD awarded	1	0	2	3	0	0	1	1	3	0	1	4
No. currently enrolled	7	0	14	21	8	0	15	23	6	0	17	23

Department of Landscape Architecture and Regional Planning

Department of Landscape Architecture and Regional Planning	2007-2008				2008-2009				2009-2010			
	Woman	Minorities	Other	Total	Woman	Minorities	Other	Total	Woman	Minorities	Other	Total
No. applicants to PhD program	0	0	0	0	5	2	6	13	3	1	5	9
No. applicants accepted by program	0	0	0	0	5	0	3	8	2	1	4	7
No. that matriculated	0	0	0	0	3	0	1	4	0	1	1	2
No. PhD awarded	0	0	0	0	0	0	0	0	0	0	0	0
No. currently enrolled	3	1	1	4	4	1	2	6	4	1	2	6

Department of Mechanical and Industrial Engineering

Department of Mechanical and Industrial Engineering	2007-2008				2008-2009				2009-2010			
	Woman	Minorities	Other	Total	Woman	Minorities	Other	Total	Woman	Minorities	Other	Total
No. applicants to PhD program	6	1	11	18	5	1	15	21	4	2	16	22
No. applicants accepted by program	6	1	10	17	4	0	15	19	3	1	15	19
No. that matriculated	1	0	2	3	2	0	2	4	0	0	4	4
No. PhD awarded	1	0	3	4	0	0	1	1	0	0	2	2
No. currently enrolled	4	1	15	19	5	1	15	20	5	1	17	22

Department of Resource Economics

Department of Resource Economics	2007-2008				2008-2009				2009-2010			
	Woman	Minorities	Other	Total	Woman	Minorities	Other	Total	Woman	Minorities	Other	Total
No. applicants to PhD program	2	0	1	3	3	1	1	4	0	0	4	4
No. applicants accepted by program	1	0	0	1	2	1	1	3	0	0	2	2
No. that matriculated	1	0	0	1	1	1	0	1	0	0	1	1
No. PhD awarded	0	0	1	1	0	0	0	0	0	0	0	0
No. currently enrolled	1	0	1	2	1	1	1	2	1	1	2	3