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Graduate and undergraduate university programs in wind energy in the United States

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Abstract

Advances in wind energy technology and continued expansion of wind energy into the United States and global electricity grids will depend upon an educated and skilled workforce. While wind energy technician programs at community colleges or vocational schools have prospered in the United States over the past decade, partially due to the high demand for wind technicians, university programs that prepare graduates pursuing baccalaureate and advanced graduate degrees have lagged behind. At the same time, European university programs in wind energy have flourished, providing experts with advanced degrees who are then employed worldwide by the global wind energy industry. According to a projection of wind industry jobs needed in the U.S. Department of Energy's *Wind Vision* report[1] and estimates of education level requirements for jobs, as provided in this article, the United States may need more than 50,000 university-educated professionals with advanced degrees to support wind energy development by 2030. To provide these professionals, the number of wind energy academic programs must increase significantly beyond those available today—a task that will require collaboration among universities and external support from both industry and government. This article provides a review of the growing need for a university graduate-level-educated wind energy workforce, an overview of the current domestic wind energy workforce picture, existing global and domestic university wind energy programs, and recommendations for university-level wind energy education programs in the United States.

Keywords

Wind energy, wind power, graduate education, university wind energy programs, wind energy workforce

Introduction

Wind power is now a major source of energy in the US electric power system. Over the past two decades, the annual growth rate for wind power capacity installations in the United States has averaged over 20%. In 1995, less than 1% of the net electricity generation in the United States came from wind power; by 2016, over 5.5% of the net generation came from wind power (U.S. Energy Information Administration, 2017). In March 2017, for the first time, wind energy, together with solar photovoltaics, provided 10% of the energy consumed in the United States, with wind energy providing 8% of the combined wind and solar electric generation (see Figure 1).

With increasing wind energy capacity additions and other utility technology improvements, the electric power industry is rapidly changing and evolving. Natural gas, long thought to be a clean and desirable resource for energy production, was in short supply for many years. In the 1970s, federal regulations prohibited natural gas-fired boilers due to shortages of natural gas and its need for heating homes. Today, natural gas and renewable power sources—such as wind and solar—are replacing coal-fired generation. Nuclear generation, which grew rapidly during the 1960s and 1970s, saw little growth as

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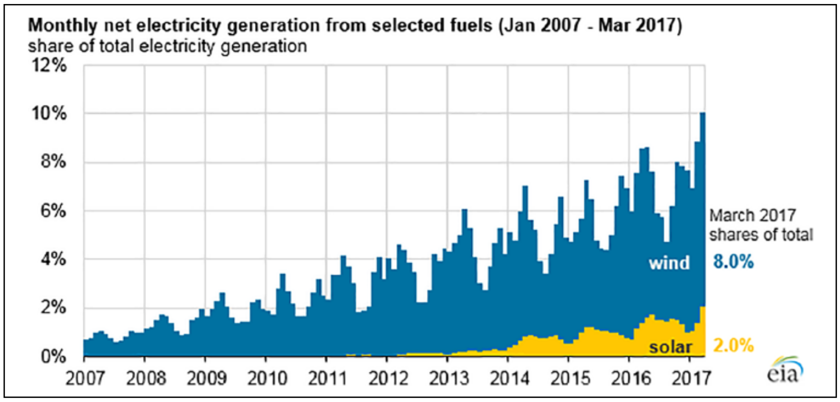

Figure 1. Growth in wind power and solar energy utilization on the US electric power grid.
Source: U.S. Energy Information Administration (2017).

a fuel source for electric power in the 1980s, and its contribution to the power grid has been nearly static since 1990 (U.S. Energy Information Administration, 2017). In addition, electric utility load growth (electricity demand) has been essentially flat during the past decade. This is unique in the history of the US electric utility industry since World War II and is the result of a combination of factors, including (1) a slower US economy over the past 10 years coupled with low population growth; (2) new energy efficient technologies, such as the use of light emitting diodes (LEDs) for lighting; (3) new energy efficiency standards programs for appliances; and (4) utility demand side management programs. Furthermore, the nature of the load served by the utility is evolving; load can now participate in electrical system balancing. Power system planners and operators are now faced with scheduling and dispatching their traditional thermal generation to meet the "net load" (i.e. the load minus wind and solar generation). More tools may become available to help balance the net load, such as electric vehicles or affordable storage devices for electricity. Another emerging application is combining wind energy systems with solar energy systems, particularly in remote locations (e.g. Khare et al., 2013). Wind power systems are being combined with other resources to form micro-grids designed for operation in either a grid-connected or a stand-alone operation for improved power resiliency, especially in remote or island locations, or in areas with a weak grid system. All of these factors are contributing to an evolving electric power industry that will function in fundamentally different ways, and with very different workforce needs and requirements than in the past.

Wind industry expansion and nascent wind power applications

In addition to a rapidly changing electric power industry, the wind energy industry is also evolving and growing, which will lead to the need for more highly qualified workers with a wide variety of skills. Although this article focuses mostly on workforce needs in the United States, there is a rapidly growing global market for wind energy and, therefore, a global demand for wind energy jobs. Global wind energy installation trends are moving into offshore, as well as the more traditional on-shore development. European wind energy development has been rapidly moving to offshore installations over the past 15 years. Figure 2 shows global offshore wind energy installations and announced projects as of early 2017 (Musial et al., 2017). In 2016, Deepwater Wind opened the Block Island 30-MW Wind Farm, the first operational offshore wind power plant in the United States. Future expansion of offshore wind is expected and will require advances in both offshore wind technology and new workforce requirements.

Although still nascent in the United States, offshore wind energy is poised to undergo expansion in the near future, with thousands of megawatts (MW) of commercial projects already in the planning stage in a number of states. Development of offshore wind energy also involves a wide range of specialties beyond the turbines, including design and fabrication of the support structures and electrical systems, as well as in logistics, maritime facilities, and ports (Gilman et al., 2016).

The combination of these developments—on-shore wind as a mainstream electric generation technology, new emerging applications of wind power, and offshore wind energy development—has led to strong job growth in the global wind-electric power sector. Such developments have also created a parallel need for education and skills training to meet the wind energy industry's engineering, research, business, manufacturing, construction, operations, and maintenance workforce needs. A March 2017 article in RE News reported that a "lack of talent" has hit the renewables industry.[2] This article followed a comprehensive review of the energy industry in a 2016 survey, called the Global Energy Talent Index report (Marx and Peet, 2017), which surveyed more than 16,000 energy professionals worldwide in the oil, gas, renewables,

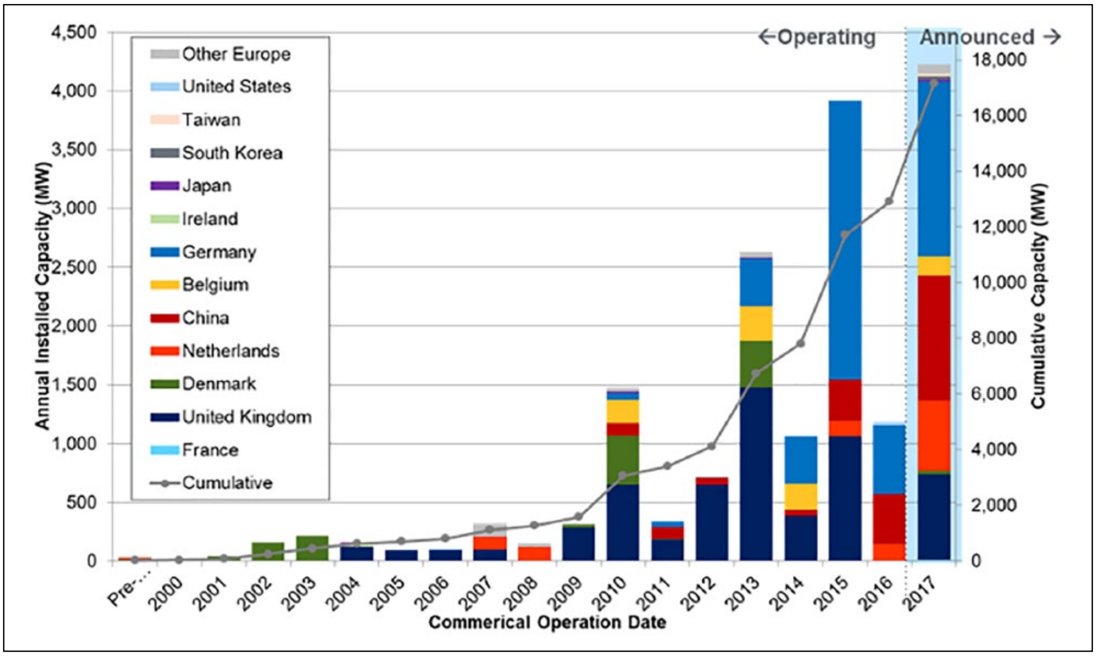

Figure 2. Global offshore wind energy installations—operating and announced (Musial et al., 2017).

electric power, nuclear, and petrochemicals sectors. The renewables section of the report discussed skills and training and summarized the situation

> Essentially these results show us this is crunch time for the renewables sector. The overwhelming majority (of energy professionals interviewed) believe there is a skills shortage and that a lack of planning for knowledge transfer and training is to blame. (Marx and Peet, 2017).

With the continued increase in wind power capacity installed and integrated into the electricity delivery system, the industry will require more highly qualified workers to research, design, construct, operate, maintain, and transmit wind energy in the future. The purpose of this article is to present an overview of the domestic wind energy workforce picture; to provide a review of existing university wind energy programs in the United States and abroad, including an assessment of their adequacy; and to outline recommendations for a path forward for university wind energy education programs in the United States.

Domestic wind energy workforce picture

Background

The need for a qualified wind energy workforce was previously addressed by the U.S. DOE in a major wind energy assessment released in 2008 titled: *20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply* (U.S. Department of Energy, 2008). In that publication, projections for the future US wind energy workforce were presented and discussed. The report estimated the workforce for direct jobs would grow from less than 20,000 in 2007 to over 170,000 in 2030 and expressed concerns about the available workforce:

> One potential gap in achieving high rates of wind energy development is the availability of a qualified work force. … More support from industry, trade organizations, and various levels of government could foster university programs in wind and renewable energy technology, preparing the work force to support the industry's efforts. (U.S. Department of Energy, 2008)

In order to better quantify the need for university undergraduate and graduate wind energy programs to support the growing industry, a 2010 study at Texas Tech University (Walker et al., 2010) estimated the percentage of wind energy direct jobs requiring university-level education with wind energy content. For that analysis, direct jobs were categorized as either (1) professional jobs, requiring a college degree from a 4-year university; (2) technical jobs, requiring some technical

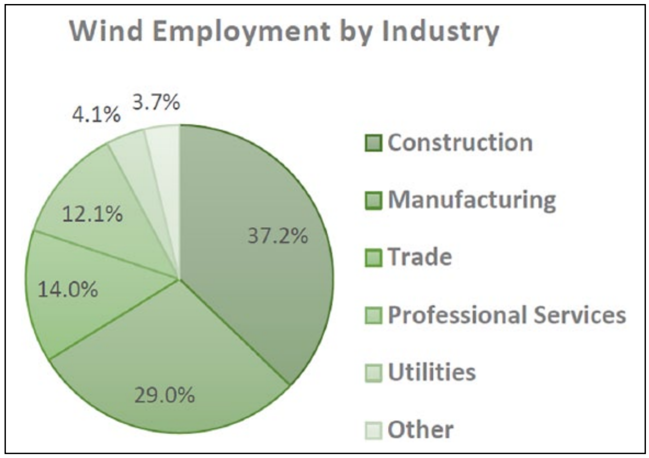

Figure 3. Composition of the domestic wind energy workforce in 2016 by industry sector (U.S. Department of Energy, 2017).

or vocation training; or (3) clerical jobs, which may also require some training. The study used U.S. Bureau of Labor and Statistics (USBLS) North American Industry Classification System (NAICS) industry code data for comparable industries as a proxy for the wind industry because of limited availability of wind-industry-specific data. The codes used were Machine Manufacturing as a proxy for the wind turbine manufacturing industry; Electric Power Generation, Transmission, and Distribution as a proxy for wind energy operations and maintenance; and Utility System Construction as a proxy for wind energy construction. Using the USBLS database and experience in renewable power within the utility industry, best estimates for the fraction of direct jobs requiring university-level education for each job category were listed. The analysis resulted in the following percent of direct jobs in each category requiring university-level education with wind energy content:

Wind turbine and component manufacturing sector: 14%;

Wind project construction sector: 6%;

Wind project operation and maintenance sector: 17%.

By applying these percentages to the estimated number of direct jobs projected in the DOE's 20% by 2030 study, it was estimated that 20,900 direct jobs, or about 12% of the direct jobs projected, would benefit from university education programs in wind energy.

Job growth

According to the U.S. Energy and Employment Report (U.S. Department of Energy, 2017), there are nearly 102,000 people working in the US wind energy industry, and, consequently, this sector has the third-largest share of electric power generation employment. Figure 3 shows the composition of the US wind energy workforce by industry sector.

In a report by the U.S. National Renewable Energy Laboratory (Tegen, 2017), and resulting from interviews with 249 wind energy companies based in the United States, the 2016 domestic wind energy workforce is broken down by occupation. As shown in Figure 4, the American wind energy workforce is diverse and made up of occupations spanning from engineering to construction and from marketing to communications. Educational requirements vary greatly, ranging from engineers who require undergraduate or graduate degrees to trade workers who require a high school diploma or equivalent, sometimes including hands-on, vocational, or specialized training from a community college or other educational institution.

The workforce needs of the offshore wind energy sector are similar, but of a broader scope than the land-based wind energy sector. A wide variety of people with advanced skills is needed to help improve the technology, reduce its costs, and increase reliability, thus allowing ever larger turbines to be placed cost-effectively in progressively deeper water. In addition, and similar to the offshore oil and gas industry, technicians with many different types of skills will be needed to construct and maintain offshore projects. Most technicians will need practical knowledge of electricity, mechanics, and hydraulics, as well as an understanding of the basic principles of wind turbines. In addition, technicians will need courses in both working at height and training in environmental health and safety (Vigeant et al., 2017). Furthermore, technicians will need more advanced training in their own areas of expertise. Typical examples include operation of

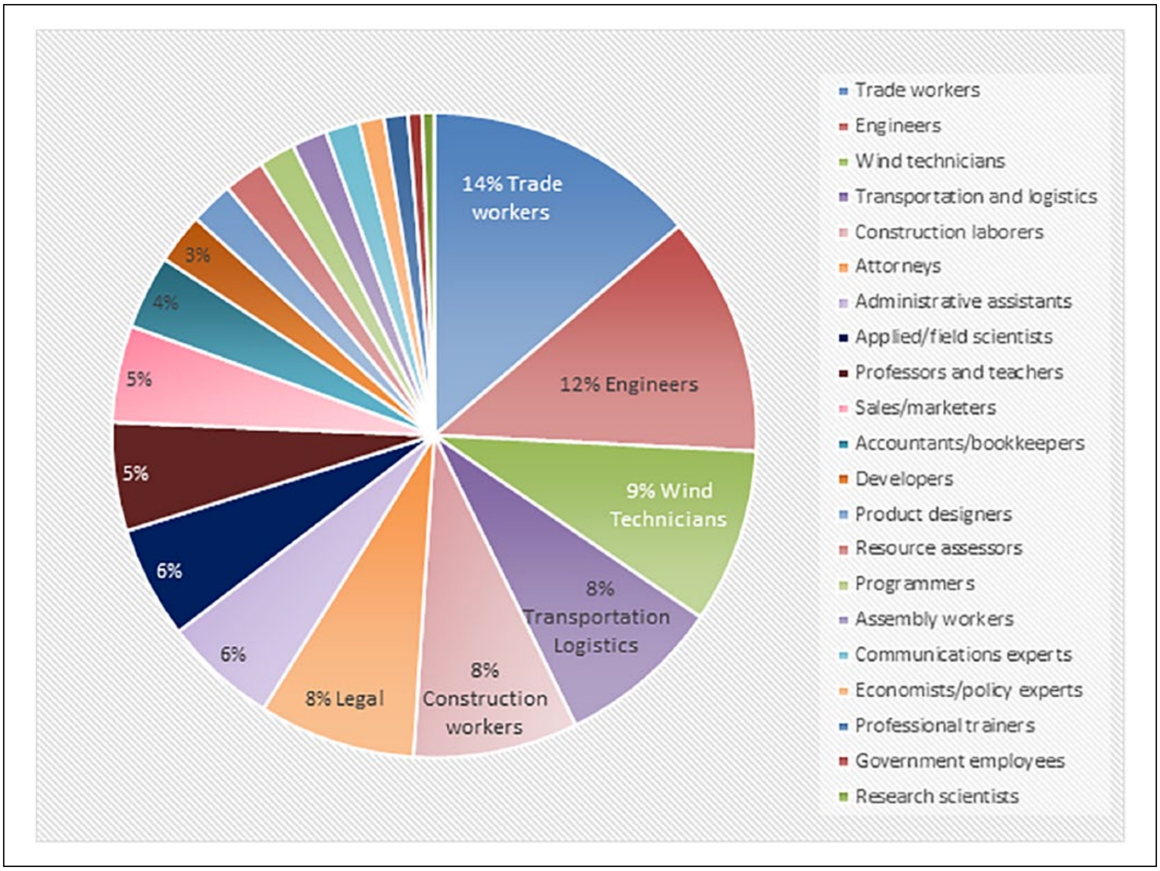

Figure 4. 2016 US domestic wind energy workforce by occupation according to interview with 249 firms (Tegen, 2017).

supply vessels, underwater welding, and support structure fabrication. As offshore wind energy technology evolves, there will be continual need to keep technician training up to date and to take field experience of technicians into account in the design process.

It is worth noting that in the United Kingdom, National Vocational Competencies have been developed that classify required skills for a range of industrial sectors, including offshore wind energy. Five levels have been defined, ranging from Level 1 (activities routine and predictable) to Level 5 ("which involves the application of skills and a significant range of fundamental principles and complex techniques across a wide and often unpredictable variety of contexts") (see Vigeant et al., 2017). An analogous system would be beneficial for the United States, and it is expected that instructors in these areas, as well as faculty in university-based academic programs, will have to coordinate efforts, especially at the higher levels. In addition, university-level academic programs will need to be available to provide the required education and certification for instructors in these technical programs.

The aforementioned U.S. Department of Energy and National Renewable Energy Laboratory (NREL) studies create a picture of today's wind power workforce. The U.S. Department of Energy *Wind Vision* report sets forth plausible scenarios in which 20% of the US electrical energy requirement in 2030 is served by wind energy, and 35% by 2050 (Central Study Scenario in U.S. Department of Energy, 2015). As shown in Figure 5, the estimated number of jobs in these scenarios—on site, supply chain, and induced—necessary to achieve the proposed levels of wind energy penetration with mid-range domestic content are approximately 350,000 in 2030 and 600,000 by 2050, which are substantially greater than today's level.

The need for university graduate-level wind energy programs

According to results from NREL (Tegen, 2017) on the domestic wind workforce, employers require or prefer baccalaureate, MS, or PhD degrees for a large fraction of wind energy occupations (Tegen, 2017). This report also shows the preferred level of education prospective employers seek in the various wind energy occupations based on industry interview data from 249 wind energy-related firms.

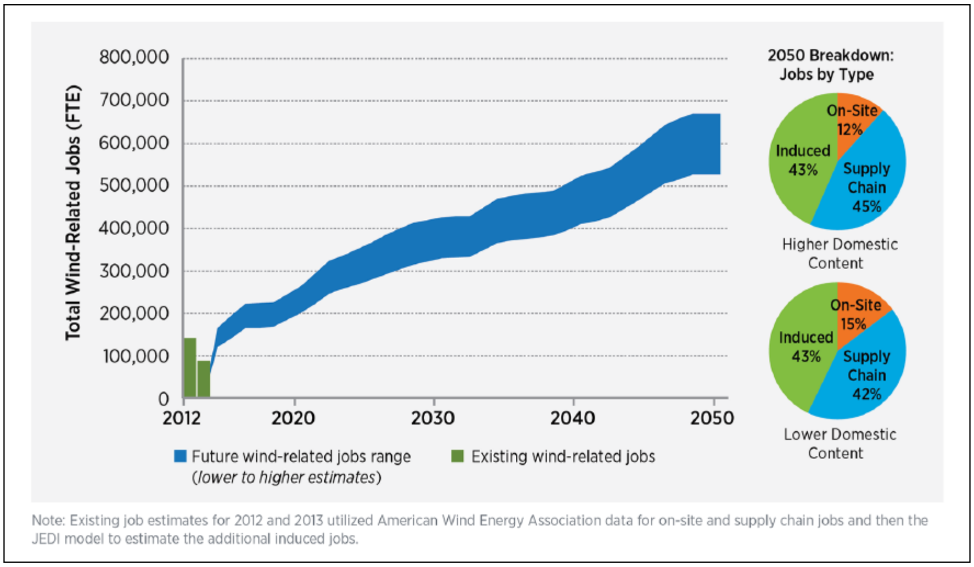

Figure 5. Wind-related gross employment estimates from the *Wind Vision* (U.S. Department of Energy, 2015) for on-site, supply chain, and induced jobs for a range of domestic content.

Referring to the occupations listed in Table 1, Table 2 shows further results from NREL (Tegen, 2017) of the interviews of wind energy companies based in the United States, pertaining to the level of difficulty in finding qualified job applicants. In occupations such as engineering, 80% of people interviewed have either some or great difficulty finding applicants that meet their job requirements. In general, the more specific the occupation is to wind energy, or if the occupation requires a higher level degree (e.g. research scientists, research engineers, attorneys), the more difficult it is to find qualified applicants.

Hiring managers trying to find qualified applicants expand their search outside of the United States—especially for positions that require an MS or a doctoral degree. Results from the 2017 NREL interview show that 25% of wind energy firms contacted searched outside the United States for candidates. According to the NREL interviews, Europeans have more hands-on experience, as well as more wind-specific degrees (e.g. MS in Wind Energy). Employers who hire more applicants with higher education degrees (e.g. graduate school) are looking for wind-specific coursework that also offers experiential learning (Tegen, 2017).

Overview of existing wind energy academic programs

European programs

Europe has long been a global leader in wind power development. In the late 1970s and early 1980s, many countries in Europe, led by Germany, Denmark, and the Netherlands became involved in modern wind turbine design and production. Although the turbines were small by today's standards, the basic design elements of a modern wind turbine were implemented and tested. European manufacturers not only began supplying turbines for the burgeoning European market, but they also began exporting their equipment to the United States and other countries where markets for the new technology existed. To support the wind energy industry's growth in Europe, a number of university programs and other professional education and training incentives were implemented and funded to develop the necessary workforce to support the new industry. Two of the most successful programs are outlined here.

The European Wind Energy Master (EWEM) is an international MSc program. The EWEM is a consortium of four universities in wind energy and offshore research and education: Delft University of Technology (program coordinator), Technical University of Denmark, Norwegian University of Science and Technology, and Carl von Ossietzky Universität Oldenburg. The EWEM is a 2-year program and provides students with knowledge in the theoretical and applied sciences underlying wind energy systems with four specializations: Electric Power Systems, Offshore Engineering, Rotor Design, and Wind Physics. The EWEM program educates between 50 and 60 students per year, supplying highly qualified wind energy professionals with post-graduate education.[3]

The second European program, The European Academy of Wind Energy (EAWE),[4] is a consortium of more than forty member universities from 14 participating European Union countries. Founded in 2004, the EAWE is an organization of

Table 1. Education level preferred, or required, for wind energy occupations based on interview data from 249 wind energy-related firms (Tegen, 2017).

Occupation	High school diploma or less	Post-2-year professional certificate	Associates degree	Bachelors degree	Post-bachelor professional certification	Masters degree	PhD or JD
Attorneys	0%	0%	0%	1%	6%	7%	86%
Professors and teachers	0%	0%	2%	1%	2%	14%	81%
Research scientists	0%	0%	3%	5%	0%	26%	66%
Government employees	0%	0%	0%	55%	9%	20%	16%
Economists and policy experts	0%	5%	0%	13%	5%	65%	10%
Electrical and mechanical engineers	0%	0%	1%	47%	24%	20%	8%
Other engineers	1%	1%	3%	54%	6%	28%	7%
Product designers	0%	1%	2%	77%	0%	10%	5%
Applied/field scientists	0%	1%	0%	55%	1%	40%	3%
Power systems engineers	0%	0%	1%	7%	54%	35%	3%
Assembly workers	72%	11%	15%	0%	0%	0%	2%
Professional trainers	3%	21%	1%	57%	5%	8%	1%
Programmers	0%	2%	1%	61%	4%	17%	1%
Resource assessors	0%	2%	9%	86%	1%	2%	1%
Admin/clerical	21%	15%	26%	34%	1%	1%	0%
Wind technicians	22%	46%	30%	2%	0%	0%	0%
Trade workers	37%	62%	1%	0%	0%	0%	0%
Developers	0%	0%	1%	37%	18%	44%	0%
Civil engineers	0%	0%	0%	21%	2%	76%	0%
Transportation and logistics	76%	18%	1%	4%	0%	0%	0%
Construction laborers (other than skilled trade)	100%	0%	0%	0%	0%	0%	0%
Sales and marketers	4%	1%	2%	79%	0%	10%	0%
Communications and public relations	1%	1%	3%	86%	4%	3%	0%
Accountants/bookkeepers	1%	4%	5%	57%	10%	21%	0%

research institutions and universities in Europe working on wind energy research and development. The academy's main office is located in Oldenburg, Germany. The goal of the academy is to foster academically centered research related to the wind energy community and keep Europe a global leader in wind energy technology and pre-competitive innovation. Academy members meet at least once a year at an annual PhD seminar where doctoral students present their latest research.

In 2013, the European Wind Energy Association (EWEA) sponsored a study titled "Workers Wanted: The EU Wind Energy Skills Gap" (Fitch-Roy, 2013). The study examined a number of wind energy-related job areas in the European sector, including academic research and development, project engineering, project development and related multidisciplinary skills, business and finance, and manufacturing engineering. After examining the workforce needs and expected industry growth in the European Union (EU) through 2030, a gap analysis focusing on workforce education, training, and needed skills in the wind industry was completed. Results indicated a skills shortage (measured in equivalent full-time employees, or FTEs) approaching 15,000 by 2030, with the largest gap in operations and maintenance. The report listed areas for action, including project management and development, where multidisciplinary skills are critical to the power development sector. Project management and development currently accounts for 16% of wind energy employment and shows a continuing skills gap. Another area of action identified that limited EU-wide postgraduate training programs exist and are needed. The report concluded with recommended actions related to university academic programs. These included improving core/STEM (Science, Technology, Engineering and Math) skills; expanding graduate-level wind energy generalists that possess the skills required to develop, build, and operate wind farms; and incorporating industry experience into training and education.

US wind energy programs

The North American Wind Energy Academy (NAWEA) was established in 2013 by a consortium of representatives from US national laboratories and universities. As stated in its charter,[5] the purpose of NAWEA is to facilitate the growth of

Table 2. Level of difficulty in finding qualified applicants, by occupation.

Occupation	No difficulty	Some difficulty	Great difficulty
Research scientists and research engineers	18%	35%	47%
Professors and teachers	33%	33%	33%
Developers	34%	38%	28%
Trade workers	20%	54%	26%
Programmers and computer scientists	26%	51%	23%
Engineers—other	32%	46%	21%
Engineers—power systems/transmission	20%	60%	20%
Professional trainers and industry educators	35%	45%	19%
Sales and marketers	41%	40%	19%
Engineers—electrical or mechanical	25%	60%	15%
Product designers and design engineers	20%	66%	14%
Government employees—regulatory workers	25%	63%	13%
Wind technicians	33%	53%	13%
Resource assessors and surveyors	38%	50%	13%
Paralegals	50%	38%	13%
Economists and policy experts	35%	53%	12%
Construction laborers (other than skilled trade workers)	33%	56%	11%
Applied/field scientists (biologist, environmental)	37%	52%	11%
Accountants/ financial professionals	56%	34%	10%
Engineers—civil	35%	58%	8%
Attorneys	52%	40%	7%
Assembly workers	39%	56%	6%
Transportation/logistics workers	42%	53%	5%
Communications and public relations	50%	46%	4%
Administrative and clerical assistants	62%	36%	2%

Source: Tegen (2017).

wind power into a cost-effective, high-penetration, and sustainable national energy source, producing at least 10 times the 2012 wind energy electricity production levels. NAWEA's Educational Committee's goal is to expand the breadth and competence of the wind energy academic community throughout North America by working collaboratively to develop and offer relevant curricula. The unifying theme is that wind energy—together with other renewable sources, particularly solar energy—will be expected to provide a continuously greater fraction of the US energy supply. Knowledgeable people in many inter-related disciplines will be required to make this possible.

With support from the Wind Energy Foundation via the Southwest Renewable Energy Institute (now named the Western Energy Futures Institute), an ad hoc subcommittee of the NAWEA Education Committee undertook a project to advance US education initiatives. The project's goals were to identify existing university programs in wind energy; to review similar programs in other energy-related fields to understand their scope and funding; and to identify ways to build robust and healthy wind energy educational programs in support of national, international, and wind energy industry–related research and development goals. The project resulted in a report titled "Plotting the Course for Education Programs through the North American Wind Energy Academy" (Manwell et al., 2015). Several educational initiatives were recommended that cover wind energy-related topics from business to policy to engineering to environmental impacts, with a focus on professional education for university graduate- and undergraduate-level students. These include the following:

- Coordinated curriculum development across universities;
- Coordination of program/course development with organizations in need of wind energy expertise;
- Coordination with international wind energy educational programs;
- Program certification and certified courses;
- Wind energy "certificate" or "diploma."

A 2015 review of existing university wind energy-related programs in the United States showed that at least 45 universities offer wind energy courses, with at least 30 offering an undergraduate course, and at least 17 offering graduate courses in wind energy, see Table 3 (Acker et al., 2015; Manwell et al., 2015). Concerning universities with undergraduate

Table 3. Summary of university wind energy educational programs and courses in the United States.

Wind energy offerings at US universities	
Number of universities with courses or programs	45
Universities with undergraduate courses	30
Number of different courses {1, 2, 3, >3}	{22, 4, 1, 3}
Universities with graduate courses	17
Number of different courses {1, 2, 3, >3}	{10, 1, 5, 1}
Universities offering graduate certificates	6
Universities offering BS degrees	1
Universities offering online courses	4

Source: Acker et al. (2015) and Manwell et al. (2015).

offerings, 22 offer one undergraduate wind-related course and 8 offer more than one. At the graduate level, 10 of the 17 offer only one wind-related graduate course, while 7 offer more than one. Five of the wind energy courses are available online (three undergraduate and two graduate). Of the institutions offering graduate programs, six schools offer a graduate certificate in wind energy: the University of Massachusetts Amherst, Texas Tech University, Pennsylvania State University, the University of Iowa, the University of Delaware, and Clemson University. In addition to these US efforts, 12 Canadian universities have renewable or wind energy–related programs or coursework, and 14 Mexican universities participate in the Mexican Center of Innovation in Wind Energy.

When considering other fields of energy education and research, researchers identified and reviewed two similar programs: the Nuclear Energy University Program of the U.S. Department of Energy and the U.S. DOE National Energy Technology Laboratory University Coalition for Fossil Energy. Both of these programs have federally-funded educational efforts related to the US and North American energy future, with funding for university research, education, and student scholarships. As wind power is now a mainstream energy resource, it would be appropriate that focused wind energy education programs be considered for federal research and scholarship funding similar to those in the nuclear and fossil programs, and with similar objectives of sustaining and advancing the energy resource.

As for future wind energy educational programs, Manwell et al. (2015) suggested forming a consortium agreement among collaborating universities offering graduate and undergraduate wind energy courses and certificates. The basic idea behind this agreement is that wind energy courses will be made available online to students from all participating institutions, thus expanding the depth and breadth of courses available to students, as well as the frequency of course offerings. Such an agreement could be modeled after an existing program, such as the Great Plains Interactive Distance Education Alliance (Great Plains IDEA), which is a partnership of 19 public universities providing educational opportunities by collaboratively developing and delivering high-quality, online academic programs. The purpose of the consortium will strengthen and enhance graduate and undergraduate wind energy programs of the participating institutions. Beyond course sharing, the universities will promote collaborative teaching, faculty exchanges, and faculty serving on graduate committees at universities other than their own.

Gaps in wind energy educational programs

Using data from Manwell et al. (2015), Tegen (2017), and from the U.S. Department of Energy's *Wind Vision* report (U.S. Department of Energy, 2015) related to wind industry jobs over the next several decades, one can estimate the number of wind energy jobs requiring university-graduate-level education that will be needed in the United States in the future. Table 1 shows that for many occupations, wind energy firms prefer to hire candidates with graduate degrees. For example, nearly half the firms hiring applied scientists prefer graduate degrees, and 42% of firms hiring power system engineers prefer candidates that have a Master's degree or a PhD. By combining the interview data in Table 1 with the occupation data in Figure 4, one can estimate that the percentage of wind energy workers that would need graduate degrees is approximately 25%.

Table 4 shows the average number of on-site and supply chain jobs estimated in the *Wind Vision* report for the years 2020, 2030, and 2050. The percentage numbers indicate the penetration of wind energy into the US electricity supply. Applying the 25% estimate from above, one obtains the expected number of wind energy jobs requiring graduate-level education.

Given that the domestic wind workforce will require or prefer approximately 25% of employees to have graduate degrees, it is important to assess the gap between graduate programs needed to fill future requirements and those that

Table 4. Estimated future wind energy jobs requiring graduate-level training, based on the U.S. Department of Energy *Wind Vision* report projections and data from Tegen (2017).

Estimate of future wind energy jobs requiring graduate-level training	2020	2030	2050
Estimated percent of wind penetration in the United States	10%	20%	35%
Estimated on-site and supply chain jobs from DOE *Wind Vision* report-mean value	131,500	212,000	339,500
Estimated number of jobs requiring graduate-level education	33,000	53,000	85,000

exist today. For example, using Figure 4 data, approximately 12% of the workforce is made up of engineers, and, using the interview data for engineers, shown in Table 1, approximately 46% of engineers need a graduate degree. In 2020, the United States will require about 7300 engineers with graduate degrees for the wind industry.[6] A similar methodology can be used for the other occupations.

Tegen (2017) also researched whether wind energy–specific degrees were important, and 25%–50% of firms responded that they preferred the engineering degree to be wind energy specific (depending on the type of engineer). Projecting 25%–50% wind energy–specific graduate degrees in 2020, the number of engineers needed with wind energy–specific graduate degrees would be between 1800 and 3600; and in 2030, the number would grow to between about 3000 and 6000, based on the DOE *Wind Vision* scenario data in Table 4.[7] This level of growth would require US universities to produce approximately 120 to 240 graduate-level engineers each year with wind energy–specific degrees in the years from 2020 to 2030. With today's limited number of wind energy-focused programs as shown in Table 3, the United States will fall far short of meeting its own workforce demand.

In addition, Tegan (2017) found that only 31% of graduates from wind-specific programs entered the wind industry. This percentage must be considered when evaluating the number of graduate offerings needed. They found that there were only about 60 wind energy graduates from Master's or PhD programs in 2016 (engineering and other) around the country. To meet future demand, there will need to be a very significant increase in graduate programs offering wind-specific graduate courses and degrees.

Graduate certificate programs

Another way to specialize in wind energy with a graduate degree is to obtain a graduate-level certificate in addition to the Master's or PhD in a related discipline. However, as shown previously in Table 3, the United States presently has only six universities offering a graduate certificate in wind energy. Given the current number of wind energy–specific graduate programs discussed above, this quantity would need to grow substantially to better support the need for graduate-level wind energy programs. A previous National Renewable Energy Laboratory report (Leventhal and Tegen, 2013) estimated that the United States would need 70 post-bachelor certificate programs and 190 programs offering wind energy Master's or PhD programs to reach the workforce needs projected in the 20% wind energy by 2030 scenario.

Perspectives

Considering the rapid growth in the wind energy industry, and the new and limited university wind energy programs as described above, it is not surprising that most industry leaders and industry professionals have had no formal university-level courses or programs with wind energy–specific content—simply because no programs existed at the time when they were at university. Building new university programs requires a clear understanding of what students who graduate from the program need to know and will be able to do, so that a well-defined curriculum can be put in place and qualified faculty can be hired. Without formal experience in university-level wind energy–specific education, industry leaders may be challenged to provide the necessary industry catalyst and guidance necessary to start and help develop new university-level wind energy–specific programs.

A second perspective comes from another energy field: oil and gas. Examining the history of petroleum engineering programs may be instructive. In 1859, the first US oil rig was installed in Titusville, Pennsylvania, and began producing crude oil. The energy industry was growing rapidly in the late nineteenth century: automobiles and internal combustion engines came on the scene, and providing kerosene for lighting had become a growing enterprise. Rapid adoption of these new technologies resulted in a hurried demand for petroleum products and accelerating industry growth. In 1910, 51 years later, the first petroleum engineering program was established at the University of Pittsburgh; there are now seventeen accredited petroleum engineering programs in the United States. The 50 years, from the beginning of the oil industry to a massive global petroleum energy enterprise, is a time-scale reference for how long it may take to develop university programs to support a growing energy industry. The wind energy industry in the United States essentially began in the 1980s, and 2030 will be the 50-year mark since that beginning.

Conclusion and recommendations

The purpose of this article is to present the status and future need of university programs in wind energy in the United States. Wind energy's contribution to the US electrical energy supply continues to grow rapidly, as it has done over the past decade, recently supplying 8% of the total electrical energy generation in March 2017. This growth of wind power into a mainstream energy source, combined with the onset of offshore wind power, emerging new applications of wind power, and evolution of the power system, has led to strong job growth. As well, the widespread development of wind power in the United States has also created a parallel need for education and skills training to fill wind energy research, business, manufacturing, construction, operations, and maintenance jobs. Focusing on jobs requiring university-level graduate degrees, it is estimated that the United States may need more than 50,000 university-educated professionals with graduate degrees in various fields by 2030, including up to 6000 engineers with wind energy–specific graduate degrees to meet the wind energy workforce's needs. A 2015 review of wind energy academic programs in the United States revealed that there are fewer than 50 US universities that offer formal coursework focused on wind energy, and of those, only 17 offer graduate-level coursework with most offering only a single wind energy–specific graduate course. Furthermore, only six universities offer graduate certificates in wind energy, four have online wind energy courses, and only one offers a formal degree in wind energy. The lack of US university programs in wind energy reveals a sizable gap between the need for university-educated wind energy professionals and the ability of universities to provide them. As a consequence, US-based companies must hire from abroad or train their own workforce. In Europe, wind energy academic programs are much better developed, thus representing a competitive advantage in providing a well-trained workforce and advancing wind energy technology. While planning for the future, universities and NAWEA have identified strategies to address the lack of university programs, most of which rely on collaboration. These include coordinating wind energy curriculum development and course offerings across universities; working with industry and other organizations to develop wind energy programs and courses; cooperating with international wind energy educational programs; developing and promoting program and course certification to guarantee quality; and offering more wind energy certificate programs and degrees, both in class and online.

Recommendation 1: Wind energy education programs at the university level must be considered for federal research and scholarship funding, similar to those in the nuclear and fossil energy federal programs, and with similar objectives of sustaining and advancing the energy-specific workforce. This could be established under the auspices of the National Science Foundation and/or the U.S. Department of Energy and could be administered by NAWEA.

Recommendation 2: Support from the federal government, state agencies, national trade organizations, and industry is needed for universities offering graduate and undergraduate wind energy courses and certificates. Doing so would help grow higher education programs, and make wind energy education available both on-campus and online to students across the nation.

Recommendation 3: Government and industry also need to strongly support the goals and objectives of the NAWEA Education Committee—to include expanding the breadth and competence of university programs in wind energy throughout North America and develop the multidisciplinary workforce required to support the growing wind energy industry.

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Notes

1. The projection used in this article is from one scenario (Central Study Scenario) detailed in the U.S. Department of Energy (2015).
2. RE News (2017).
3. http://ewem.tudelft.nl/
4. http://www.eawe.eu/5. http://www.nawea.org/charter/
6. Not all engineers are required to have wind-specific training.
7. Throughout this report, the Wind Vision scenario referred to is the Central Study Scenario.

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