A Comparative Study on the Offshore Wind Education Systems in Denmark and New England

An Interactive Qualifying Project Report
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Abstract

Offshore wind is a growing industry however, there are few offshore wind education programs in the United States. We compared the teaching strategies, courses, and industry involvement of the European and New England universities by collecting data from interviews, surveys, and research. We discovered similarities and differences between them and recommend that offshore wind industries in New England partner with local universities to establish an offshore wind educational program that prepares students for the industry.

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Executive Summary

Since installing the world's first offshore wind turbine in 1991, Denmark established a world-renowned offshore wind industry and complementary education system. The European Wind Energy Master program (EWEM) is one of the best offshore wind education programs. It consists of the specialties from the Technical University of Denmark, Delft University of Technology, the Norwegian University of Science and Technology, and the University of Oldenburg to prepare students for the industry.

Interest in the New England offshore wind industry grew rapidly over the last decades. The problem is that there is no established education system in this area. Lautec, a Danish IT and software consultancy company for the offshore wind industry, has trouble hiring workers with experience and educational backgrounds in offshore wind energy. Our research goal was to conduct a comparative study between the education programs for offshore wind in Denmark and New England.

Objectives and Methods

We completed this project to help Lautec, and other offshore wind companies, gain a better understanding of how a workforce can develop in the United States. We achieved this goal through a comparative study between the offshore wind educational programs in Denmark and New England. The completion of the following objectives helped guide our project:

1. *Determine workforce challenges that Lautec's Boston office faces.* This was to understand what background is necessary for Lautec's development. We conducted interviews with both the Denmark and Boston Lautec offices. We collected information of where the offshore wind industry can employ new workers. The questions we used revolved around what experience and education employees need to work in this industry, and what skills workers developed over time.

2. *Identify the skills the EWEM students gained at the graduate level.* This is important to understand the success of the EWEM program. We conducted interviews with professors and sent out surveys to students that are both involved in the EWEM program. We formed our interview and survey questions through our research about the OECD Future of Education and Skills 2030 Project. The interview questions centered around the important teaching techniques, skills, and values needed to develop an education system for an emerging industry. The survey we sent out to students gave us data about their educational experiences, skill development, and their opinions on the EWEM program.

3. *Compare the teaching methods and skills promoted in the EWEM program and the OECD Future of Education and Skills 2030.* To compare the EWEM with the OECD research, we conducted interviews with professors and sent surveys to students. After completing our interviews and gathering our survey data, we created another document to highlight the important information we gathered. The comparison was done by compiling the Future of Education and Skills 2030's six elements of Phase 1. We compared four of the six to the teaching methods and skills used throughout the EWEM. The four elements we focused on were knowledge, skills, attitudes and values, and core foundations.

4. *Compare the offshore wind educational tracks, teaching methods and industry involvement in New England and European Universities.* We collected data for this objective in two parts. The first was to study and understand the Danish education system for offshore wind through interviews, surveys, and online research. The second part was to research offshore wind programs in the United States. We researched and collected information regarding the educational tracks and courses, the main values of schools, and the offshore wind industry's involvement and collaboration with schools. Through this comparison we highlighted the similarities and differences between the skills, teaching values, and the industry involvement in the offshore wind educational tracks in New England and Denmark.

Findings

From the data we researched and collected, we found that:

1. *Industry involvement in education systems is more prevalent in EWEM universities when compared to the New England universities.*
2. *Three of the New England universities we researched have similar teaching methods as the EWEM universities.*
3. *Tufts University and the EWEM universities have similarities with their offshore wind energy program's courses.*
4. *New England and EWEM education offer a vast number of engineering degrees that apply to the offshore wind industry.*

Recommendations

We have three recommendations for the use of this information. One recommendation we have for future research is for offshore wind companies in New England to establish connections with Northeastern University and become a part of their co-operative education program.

Our second recommendation is for offshore wind companies in the United States to establish a partnership with universities that don't have a connection to the offshore wind industry. Specifically, universities that have project-based learning and engineering programs.

Our third recommendation is for the United States offshore wind energy companies to host employee-student workshops similar to that of the Norwegian university of science and Technology's workshops.

Conclusion

Our results showed that the offshore wind energy education in the EWEM program is far more advanced than the ones in New England. Although Tufts university, Northeastern university, and the University of Massachusetts Lowell have a form of a renewable energy engineering program, the course topics are broad. The EWEM and New England universities utilizes industry collaboration, project-based learning, and innovative teaching methods. Tufts university is the closest comparable university to the EWEM to produce a specialized workforce for the United States Industry.

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AAR - Anticipation-Action-Reflection
CATLR - Center for Advancing Teaching and Learning Through Research
CS - Computer Science
DTU - Technical University of Denmark
ECE - Electrical & Computer Engineering
EWEM - European Wind Energy Master's Program
ME - Mechanical Engineering
M.S. - Master of Science
M.Sc. - Master of Science
MARTINTEK - Norwegian Marine Technology Research Institute
Northeastern - Northeastern University
NOWITECH - Norwegian Research Center for Offshore Wind Technology
NTNU - Norwegian University of Science and Technology
O&M – Operations and Management
OECD - Organization of Economic Cooperation and Development
TU Delft - Delft University of Technology
Tufts - Tufts University
UMass Lowell - University of Massachusetts Lowell
UOL - The University of Oldenburg

Chapter 1 Introduction

Investment in education increases the productivity of workers, the economy, and the well-being of residents (Berger & Fisher, 2013). Oftentimes, the industry demands more than education systems can provide, which limits industry growth until there is a consistent production of educated workers. Educated and skilled workers both contribute to the industry by advancing technology and supporting growth.

Since installing the world's first offshore wind turbine in 1991, Denmark established an impressive offshore wind industry and complementary education system. Denmark chose offshore technology due to the scarcity of land coupled with the viable shallow water wind resources (Danish Energy Agency, 2017). Denmark is a global leader in wind energy education and established the European Wind Energy Master Program (EWEM) in 2012. The EWEM program is a university-level program that offers a Master of Science in offshore wind. The courses offered in this program are reviewed and changed, if needed, to keep up with the industry's expansion. Although the first offshore wind turbine was placed in 1991, it took nearly two decades for an effective program to evolve in a parallel manner with the industry.

Interest in offshore wind energy grew rapidly in the northeast United States due to the advances in technology, natural factors - such as wind speeds and area, and societal factors - such as climate control (International Energy Agency, 2019). As a result, a New England company, Eversource, partnered with Danish companies, Lautec and Ørsted, to begin the planning and execution of new offshore wind farms. The United States currently has one small offshore wind farm in use, the Block Island Wind Farm located off the coast of Rhode Island. Its five-turbine farm produces 30MW of power (American Wind Energy Association [AWEA], 2020). Experts estimate that the United States offshore wind farms can provide nearly 2,000 GW of power for the country (AWEA, 2020).

Currently, many developmental problems exist in the United States offshore wind industry. Regulatory issues make it difficult for companies to obtain permits for projects, causing project delays or cancellations (Frangoul, 2020). After obtaining a permit, another problem arises—hiring a qualified workforce. This is due to the scarcity of education systems related to offshore wind within the United States. It leads companies to fill positions with workers holding indirect degrees and experience (WINDExchange, 2020).

Our sponsor, Lautec, based in Copenhagen, Denmark, is an offshore wind consultancy firm and software provider. In 2019, Lautec opened an office in Boston, MA, to support wind energy companies in New England. However, they found it difficult to locate experienced employees within the United States. To analyze this gap between the offshore wind industry workforce needs and the United States higher education system, we conducted a comparative study between the educational programs for offshore wind in the EWEM and New England. Our four objectives were to determine workforce challenges that Lautec's Boston office faces; identify the skills the EWEM students gained at the graduate level; compare the teaching methods and skills promoted in the EWEM program and the OECD Future of Education and Skills 2030; and compare the offshore wind educational tracks, teaching methods, and industry involvement in New England and EWEM universities. We achieved this by carrying out interviews, surveys, and research to determine the differences between New England and the EWEM programs.

Chapter 2 Background

Chapter two encompasses information regarding offshore wind energy industries in the United States and Denmark, industries in the United States, related education systems around the world, the guidelines for education system improvements from the Organization for Economic Co-operation and Development (OECD), the European Wind Energy Master program for offshore wind energy education, and three United States educational programs. An industry investment in the development of education systems benefits the industry by supplying the workers they need.

Section 2.1 Wind Energy

Wind energy is a renewable energy source that uses kinetic energy generated by the flow of air through turbines. Renewable energy is important because the use of non-renewable energy sources, such as oil or gas, increases environmental pollution. The global demand of energy increases as the population rises, emphasizing the importance of renewable energy resources (Batliwala, 1993). Wind energy is the fastest-growing, inexhaustible, and clean renewable energy source worldwide (Qian, Xu, & Zong, 2013). Due to its environmental and social benefits it is a promising alternative for power generation (Billinton & Xie, 2011). Overall, this energy method has great potential to expand the commercialization of renewable energy.

2.1.1 Advantages and Disadvantages of Offshore and Onshore Wind

Offshore wind farms have three advantages over traditional onshore wind farms. One advantage is that offshore wind is stronger during the day, whereas onshore wind is stronger at night (Hartman, 2020). Afternoon wind strength is essential for optimal energy efficiency because this is when energy consumption peaks in highly populated areas (Hodge, 2020). This stimulates the idea of creating offshore wind farms to provide the most amount of energy to an area at a specific time of day. The northeastern part of the United States provides the largest area with high relative wind speeds, as seen in Figure 1.

A second advantage of offshore wind is the creation of new jobs. The new jobs include technicians, geography specialist, transportation workers, and engineers. The size of the turbines and farms require more technicians to assemble and maintain than the alternative onshore wind farm. The location requires geography specialists with vast knowledge and the ability to survey sea floors. The parts need to be transported to the site requiring transportation workers and a fleet of boats. The energy production is far from where it is needed and requires vast amounts of wire laying in the ocean by electrical and mechanical engineers (American Geoscience Institute, n.d.).

The last advantage is that offshore wind farms provide energy to the highly populated coastal areas. A majority of the United States population lives in coastal areas and has high energy demands. By building offshore wind farms in these populated areas, it allows more space for residential and commercial buildings on land (American Geoscience Institute, n.d.). In addition, it meets the energy demands of these high populated areas.

The main disadvantage of offshore wind farms is its higher cost of construction and maintenance compared to onshore wind farms. Offshore wind farms can be expensive because of the number of workers and amount of specialized equipment. To operate an offshore wind farm, companies need to pay for insurance, regular maintenance, repairs, spare parts, access to platforms and turbines, and administration (Kitzing and Morthorst, 2015). The main reason the maintenance cost is higher is because of the corrosion that can occur on the turbine base. Offshore wind turbines are large and require larger-scale maintenance, tools, and parts to maintain. In addition, the energy generated by the offshore wind farm has to be transported a far distance to land. The farther the length between the farm and land the more preparation and installation of pipeline is needed across the seafloor. More maintenance increases the need for highly trained technicians (Anderson, 2013). Figure 2 shows a table of the cost distributions between items of a 150MW wind farm in both onshore and offshore areas. The table shows that the foundations and grid connections will cost much more for offshore wind compared to onshore. The offshore foundation structures are more advanced to suit the needs of the location. The offshore farms require two other items, offshore transformer stations and operation and maintenance (O&M) facilities. The production and maintenance of offshore wind farms require more personnel to complete, increasing the cost of the entire process (Deutsches Windenergie-Institut GmbH, Tech-wise A/S, & DM Energy, 2001).

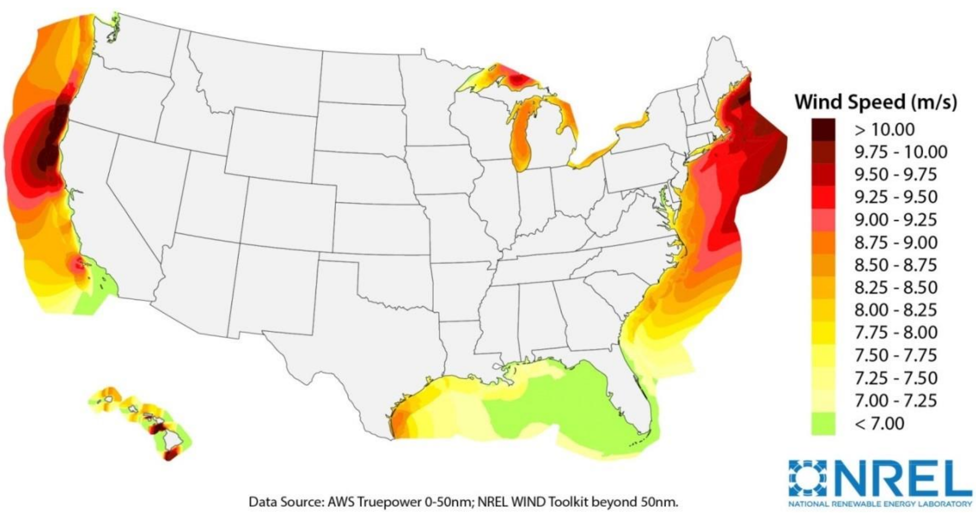

Figure 1: This figure depicts a map of the United States. This map color codes the wind speeds of the United States with red being high wind speeds and green being low wind speeds.

Item	Offshore		Onshore
	Costs in Mill. €	%	%
Foundations	36	16	5.5
Wind turbines	113	51	71.0
Internal electric grid	11	5	6.5
Offshore transformer station	4.5	2	-
Grid connection	40	18	7.5
O&M facilities	4.5	2	-
Engineering and project administration	8.9	4	2.5
Miscellaneous	4.5	2	7
Total:	222	100	100

Figure 2: Cost distribution of a 150WM wind farm for onshore and offshore locations.

2.1.2 Offshore Wind Industry in Denmark

The Offshore Wind Industry is thriving in Denmark. Since 1991, Denmark has constructed 15 connected offshore wind sites, and 3 more are under construction and plan to finish by 2023 (Ramirez, Fraile, & Brindley, 2020). Today, Denmark produces 1703 MW of power from all the offshore wind farms combined (Ramirez, Fraile, & Brindley, 2020). That is twice as much wind energy per capita as the runner-up among industrialized countries in the Organization of Economic Co-operation and Development. Denmark's largest offshore wind farm is Horns Rev III, created by Vattenfall in 2019. It has the capacity to produce 407 MW of power, 24% of the entire offshore wind production (4COffshore, 2020). In 2019, the wind energy sector produced 47% of Denmark's total energy consumption (Gronholt-Pedersen, 2020). This then breaks down to 29% coming from land-based wind farms, and 18% coming from offshore wind farms. Plans to construct larger offshore wind farms will even out this percentage disparity between the offshore and land-based industries. By 2023, the three offshore wind farms under construction will produce an added 995 MW of power (Ramirez, Fraile, & Brindley, 2020).

2.1.3 Offshore Wind Industry in the United States

Offshore wind in the United States is a budding industry. In 2016, a Danish company, Ørsted, built the first offshore wind farm in Rhode Island, the Block Island Wind Farm (Office of Energy Efficiency and Renewable Energy, n.d.). For reference, in 1991, SEAS and Elkraft created the first offshore wind farm, Vindeby Offshore Wind Farm, off the Danish Island of Lolland (Danish Energy Agency, 2017). The five turbines of the Block Island Wind Farm generate 30 MW total, enough to power more than 17,000 homes. This offshore wind farm supplied local economic growth and jobs to build and maintain renewable energy projects (Ørsted, 2020).

The United States could obtain 2,000 GW of power from an energy sector dedicated to offshore wind processes. That is nearly double the nation's current use of electricity (AWEA, 2020). Figure 3 details the net technical energy potential of offshore wind energy in different coastal states. The technical energy potential is the upper-boundary estimate of energy generation, given system performance, as well as topographic and environmental constraints. The states with higher energy potential can have more wind farms, which could possibly produce 83,000 new jobs. Currently there are nine offshore wind projects proposed in the northeastern region of the United States.

One of the projects is Vineyard Wind 1. It will be the first large-scale offshore wind energy project in the United States (Vineyard Wind, 2020). The commercial farm is going to be located 15 miles south of Martha’s Vineyard, Massachusetts. Each wind turbine will be eight-tenths of a mile apart and capable of generating 9.5MW of power, totaling up to 800MW. This project will provide clean, renewable energy for over 400,000 homes and reduce carbon emission by 1.6 million tons per year (Vineyard Wind, 2020). The drive to produce renewable energy and the favorable conditions in the area causes growth of the industry in New England. In 2016, the Massachusetts governor signed Bill H. 4568 189th, which seeks to have offshore wind produce 1600 MW of power by offshore wind by 2027.

Ørsted’s future projects, Constitution Wind and Bay State Wind, are 50/50 joint ventures with Eversource, New England's largest energy company and electric transmission systems builder. The Bay State wind farm will be 25 miles off of Massachusetts’ south coast and generate

800MW of clean renewable energy. The Constitution Wind project will be 65 miles off the coast of Connecticut and power up to 500,000 homes (Ørsted, 2020). The last project in development is the Garden State Offshore Energy, LLC (GSOE). This is a joint project between Ørsted and Public Service Enterprise Group, a commercial developer based in New Jersey. These companies plan to build up to 1 GW of offshore wind generation (Ørsted, 2020).

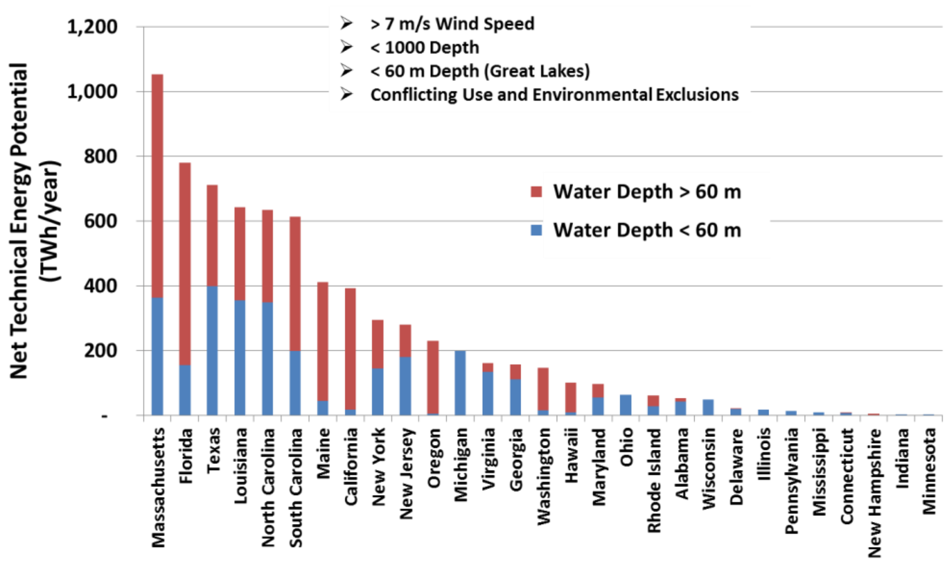

Figure 3: A bar chart of the potential of wind energy in different states. This also contains information about the energy potential with varying water depths.

2.1.4 Jobs in the Offshore Wind Industry

The offshore wind industry requires many workers with diverse backgrounds, including Geographic Information Systems, electrical or mechanical engineers, and risk managers. All the jobs are necessary for the building, completion and maintenance of offshore wind farms.

Geographic Information Systems (GIS) is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface (National Geographic, 2012). GIS specialists handle building and maintaining GIS databases. They also use GIS software to analyze and create maps of data. This line of work requires an educational background of computer science, programming, and geography (Environmental Science, n.d.)

Software, electrical, and mechanical engineers are all important in moving the offshore wind industry forward. After interviewing Lautec employees, we learned that engineers of any type are useful because of their ability to be accurate, precise, and solve problems. Software engineers are helpful in this field because they excel in programming and databases, which are critical for mapping and IT systems. Electrical engineers work on the flow of power from the turbines to a storage unit and to people's houses. Without them, the project would be harder because they are the ones who know about electricity and how to store it. Lastly, mechanical engineers have specialties in many areas and can solve problems that arise while working in this industry.

Risk managers are important to the offshore wind industry because they assess the risks of the offshore wind projects. From our interviews with Lautec employees we learned that risk managers oversee the oversight of the contingency budget. This is a budget put aside in case an accident occurs during construction. The risk manager requires a monthly meeting with project managers to discuss the risks and changes for the project (Interview with Ian Spooner).

Section 2.2 Industries in the United States

There are industries in the United States that have jobs similar to the offshore wind industry. These jobs include offshore drilling, natural gas, onshore wind, and onshore solar power.

2.2.1 Offshore Drilling

Offshore drilling is a nonrenewable process to extract petroleum from reserves located deep below the ocean floor. This process is necessary due to the worldwide demand for fossil fuels (Donev, J., 2016). Offshore drilling requires a large workforce including roustabout, roughneck, derrick hand, driller, and tool pusher. The entry level position is a roustabout, they do the physical labor for drilling oil. Roughnecks handle pipe connections, cranes, drilling engines, mud weights and checking operations of shakers. Derrick hands handle mud pits, mud pumps, and drilling the mud. Workers move up to the driller position after 5 years of experience in the earlier positions. Drillers manage a team of roughnecks and the rig's machines to ensure smooth operations. The highest position is the tool pusher, they supervise the oil rig and the teams running it. Additionally, they have many administration tasks while physically working on the drilling team (Oil, n.d.).

2.2.2 Natural Gas

Natural gas is a fossil fuel that workers get through drilling into pockets under the Earth's surface. Although it is a fossil fuel, it burns cleaner and releases lower levels of harmful byproducts. The United States population uses natural gas to cook food, heat homes, and generate electricity (NaturalGas, 2013). The natural gas industry employed 693,000 workers in 2011. Most of these workers are involved in the extraction of the gas from the Earth's surface. Occupations that are critical to this industry are engineers and geoscientists, equipment operators, and roustabouts, laborers, and helpers (Torpey, 2013).

For example, drilling engineers find the best and least expensive ways to drill into the reservoirs. Production engineers survey the function of the wells after completion (Torpey, 2013). Equipment operators receive on-site training or have work experience in a related field. Roustabouts oversee maintenance and construction. They oversee inspecting, maintaining, and fixing rig equipment. Laborers can be construction or material moving. Helpers, or Extraction worker helpers, work closely with more experienced workers. A few of their tasks include checking equipment, maintaining equipment, and noticing problems (Torpey, 2013).

2.2.3 Onshore Wind

Onshore wind farm development requires a similar workforce to offshore wind farm development. The main jobs for the onshore industry are project development, components manufacturing, construction, operations, and education and training research (Wind Energy Technologies Office, 2020). For example, component manufacturers build all of the parts necessary for the wind turbines. Construction workers build the wind turbines with the parts component manufacturers built. Operation workers check to see if the turbines will function properly once workers install them. Lastly, the education and training researchers research wind energy through universities and companies related to wind energy.

2.2.4 Onshore Solar Power

Onshore solar has a similar workforce to offshore wind. The main jobs in onshore solar are installation/project development, manufacturing, and operations/maintenance (The Solar Foundation, 2020). Installation and project developers oversee managing the project teams to make sure the installation of farms is done correctly and safely. Manufacturers make the parts of the solar farms. Operators and maintenance workers ensure the farms function properly after installation. The positions that onshore solar developers have trouble filling are sales, customer service, management, and electricians and construction workers.

Section 2.3 The Organization for Economic Co-operation and Development (OECD)

The Organization for Economic Co-operation and Development (OECD) is an international organization that works to build better policies for developing nations. There are 35 countries from Europe, the Americas, and the Pacific that compose the OECD. A problem the member nations face is how to develop an education system for fast-growing industries. In 2015, the OECD launched the Future of Education and Skills 2030 project to help combat this issue. The goal of the OECD project is to help prepare students for jobs that have not yet been created, tackle societal challenges that we can't yet imagine, and to use technologies that have not been invented (Organization for Economic Co-operation and Development [OECD], 2020).

The Future of Education and Skills 2030 is broken down into two phases: Phase I focuses on curriculum redesign and developing a conceptual framework for learning 2030 and Phase II focuses on curriculum implementation and creating a conceptual framework for teaching 2030 (OECD, 2020). The Learning Compass describes phase 1 and is broken down into six elements: knowledge, skills, attitudes and values, core foundations, transformative competencies, and the Anticipation-Action-Reflection cycle to help shape the future.

Knowledge, skills, attitude, and values are defined as the competencies students need to fulfill their potential and to contribute to the well-being of the communities and planet (OECD 2020). Knowledge includes theoretical concepts and ideas, and practical understanding based on the experience of performing a task. The OECD recognized four types of knowledge: disciplinary, interdisciplinary, epistemic, and procedural (OECD 2020).

Skills are the ability to carry out a process and be able to use one's knowledge in a responsible way to achieve a goal (OECD 2020). There are three different types of skills: cognitive and metacognitive skills; social and emotional skills; and practical and physical skills. Skills involve mobilizing knowledge, attitudes, and values to meet complex demands (OECD 2020).

Attitudes and values refer to the principles and beliefs that influence one's choices, judgments, behaviors, and actions on the path towards the individual, societal and environmental well-being (OECD 2020). The curriculum framework integrates these four competencies, as education systems pursue these to develop values and attitudes based on cultural and societal traditions.

Core foundations are the fundamental skills, knowledge, attitudes, and values that are necessary for further learning. They supply a basis for developing student agency and transformational competencies (OECD 2020). The core foundations include; cognitive foundations such as literacy and numeracy, health foundations including physical and mental health, and social and emotional foundations.

The OECD has three transformative competencies; creating new value, reconciling tension and dilemmas, and taking responsibility that are meant to empower students. Creating new value means creating new jobs and businesses, developing new knowledge, techniques, strategies, and solutions, and applying them to problems both old and new (OECD 2020). Reconciling tensions and dilemmas means understanding the inter-relations between ideas, logics, and positions, and considering the results of actions both short and long term (OECD 2020). Taking responsibility is the ability to reflect and evaluate one's own actions and consider the personal, ethical, and societal growth of the situation (OECD 2020).

The Anticipation-Action-Reflection (AAR) cycle is an iterative learning process whereby learners continuously improve their thinking while moving towards long-term goals. (OECD 2020). Anticipation involves projecting the consequences and potential impacts of one's actions. Reflection allows learners to gain a sense of perspective and power over their future actions (OECD 2020). Each of these elements is crucial for the progression and application of the Future of Education and Skills 2030 project.

Section 2.4 Incorporation of Offshore Wind Energy Education

Wind energy research and education have been a part of the Danish education systems since the 70s (European Wind Energy Master [EWEM], 2020). Wind energy education in Europe grew in 2012 to form the European Wind Energy Masters (EWEM) program.

The four universities that take part in the EWEM program are: The Technical University of Denmark (DTU), Delft University of Technology (TU Delft), Norwegian University of Science and Technology (NTNU), and the University of Oldenburg (UOL). These four universities are world leaders in wind energy and offshore wind energy research and education. The program length is two years and offers four different specializations: Electric Power Systems, Offshore Engineering, Rotor Design, and Wind Farm and Atmospheric Physics (EWEM 2020). Individually, the four universities of the EWEM are experts in their field of offshore wind energy, but together they excel in everything encompassing offshore wind energy. The EWEM program path allows students to experience each university's expertise and receive a degree in their specialized field.

The EWEM is one of the only university-level programs that offer a master's degree in offshore wind. A unique feature of the EWEM program is that it allows students the opportunity to study at different universities. The students' specialization they choose determines the path they follow in the program, which Figure 4 shows. All the four specializations start their first semester at the DTU. The second semester of the first-year students spend at TU Delft or UOL, depending on their specialization. Then, students complete their second year, the third semester, at either DTU or NTNU. The final semester of the second year is when students complete their thesis at any of the four universities.

	First year (60 ECTS)		Summer School	Second year (60 ECTS)	
	1st semester	2nd semester		3rd semester	4th semester
Electrical Power Systems	Introduction to Wind Energy DTU	TU Delft	Summer School	NTNU	M.Sc. Thesis Free mobility
Offshore Engineering		TU Delft		NTNU	
Rotor Design		TU Delft		DTU	
Wind Physics		Carl von Ossietzky Universität Oldenburg		DTU	

Figure 4: EWEM Program path based on specialization (EWEM 2020).

Chapter 3 Methodology

Our research goal was to conduct a comparative study between the education programs for offshore wind in the EWEM and New England. Through our comparative study, we examined specific schools and programs in New England to help Lautec with their workforce development issues. To achieve this goal, we developed the following research objectives:

1. *Determine workforce challenges that Lautec's Boston office faces.*
2. *Identify the skills the EWEM students gained at the graduate level.*
3. *Compare the teaching methods and skills promoted in the EWEM program and the OECD Future of Education and Skills 2030.*
4. *Compare the offshore wind educational tracks, teaching methods, and industry involvement in New England and EWEM universities.*

In this chapter, we describe the methods used to complete each of the above objectives and reach our goal.

Section 3.1 Objective One

Objective one was to determine workforce challenges that Lautec's Boston office faces. This was to understand what background is necessary for Lautec's development. To complete this, we conducted interviews with employees at both the Denmark and Boston offices. We used a video conference app to conduct interviews. The use of virtual interviews allows a face-to-face connection and fast communication about a specific subject (Guest, Mack, McQueen, 2005). All interviews had the same structure to ensure standardization. Even with this structure, interviews had flexible dialogue since we left time outside of the agenda for follow-up questions or extended responses (Guest, Mack, McQueen, 2005). Interviews are a method used for qualitative research and one of the best ways to learn about the motivation behind people's choices, behavior, attitudes, beliefs (Raworth, 2019). Before conducting the interviews, we supplied a consent script, Appendix A, for the interviewee detailing our plans for the information we collected.

The interview questions revolved around what experiences, education, and skills employees need to work in this industry. We listed the interview questions in Appendix B. We had to understand the differences between the two office locations, to know if workforce development challenges were industry wide, or just in the United States. This information allowed to determine the workforce challenges limiting the offshore wind industry's growth in the United States.

Section 3.2 Objective Two

Objective two was to identify the skills EWEM students gained at the graduate level. This is important to understand the success of the EWEM program. To gather this information, we conducted interviews with professors and sent surveys to students involved in the EWEM program. We formed our interview and survey questions based on our research of the OECD Future of Education and Skills 2030 Project, shown in Appendix C and D.

We interviewed four professors from the Technical university of Denmark and the Norwegian University of Science and Technology within the EWEM program. These interviews questions centered around the important teaching techniques, courses, and skills used by the

EWEM program. This provided us with information about the function and successes of the EWEM program.

We received eight responses on our student survey. Surveys are a research method we used to gather data from large groups. From surveys we could produce models from the data (Jones, TL., 2013). Since we had trouble reaching our respondents from the United States, we sent surveys out electronically through emails. Surveys created an environment for respondents to be honest and unbiased in their responses about offshore wind education (Jones, TL., 2013).

We sent the survey to students enrolled in the EWEM program. The survey questions revolved around student's educational experiences, skill development, and their opinions of the EWEM universities. We obtained our data through a Google survey, which generated a pie chart of our multiple-choice questions. The Google form models helped us draw conclusions because we compared the answers among respondents. From this survey, we obtained data about students' education experience, skill development, and their opinions on the EWEM program.

Section 3.3 Objective Three

Objective three was to compare the teaching methods and skills promoted in the EWEM program and the OECD Future of Education and Skills 2030. This was important to understand how education systems work with a growing industry. To begin collecting data for the comparison, we conducted interviews with EWEM professors and transcribed them. Transcripts provide us with an accurate record of what the professors discussed during the interviews. After we completed the transcripts, we created a document to highlight the important information from the interviews.

We compiled our research of the Future of Education and Skills 2030 plan and the information we collected from EWEM professors and students. The six elements of OECD's plan are: knowledge, skills, attitudes and values, core foundations, transformative competencies, and the Anticipation-Action-Reflection cycle. The elements we focused on out of the six listed above were knowledge, skills, attitudes and values, and core foundations. These four elements were the most applicable for a higher education program because Transformative competencies and the Anticipation-Action-Reflection cycle focus on personal growth and development. We compared these to the teaching methods and skills used throughout the EWEM program.

A comparative study identifies patterns and establish connections between two or more things. Using a comparative method benefited us by highlighting key differences and similarities between the EWEM program and the OECD Future of Education and Skills 2030 program (Bryman, Lewis-Beck, & Liao, 2004).

Section 3.4 Objective Four

Objective four was to compare the offshore wind educational tracks, teaching methods and industry involvement in both New England and the EWEM universities. This helped us understand the similarities and differences between the educational systems. We collected data for this objective in two parts. The first was to study and understand the Danish education system for offshore wind through interviews, surveys, and online research. The second was to research offshore wind programs in the United States. Information we researched included: the educational tracks and courses, the teaching methods, and the offshore wind industry's involvement and collaboration with schools.

Section 3.5 Challenges and Limitations

There are three challenges and limitations we faced with this research project. The first challenge was location and time zones. Since we are in the United States, we struggled with contacting professors in Europe. Due to the hybrid learning that was taking place in Denmark at the time, we scheduled interviews via email and often resulted in back and forth messages. We set up interviews over zoom with the professors who responded. Not being able to have in person interviews limited our ability to establish a relationship with the interviewee. However, the use of an online video conference platform was the closest way we would have that interaction.

Another challenge we faced was the lack of fluid conversation over zoom. Oftentimes, multiple people talked at once during a zoom conference and interrupted the interviewee. An in-person interview would have been easier than virtual to interpret social cues as it was hard over zoom to know when the right time to talk was. To overcome this challenge, we worked to leave a moment of silence between each speaker before moving forward with the interview. Additionally, we chose to complete our interviews with only two group members, instead of all four. This allowed us to dictate questions and reduce the number of people talking.

A final challenge we faced was the difficulty to get in touch with two of the universities from the EWEM program, and schools in the United States. The two universities we had trouble reaching in the EWEM program were Delft University of Technology (TU Delft) and the University of Oldenburg (UOL). After sending multiple follow up emails over many weeks, TU Delft responded. At that point, we completed our interviews and the analysis was in progress. UOL never responded to us after we sent multiple emails. This was a problem because the lack of communication at both universities, as part of a multi-university program, led us to only gather data from two out of the four universities. In the United States, Tufts University did not want to set aside time to speak with us until late October after our project's completion. This posed an issue because we could not hold an interview with professors from the only offshore wind energy master program offered in the United States. As a result, we collected our data about these three universities through research.

Chapter 4 Analysis

By analyzing the information gathered from interviews and surveys, we found that because of the lack of offshore wind education in the United States most employees had indirect experience in the industry. When we analyzed the surveys, we found that students felt prepared for the industry after graduating. Throughout the EWEM program, students developed skills such as communicating with professionals in the offshore wind industry and project-based skills.

Section 4.1 Findings from Objectives One, Two, and Three

Through the interviews we completed for objective one, we found that Lautec employees hired at the Boston office have indirect experience in the offshore wind industry. The office hired an experienced worker from Europe to help with projects. The United States employees had backgrounds in geography, environmental studies, economics, mechanical engineering, or Geographic Information Systems. Whereas, Denmark employees have educational backgrounds that are in sustainable energy and energy engineering. Given that Denmark has established offshore wind related degrees and can provide the necessary workers for this industry, we decided to look more into the programs offered. Specifically, the European Wind Energy Master program.

After completing objective two through interviews and surveys, we found that the European Wind Energy Master program prepares students well for the industry. 100% of the student responses on the survey said that they felt prepared to work in the industry after graduating. Students answered that the main reason was the project-based learning and industry connections that the EWEM's teaching methods provided for them. The EWEM program requires students to complete a thesis project to graduate. Students partner with two professors from two out of the 4 universities and have the option to partner with companies in the offshore wind industry.

Through the completion of objective three, we found that the knowledge, skills, attitudes and values, and core foundations overlapped between the OECD's plan and the EWEM program. This means that the EWEM program is a perfect fit as an education program to help the growing offshore wind industry in the United States. Unfortunately, the United States doesn't have the EWEM program or even one entirely similar. This requires us to do further research to find other educational programs present in the United States.

Section 4.2 Further Research for Analysis of Educational Comparison

This section has additional information about the EWEM universities and the New England universities: Tufts University, Northeastern University, and the University of Massachusetts Lowell. We determined the EWEM and New England Universities' educational tracks, courses, teaching methods and the offshore wind industries collaboration with schools. This information is necessary to complete objective four.

4.2.1 Technical University of Denmark

The Technical University of Denmark (DTU) offers a two-year Master program in Wind Energy. The DTU started research for wind energy in the 1970s, however, their Master program started in 2002 (Just, 2020). There are 5 specializations in electrical and mechanical engineering: mechanics and aerodynamics, mechanics of materials and structures, testing and measurements, electrical wind turbine systems, and electrical wind turbine technology (Just, 2020). Refer to Appendix E for the degrees and specializations at the DTU.

Along with their own Master program, DTU is part of the EWEM program. DTU administers the general introductory course for the EWEM program. These courses provide students with an overview of the current wind energy technology, as well as an engineering focus of wind turbine design. Each course in the EWEM at the DTU has weekly modules with different learning activities such as, video lectures, presentations, understanding reports, readings, quizzes, and calculation exercises (Linde, 2020). This program teaches students how to design, analyze, run, and develop future wind energy systems (Just, 2020).

The DTU wants to be the nation's center of technological advancements through research, innovation, collaboration, and scientific consultancy. The DTU delivers technical-scientific research at internationally high levels. They collaborate with other technical universities to increase their societal value, further growth, and create new jobs. In addition, DTU students enrolled in the EWEM collaborate with the offshore wind industry, allowing them the opportunity to complete thesis and research projects (Tonsberg, 2020).

4.2.2 Delft University of Technology

Delft University of Technology (TU Delft) started wind energy research in the 1970s. They offer a Wind Energy M.Sc. program as a variant of the Aerospace Engineering, Offshore Engineering, and Electrical Engineering M.Sc. program (Delft University of Technology, n.d.b). The courses for these master programs are in Appendix F. TU Delft incorporates information from each field into the EWEM program. The university's expertise is in the design of wind turbines, rotors, offshore bottom-mounted wind turbine support structures, offshore wind farm design, offshore operation and maintenance, direct-drive generators, and electric grid integration and optimization (Delft University of Technology, n.d.b). This ability is to analyze the electrical components and power production of offshore wind energy.

Through research with industries and academic advisors, TU Delft hopes students learn fundamental aspects of dynamical systems and control, and advance technological applications (Delft University of Technology, n.d.a). To graduate, students take part in offshore renewable research projects. The Valorisation Centre of TU Delft sets these projects up for students to collaborate with the industry, government and knowledge institutions on global challenges (Delft University of Technology, n.d.c).

4.2.3 Norwegian University of Science and Technology

The Norwegian University of Science and Technology (NTNU) offers research-based education at all levels. NTNU improves students' education by prioritizing innovative learning processes. This includes developing a close relationship with the private and public sectors, incorporating new technology, and connecting research with work opportunities. In addition to the EWEM program, NTNU offers an international M.Sc. in Electrical Power Engineering. Reference Appendix G for the master degree and specializations of NTNU. This program focuses on wind turbine generators, energy conversion, and onshore/offshore grid.

NTNU lists three pillars of innovative strategies which are collaboration with established businesses, collaboration with the public sectors, and helping to create a new business. Working with businesses and the public sector allows students to combine theory and practice for the opportunity to help solve problems. To collaborate on these projects, NTNU created the NTNU Bridge. NTNU Bridge is a career portal that connects students and employers on academic projects, internships and permanent positions. Students partner with companies on assignments, internships, and jobs that expand their knowledge of their specialty (Lie, 2019). The largest number of projects are master's or bachelor's thesis. Students in the EWEM working on their thesis have two advisors from two of the four universities and one from the industry. This allows students to understand what problems the industry faces and how to improve it.

In addition to the NTNU Bridge, five to six employees from an organization participate in workshops with students. Employers give a short presentation of their company and potential projects. NTNU's research program works closely with Sintef Energy, MARTINTEK, and the NOWITECH. These partners specialize in the fields of renewable energy, small-scale hydropower, wind, solar, wave, bioenergy, and offshore and electrical engineering.

4.2.4 The University of Oldenburg

Research about wind energy at the University of Oldenburg (UOL) university started in the 1980s (EWEM, 2020). UOL specializes in fundamental and applied aspects of wind physics. Wind physics describes the properties of energy and matter associated with wind. A table of the master degrees offered at UOL can be reference in Appendix H. This breaks down into understanding the fundamentals of atmospheric flow and turbulence and how it interacts with wind farms, wind turbines, and energy systems (EWEM, 2020). UOL professors work with students to find answers to key challenges that society faces through interdisciplinary, cutting-edge research (Carl Von Ossietzky Universität Oldenburg, 2020).

UOL values preparing students for professional life by emphasizing interdisciplinary collaboration. These collaborations are through research, education, culture, business, and industry. UOL works closely with universities, institutions, companies, and scientists around the world (University of Oldenburg, 2020).

4.2.5 Tufts University

Tufts University (Tufts) offers a Master of Science program for offshore wind energy engineering. The master degrees and specializations for this master program are listed and can be referenced in Appendix I. The courses offered for the M.S. Program at Tufts are in Appendix N. Students in this program receive graduate-level training in wind policy, technical applications, and project management (Tufts University, n.d.). This training prepares them for jobs in the industry and academics. Research areas for this program are infrastructure and transmission, site characterization and permitting, and foundation design and monitoring (Tufts University, n.d.).

Tufts teaching methods range from interactive lectures to experience through team-based learning. Interactive lectures engage students with professors and peers in the classroom. Students take part in team-based learning that promotes collaboration and communication for the industry environment (Harris, 2013).

Students make connections with the industry through Tufts University's Office of Technology Transfer and Industry Collaboration. The office at the university works with faculty to identify and market student projects and discoveries. Through this office students can transfer innovative ideas to problems in the working world (Harris, 2013).

4.2.6 Northeastern University

Northeastern University offers a Master of Science in Energy Systems through the Department of Engineering. Reference Appendix K for other master degrees and specializations offered at Northeastern. The required courses focus on the economic side of energy systems, while the electives specialize in energy engineering (Northeastern University, n.d.b). Refer to Appendix P for a detailed list of the required courses and electives for this M.S. program.

Northeastern created a learning center, the Center for Advancing Teaching and Learning Through Research (CATLR), to support their educators. CATLR supplies a broad range of opportunities to enhance student learning through workshops, research, customized programming, and the development of innovative models for learning (Northeastern University, n.d.a). Their biggest emphasis is evidence-based teaching which combines learning through literature. Class discussions, visible quizzes, and group collaboration engages students and challenges their knowledge on a subject.

Northeastern uses learning through experiences to better integrate industry into learning. Their programs engage students with the industry through professional work and research. Unlike most colleges, Northeastern alternates semesters of academic study with periods of full-time work, also known as cooperative education (co-op). Co-op provides students the opportunity to explore potential career paths, make industry connections, and acquire the skills and knowledge needed to succeed (Northeastern University, n.d.a).

Another industry connection is NUworks that Northeastern created to help students connect with co-ops. NUworks is a career management portal for sharing jobs, co-ops, and internship opportunities with current students at all levels (Northeastern University, 2020). In addition to NUworks, employers can participate in career fairs and host a recruiting or branding event. Each method helps students connect with the industry and learn from hands-on experience.

4.2.7 University of Massachusetts Lowell

The University of Massachusetts Lowell (UMass Lowell), offers a Master of Science in Energy Engineering. The classes required are specific to renewable and nuclear engineering, but the electives offered are broad. The courses for this program can be referenced in Appendix O. The electives include classes such as Wind Energy Fundamentals, Aero/Wind Engineering, and Advanced Aerodynamics. Refer to Appendix J for more graduate degrees and specializations that can relate to offshore wind.

UMass Lowell professors use innovative methods, that use technology and physical space to contribute to effective student learning. UMass Lowell’s mission is to create and keep a high-level, living, learning, and research environment that is safe, sustainable, and healthy. The university supplies career preparation for students (University of Massachusetts Lowell, n.d.a).

UMass Lowell involves industry collaboration by partnering with organizations that want to prepare students for work in the industry. The university collaborates with a professional community of collegial interactions that learn with and from one another (University of Massachusetts Lowell, n.d.b).

Section 4.3 Findings from Objective Four

1. *Industry involvement in education systems is more prevalent in EWEM universities when compared to the United States universities.*

For students to feel prepared, gain experiences, and build connections, universities use industry collaboration as a part of their education. All EWEM universities offer an offshore wind industry collaboration program. Whereas, only two of the discussed New England universities offer industry collaboration programs, but both are not specific to offshore wind.

We sent out a survey to students in the EWEM program asking if they felt prepared to work in the offshore wind industry after graduating and why. The results showed that 100% of the respondents said that they felt prepared. The first reason students felt prepared was the small class sizes. This allowed them to establish better relationships with their professors and peers. The second reason was that students completed a combination of group work and individual work. All of the survey participants said that their classes combine projects and exams. This combination allows professors to assess the student's individual knowledge while giving them an opportunity to solve problems on a team. Lastly, one of the respondents mentioned the range of topics for the thesis project. Since four universities compose the EWEM, there are more thesis project topics for students to choose from than if it was one university.

The EWEM universities often require collaboration with the industry in some form of their curriculum. When applying for a thesis, students have academic outlets they can consult to explore potential projects. These outlets include DTU's Partnerships, the Valorisation Centre, and the NTNU Bridge.

DTU hopes to be the nation's center of technological advancements through research, innovation, collaboration, and scientific consultancy. This university collaborates with the industry to further growth, and create new jobs through their program, DTU Partnerships. DTU Partnerships organizes networking events between students and companies which allows DTU to actively seek more industry involvement. Through our interviews with professors at DTU, we learned that there is a yearly conference where the department heads at DTU collaborate on their curriculum with experts in the industry.

To graduate, TU Delft requires students to participate in offshore renewable research projects. The Valorisation Centre of TU Delft sets research projects up for students to collaborate with the industry, government, and institutions on global challenges and technological advancements (Delft University of Technology, n.d.c).

The NTNU Bridge is a career portal that connects students and employers on academic projects, internships and permanent positions. Students partner with companies on assignments, internships, and jobs that expand their knowledge of their specialty (Lie, 2019). In addition to the NTNU Bridge, organizations participate in workshops for students. At the workshop employers give a short presentation of their company and students are then able to discuss the projects with employers. This allows a more interactive and engaging learning environment for students to learn about the offshore wind industry.

These EWEM universities actively seek research opportunities from offshore wind companies. However, in the United States, there aren't enough established offshore wind educational programs for companies to seek out for collaboration opportunities. In New England, Tufts and Northeastern both have a form of industry involvement; however, it is not a program dedicated to only the offshore wind industry.

Tufts has an Office of Technology Transfer and Industry Collaboration that helps to expose students to the industry. Their goal is to incorporate global experiences and issues into the structure of the university (Harris, 2013). Through this office students are able to transfer their innovative ideas into the world.

Northeastern uses a career management portal, NUworks. NUworks connects students to cooperative education (co-op), and internship opportunities (Northeastern University, 2020). Co-ops allows students to experience working in their field of study before graduating. Students can establish relationships with companies they work for so in the future they can be offered a more permanent position (Northeastern University, n.d.a). In addition, Northeastern holds career fairs for businesses and employers to participate and gain the interest of students. Each method helps students connect with the industry and learn from hands-on experience.

2. *All three of the New England universities we researched have similar teaching methods and values to the EWEM universities.*

Since the EWEM program comprises four different universities, there can be a large number of different teaching methods used throughout the program. We hypothesized that depending on the specialization track that students follow; they may experience differences in these. Refer to figure 4 for information of which university offers each track. Every program starts at the DTU, which means the DTU's teaching methods would influence everyone. The second semester occurs at TUDelft. This is where three of the four educational tracks are. These are electrical power systems, offshore engineering and rotor design. The last track offered in the EWEM is wind physics and students can only complete it at UOL during the 2nd semester. The third semester has two tracks that offered at NTNU - offshore engineering and electrical power systems, and two that attend the DTU - wind physics and rotor design. Since students spend the most time at the DTU, it's teaching methods have a large impact on students.

When conducting more research and interviews, our original hypothesis was wrong. We discovered that all the EWEM universities have very similar teaching methods to each other. The EWEM universities practice the use of innovation, interdisciplinary and societal collaboration, project and group based learning, and individual assignments. These school all use up-to-date technology for project and group-based learning as their primary teaching methods. In the interviews with professors, many agreed that this method was the most effective way to produce students with proper skills for the workforce. These were skills such as communication, leadership, problem solving, and conflict resolution. Other methods such as individual assignments, used to promote independent skills, exist but to a small extent compared to the other methods.

From interviews and surveys, we discovered that student-professor relationships in the EWEM are much closer than what is present in the United States. The cultures in the locations of these universities promote a flat hierarchy where students and professors are on equal social levels. In the United States a strong social hierarchy is present in all things, which effects the relationship between two parties. Professors and students in the EWEM agreed that close connections between the two parties make the process of research and learning much easier.

Tufts University uses interactive lectures and team-based learning. The team-based learning is group projects to promote the same skills as the EWEM program. The interactive lectures allow for a closer student-professor interaction. This tries to break the relationship conception told above. Since universities, such as the EWEM ones, show great success from these close relationships, it became important for universities in the US to incorporate means of producing them.

Northeastern University has a Center for Advancing Teaching and Learning Through Research department (CATLR), which supports their educators and enhance student learning through workshops, innovative research, and industry-related projects. Students at Northeastern University learn through experience. The university requires most students to go through a co-op program. This is used to develop skill in students, such as collaboration, communication, and problem solving. Students tend to acquire or further develop these skills after the education process, typically when working in the industry. When students have these skills before working, prosperity for the industry is easier to obtain.

UMass Lowell follows a similar path as the other two New England Universities. They incorporate innovation and technology into their teaching methods to be as effective as possible. Many classes use model programs and simulations to increase knowledge gained through experience rather than memorization.

All these universities, from the EWEM and New England, share a very common goal when it comes to students. They want to prepare them for the industry as much as possible.

3. *Tufts University and the EWEM universities have similarities with their offshore wind energy program's courses.*

The EWEM program offers four specialization tracks: Wind Farm & Atmospheric Physics, Rotor Design, Electrical Power Systems, and Offshore Engineering, as seen in Appendix K. The M.S. program offered at Tufts University overlaps the most with the offshore engineering track at the EWEM. The main research areas of Tuft's program are infrastructure and transmission, size characterization and permitting, and foundation design and monitoring. The main research area of the EWEM offshore engineering track is the design and maintenance of offshore structures and support systems which includes the effects of soil dynamics and hydrodynamics. The research areas of both programs are fundamentals of civil engineering. When knowing that the main research areas of both programs follow similar fields, we can assume that the courses will correlate in many ways.

Figure 4 shows the list of courses that students complete in Tufts' program and the comparable courses offered by the EWEM program. The offshore engineering specialization in the EWEM program encompasses most of the courses that correlate to the Technical Core courses in Tufts' program. The Technical Elective courses in Tufts' program have comparable courses from each specialization track of the EWEM program, rather than just one. This is due to the broad nature of electives, allowing students to choose alternate topics to study. The Policy, Economics, and Management Elective courses, in the program at Tufts, have comparable courses offered as electives in the EWEM program. Refer to Appendix M for the courses in the Tufts' program and refer to Appendix L for EWEM program courses.

These similarities provide hope for the future of the offshore wind industry in the United States. Nevertheless, there still are large differences between these programs. The offshore engineering track offers more courses, which provide deeper knowledge on the correlating topics and include other essential topics. Refer to Appendix L for the course list. In addition, the EWEM program has three other specialization tracks which follow topics related to offshore wind that the Tufts program does not cover. Refer to Appendix K for the specialization tracks. Although Tufts program does not cover these topics, the fundamentals taught in them exist in other degree programs in the United States.

Overlapping Course in Offshore Wind Energy Programs	
Tufts University	**EWEM**
- Finite Element Analysis	- Finite Element Method in Structure Analysis

<table>
<tr><td>- Structural Dynamics</td><td rowspan="2">- Structural Dynamics
Other topic specific courses*</td></tr>
<tr><td>- Advanced Structural Dynamics</td></tr>
<tr><td>- Structural Health Monitoring</td><td>- Structure Analysis
- Fatigue & Fracture in Marine Structures
- Load Identification and Monitoring of Structures</td></tr>
<tr><td>- Foundation Engineering</td><td>- Bottom Founded Structures
- Stability & Analysis of Structures I & II</td></tr>
<tr><td>- Advanced Soil Mechanics</td><td rowspan="2">- Advanced Soil Mechanics
- Soil Structure Interaction
- Soil Dynamics
- Soil Modeling</td></tr>
<tr><td>- Laboratory Measurements of Soil Properties</td></tr>
<tr><td>- Geomechanics</td><td>- Geotechnical Engineering
- Offshore Geotechnical Engineering</td></tr>
<tr><td>- Design & Analysis of Offshore Support Structures</td><td>- Offshore Wind Support Structures
- Stability & Analysis of Structures I & II
- Design & Analysis of Structures I & II</td></tr>
<tr><td>- Clean Energy Engineering</td><td>- Offshore Wind Energy
- Solar Energy</td></tr>
<tr><td>- Energy Entrepreneurship and Finance</td><td rowspan="3">- Feasibility Study of Energy Projects
- Energy Economics, Markets and Policies
- Successful Leadership & Innovation Within the Energy Sector.</td></tr>
<tr><td>- Economics of Energy Markets</td></tr>
<tr><td>- Leading Teams and Organizations</td></tr>
<tr><td>- Project and Operations Management</td><td>N/A**</td></tr>
<tr><td>- Geographic Information Systems</td><td>- Geotechnical Engineering
- Offshore Geotechnical Engineering
- Experimental Simulations</td></tr>
<tr><td>- Building Information Modeling</td><td>- Experimental Simulations
- Model Predictive Control</td></tr>
<tr><td>- Applied Data Science</td><td>- Optimization & Data Fitting</td></tr>
<tr><td>Courses from the ECE department*</td><td>Electrical Power Systems Track*</td></tr>
</table>

Courses from ME department*	All tracks*
Courses from CS department*	programming in software classes as electives Electrical Power Systems Track* CS courses**

* Not a specific course of the program, but incorporates many courses that the student can choose from
**Not available in the program, but available outside the program, and can possibly be used as an elective

Figure 5: Overlapping courses in the offshore wind energy programs from both Tufts University and the EWEM program. Reference Appendices L & M.

4. *Both the United States and Danish education systems can provide a vast number of engineering degrees that apply to the offshore wind industry.*

Although the offshore wind energy industry needs offshore wind energy engineering degrees for specialty jobs, other fields of engineering overlap. During our interviews, Lautec employees said that they would like to hire engineers, since they are adaptable and have experience in the field and on projects. Some of the most common degrees mentioned include civil, mechanical, and electrical engineering. The broad coverage of topics and desirable skills developed in the degrees can provide the growing offshore wind industry with a viable workforce.

All of the universities, we researched, offer Mechanical, Civil, and/or Electrical Engineering Master degrees. Electrical engineers have skills to work through problems of power transferring from offshore wind farms to energy storage systems. Mechanical engineers have skills to work well on diverse projects, including the function of offshore wind turbines. Civil engineers design, build, and supervise the construction of various structures, which can include offshore wind farms. The various jobs emphasize the overlap and relationship between engineering degrees and their importance in the field.

In our survey, we asked EWEM students what they studied for their undergraduate degree. The respondents listed Aerospace Engineering, Mechanical Engineering, Environmental Engineering, and Naval Architecture & Marine Engineering as their background. Appendix E-L list all the master degrees and specializations of each university in the EWEM. Not all the universities offer the degrees that the survey students responded with. This shows that so many degrees can be beneficial to the offshore industry. All forms of engineering can help to some extent. The greatest benefit that the US has over other countries is its vast number of universities, many of which have viable engineering degrees, where every engineering field is covered.

Although, Northeastern University, and the University of Massachusetts Lowell have a form of a renewable energy engineering program, the course topics are broad and cover the fundamentals of engineering. The course offerings for their programs cover many topics with no specialization to offshore wind. Refer to Appendices O & P for courses required in both programs. This means that a more developed degree program, such as civil, mechanical, or electrical, from these universities would provide more benefit to the industry.

Chapter 5 Conclusion and Recommendations

Section 5.1 Introduction

The goal of our project was to conduct a comparative study between the educational programs for offshore wind energy in the EWEM and New England.

The objectives we created to achieve this goal were:

1. *Determine workforce challenges that Lautec's Boston office faces.*
2. *Identify the skills the EWEM students gained at the graduate level.*
3. *Compare the teaching methods and skills promoted in the EWEM program and the OECD Future of Education and Skills 2030.*
4. *Compare the offshore wind educational tracks, teaching methods, and industry involvement in New England and EWEM universities*

We completed this project to help Lautec, and other offshore wind companies, gain a better understanding of the similarities and differences between the EWEM and New England programs. We achieved this goal through a comparative study between the offshore wind educational programs in the EWEM and similar programs in New England.

Section 5.2 Summary of Findings

Our results showed that the offshore wind energy education in the EWEM program is more advanced than the ones present in New England. The EWEM program provides more courses and specializations to allow in-depth knowledge on many parts of the offshore wind field. However, the EWEM and New England universities relate by utilizing industry collaboration, project-based learning, and innovative teaching methods.

Industry collaboration appears in each university through a dedicated program. Examples of the EWEM universities programs are the DTU Partnerships, TU Delft's Valorisation Centre, and NTNU Bridge. In New England, Northeastern and Tufts offer their own industry collaboration programs through co-op, internships, and project departments.

The EWEM universities practice the use of innovation, interdisciplinary and societal collaboration, project and group based learning, and individual assignments. The New England Universities use similar techniques. Both Tufts and Northeastern have interactive lectures and team-based learning to promote collaboration, communication, and problem-solving skills. UMass Lowell uses innovation and technology in their courses to model programs and simulations providing students with experience for industry topics.

Through our comparison of the EWEM and New England programs' courses, we discovered that Tufts university has the closest comparable program to the EWEM. We conclude that it can produce a specialized workforce for the United States offshore wind industry. However, we have not seen its effects because its establishment is recent.

Although Tufts university, Northeastern university, and the University of Massachusetts Lowell have a form of a renewable energy engineering program, the course topics are broad and cover the fundamentals of engineering. This is the greatest benefit of the United States education system. Most universities in the US have core engineering degrees that provide both fundamental knowledge and skills useful to offshore wind. From our four findings, these New England universities can benefit the offshore wind industry, in similar ways that the EWEM universities would.

Section 5.3 Recommendations

We have three recommendations to build off our findings. Our first recommendation is that offshore wind and relating companies in New England establish connections with Northeastern University and become a part of their co-op program. This type of program allows students to receive industry training and education at the same time. In addition, the industry can work along the university and promote the resolution of current issues.

Our second recommendation is that offshore wind companies in the United States establish a partnership with universities and vice versa. A key finding in our research was that the collaboration between the offshore wind industry and the EWEM prepared students for the industry. Education systems can establish this through meetings, conferences, internships, cooperative education, career fairs, and research projects. Meetings between the industry and education systems give each side the opportunity to share ideas on how to improve simultaneously. Conferences and career fairs allow many companies and students to attend to learn about the industry. Industry sponsored research projects create a direct connection to the education of students and advance the industry. Companies could present problems to a university where students could assist in solving them.

Our third recommendation is that United States offshore wind energy companies host employee-student workshops like that of NTNU's workshops. Workshops spark student interest about the industry. Hosting these at high schools would be different than NTNU's workshops in Europe, but beneficial to expose and increase student knowledge on offshore wind energy. At workshops, employees present information on their work and contributions to society. During workshops, students ask questions and make comments on what employers presented, creating an engaging learning environment. To start the collaborations, companies can connect with the civil, mechanical, or electrical engineering departments at United States universities since these departments overlap with the offshore wind industry.

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Appendix A Consent Script

We are a group of students from Worcester Polytechnic Institute (WPI) in Worcester, MA, USA working on a project with Lautec. We are interested in interviewing ______(insert name)_____. Are you willing to participate in this interview/survey? We will be using your responses as part of a research project aimed to understand an educational system for offshore wind and adapt the program to meet workforce development challenges.

The interview will try to be around half an hour long. Our team is requesting verbal consent to complete an interview with you. This research will be published, and quotes may be used. With your permission, this interview will be recorded but your name will remain confidential. Please note that this is a voluntary interview and you have the option to skip answering questions that you feel are uncomfortable or if you simply do not have an answer to.

We are seeking information on how students, professors, and other individuals are involved with offshore wind programs in Denmark. This information is intended to give us a general idea of people's knowledge and involvement with the new industry and whether the current academic programs are sufficient enough to produce possible employees for this industry. The following information will be used for analyzing the offshore wind education system.

Do you have any questions that you would like to ask us before we begin the interview? And feel free to contact us at gr-OffshoreWindEducation_DK_A20wpi.edu@wpi.edu at any point in time after the interview is concluded if you have any follow up comments or questions for us.

Appendix B Interview Questions for Employees of Offshore Wind Companies

- What piqued your interest in this company and field?
- How did you hear about Lautec?
- What is your educational background? What degree did you obtain? - im skipping
- What is your position and what does it entail?
- How long have you been working at Lautec?
- What degree do people with your position normally obtain?
- Did you work in the offshore wind or relating industry before working for Lautec? - im skipping
- What is the main way that Lautec connects with possible new-hirees? College connection? Conferences? Online hiring database?
- Would hiring interns, co-ops, or people with experience in this industry be more beneficial at this time?
- What positions are lautec currently looking for?
- What are the expectations of a new employee? What type of training do they recieve?
- What undergraduate backgrounds do you believe are most beneficial to move this industry forward? Im skipping
- What are the top 3-4 skills that you have developed while working in this industry?
- What current projects are you working on? With what farm/company?
  - (if applicable)
  - What are the next steps? Who is needed to continue?
- What problems do you see within the wind energy industry in the US? Im skipping
- Have you attended a conference on behalf of Lautec?
  - What did you learn from this? What did you bring back to Lautec?
  - Were there schools present at these conferences?
- What other industries do you feel overlap with the offshore wind industry?

Questions for Lautec Partners

- What is your educational background? What degree did you obtain?
- What is your position and what does it entail?
- What exactly is lautec and how/where does it fit into the offshore wind industry? (in detail) Can you explain what Lautec does ?
- Why did Lautec expand to Boston?
- How many projects has Lautec worked on?
- Are there any differences between the Denmark and Boston office?
- Does the Boston office require a different type of employee than the Denmark office? (workforce wise)
  - If so, what types of employees are Lautec looking for?
- What is the main way that Lautec connects with possible new-hirees? College connection? Conferences? Online hiring database?
- Would it be desirable to have more employees in the Boston office? If so How many?
  - Are there benefits that lautec sees for having a small amount of employees?
- How does a small company, such as lautec, compete with large companies?
  - What is the competition for lautec?
  - Do large companies like Orsted conduct the same work as Lautec?
  - Does Lautec provide something that other companies cannot?

Appendix C Interview Questions for Professors of Offshore Wind Education Programs

- How long have you been a professor at ________ university?
- What subject(s) do you teach and why did you decide to become a professor of_____?
- Have you worked in the offshore wind or relating industry?
- What is the classroom environment like for each subject? Size?
- How would you describe your teaching style?
- What are your assignments like? are the assignments group based, individualized, project based or exam based?
- What are your top 3 expectations or requirements other than the prerequisites for students starting in your class?
- What undergraduate backgrounds do you believe are most successful as they move forward in your class or program?
- Is there anything uniquely danish about the education program?
- How do the techniques you teach your students shift with the growing industry?
- What are the top 3-4 skills you try to develop with your students?
- What makes the EWEM program great, in your opinion?
- What does the EWEM program lack, in your opinion?
- What is the collaboration like between professors at this university and other universities in the EWEM program?
- Have you ever been a supervisor for a thesis project? What information did you gain from this project?
- Would it be okay with you if within the next few days we send you a follow up email with a survey for you to forward to your students?

Appendix D Survey Questions for Students Involved in the European Wind Energy Masters Program

- Where and what did you study before joining the EWEM program?
- What specialty are you following in the EWEM program?
- What university are you currently at?
- Do you prefer learning at multiple different universities while in the same program?
- In reference to question 4, why do you like or dislike this?
- Are your classes project-based or exam-based?
- What are your top 3 skills/proficiencies as a student?
- What university provided the most profound impact on your education?
- Have you completed your thesis project? If so, summarize what it was about and what you think you learned during this?
- Did this program set you up to go into the wind industry?
- In your opinion, what does the EWEM program lack?
- In your opinion, what makes the EWEM program great?

Appendix E Master Degrees and Specializations at The Technical University of Denmark

- Civil Engineering
    - Structural Engineering
    - Marine and Coastal Engineering
    - Geotechnical Engineering
- Computer Science and Engineering
    - Digital Systems
    - Embedded and Distributed Systems
    - Software Engineering
- Design and Innovation
    - Innovation Management and Entrepreneurship
    - Product Design
    - Sustainability and Eco-design
- Electrical Engineering
    - Electric Energy Systems
- Industrial Engineering and Management
    - Innovation and Strategic Management
    - Management and Analysis of Operations
    - Production and Project Management
- Mechanical Engineering
    - Engineering Design and Product Development
    - Strength and Dynamics of Structures
    - Energy Engineering
    - Maritime Engineering
- Sustainable Energy
    - Electric Energy Systems
    - Energy Conversion and Storage
    - Energy Savings
    - Energy Systems Analysis
    - Wind Energy
- Wind Energy
    - Mechanics and Aerodynamics
    - Mechanics of Materials and Structures
    - Testing and Measurements
    - Electrical Wind Turbine Systems
    - Electrical Wind Turbine Technology

Appendix F Master Degrees and Specializations at Delft University of Technology

- Aerospace Engineering
    - Aerodynamics and Wind Energy
    - Aerospace Structures and Materials
- Applied Physics
    - Physics for Energy
    - Physics for Fluids Engineering
- Civil Engineering
    - Structural Engineering
- Complex Systems Engineering and Management
- Computer Engineering
- Computer Science
    - Data Science and Technology
    - Software Technology
- Construction Management and Engineering
- Electrical Engineering
    - Electrical Power Engineering
- Engineering and Policy Analysis
- Management of Technology
- Material Science and Engineering
    - Materials in Engineering Applications
    - Materials for Sustainable Development
- Mechanical Engineering
    - Energy and Process Technology
- Offshore and Dredging Engineering
    - Bottom Founded Structures, Arctic & Wind
    - Dredging Engineering
    - Floating Offshore Structures
    - Structural Design & Analysis
    - Offshore Renewable Energy
- Sustainable Energy Technology
    - Wind Energy
    - Power
    - Storage
    - Economics and Society

Appendix G Master Degrees and Specializations at the Norwegian University of Science and Technology

- Applied Physics
    - Applied Physics
- Civil and Environmental Engineering
    - Building and Construction Engineering
    - Structural Engineering
    - Coastal and Arctic
- Computer Science
    - Software
- Electrical Power Engineering
- Electronics Systems Design & Innovation
- Energy and Environmental Engineering
    - Heat and Energy Process
    - Energy Systems Planning
    - Electrical Energy Engineering
- Geotechnology
    - Engineering and Environmental Geology
- Marine Technology
    - Marine Engineering
    - Marine Structures
    - Marine Systems Design
    - Safety and Asset Management
- Materials Science and Engineering
    - Resources, energy and environment
    - Materials Development and Properties
    - Materials for Energy Technology
- Mechanical Engineering
    - Engineering Design and Materials
    - Energy, Process and Fluids Engineering
    - Industrial Engineering
    - Applied Mechanics

Appendix H Master Degrees offered at the University of Oldenburg

- Computer Science
- Engineering Physics
- Environmental Modelling
- European Master in Renewable Energy
- Marine Environmental Sciences
- Marine Sensors
- Physics
- Sustainability Economics and Management
- Water and Coastal Management

Appendix I Master Degrees and Specializations at Tufts University

- Civil and Environmental Engineering
- Offshore Wind Energy Engineering
    - Infrastructure and Transmission
    - Site Characterization and Permitting
    - Foundation Design and Monitoring
- Computer Engineering
    - Computer Software/System
- Computer Science
    - Data Science
    - Software Systems Development
- Electrical Engineering
    - Networks and Information Theory
    - Renewable Energy
    - Control and Energy Systems
- Engineering Management
- Environmental Policy and Planning
- Innovation and Management
- Materials Science and Engineering
    - Civil
    - Electrical
    - Mechanical
- Mechanical Engineering
- Sustainability
- Sustainable Water Management
    - Water Infrastructure

Appendix J Master Degrees and Specializations at the University of Massachusetts Lowell

- Civil & Environmental Engineering
    - Environmental Engineering
    - Geotechnical Engineering
    - Geoenvironmental Engineering
    - Structural Engineering
- Computer Engineering
    - Computer Network
- Computer Science
- Electrical Engineering
    - Information Systems
    - Power and Energy
- Energy Engineering
    - Renewable Energy
- Engineering Management
- Environmental Studies
    - Atmospheric Science
    - Environmental Geoscience
- Mechanical Engineering
- Physics

Appendix K Master Degrees and Specializations at Northeastern University

- Applied Physics and Engineering
- Civil Engineering
  - Construction Management
  - Environmental, Water, and Coastal Systems
  - Geotechnical/Geoenvironmental Engineering
  - Structures
- Computer Science
- Electrical Engineering
  - Power Systems
  - Systems and Software
- Energy Systems
- Engineering Management
- Environmental Engineering
- Industrial Engineering
- Mechanical Engineering
  - Material Science and Engineering
  - Mechanics and Design
- Physics
- Project Management

Appendix L: Master Degrees and Specialization Tracks Offered in the European Wind Energy Master Program

TRACK	AWARDED DEGREES	
Electrical Power Systems	M.Sc. Electrical Engineering — TU Delft	M.Sc. Technology - Wind Energy — NTNU
Offshore Engineering	M.Sc. Offshore Engineering — TU Delft	M.Sc. Technology - Wind Energy — NTNU
Rotor Design	M.Sc. Engineering (European Wind Energy) — DTU	M.Sc. Aerospace Engineering — TU Delft
Wind Physics	M.Sc. Engineering (European Wind Energy) — DTU	M.Sc. Engineering Physics — Carl von Ossietzky Universität Oldenburg

Appendix M European Wind Energy Master Courses for Each Specialization Track, Separated by Semester

Classes for Wind Farms and Atmospheric Physics Track

Semester One

30 ECTS courses @DTU

Click here to find information about the courses at DTU.

Mandatory		ECTS
46300	Wind Turbine Technology and Aerodynamics	10
46100	Introduction to Micro Meteorology for Wind Energy	5
02425	Diffusions and Stochastic Differential Equations*	5
41129	Turbulence Theory*	5
46200	Planning and Development of Wind Farms (January)	5
Electives		
10333	Physics of Sustainable Energy	5
02417	Time Series Analysis	5
02407	Stochastic Processes	5
46211	Offshore Wind Energy	10

**Courses 02425 and 41129 could either be taken in semester 1 or 3.*

Semester Two

30 ECTS courses @UOL

Mandatory		ECTS
n.a.	Research Project EWEM (Winter Break)	9
5.04.4072	Computational Fluid Dynamics I (CFD I)	3
5.04.4074	Computational Fluid Dynamics II (CFD II)	3
5.04.4071	Fluid Dynamics II	3
5.04.4065	Advanced Wind Energy Meteorology	3
5.04.4234	Wind Physics Measurement Project	3
5.04.4236	Aeroelastic Simulation of Wind Turbines	3
5.05.656	Seminar Advanced Topics in Engineering Physics	3

Semester Three

30 ECTS courses @DTU		
Mandatory		**ECTS**
02425	Diffusions and Stochastic Differential Equations*	5
41129	Turbulence Theory*	5
Electives		
46211	Offshore Wind Energy	10
02407	Stochastic Processes	5
02417	Time Series Analysis	5
02427	Advanced Time Series Analysis	10
02610	Optimization and Data Fitting	5
46400	Wind Turbine Measurement Techniques	10
46500	Probabilistic Methods in Wind Energy	5
**Courses 02425 and 41129 could either be taken in semester 1 or 3.*		

Semester Four

30 ECTS thesis (free mobility)**		
Compulsory DTU		
	Master Thesis	30
Compulsory UniOl		
	Master Thesis	30
** The master thesis is supervised by the two degree awarding universities.		

Classes for Rotor Design Track (Aerodynamics)

Semester One

30 ECTS courses @DTU

Click here to find information about the courses at DTU.

Mandatory		ECTS
41317	Computational Fluid Dynamics	5
46300	Wind Turbine Technology and Aerodynamics	10
41320	Advanced Fluid Mechanics	5
	Choose one of the following:	
41129	Turbulent Flows	5
	Engineering Turbulence Modelling	5
Electives	**Choose one of the following:**	
46500	Probabilistic Methods in Wind Energy	5
31200	Fundamentals of Acoustics and Noise Control	5
46200	Planning and Development of Wind Farms (January)	5
41617	Advanced CAD	5

Semester Two

Mandatory		ECTS
AE4010	Research Methodologies*	2
AE4ASM506	Aeroelasticity	3
AE4W21-14	Wind Turbine Aeroelasticity	2
AE4180	Flow Measurement Techniques	3
AE4135	Rotor Aerodynamics	4
AE4W13	Site Conditions for Wind Turbine Design	3
AE4W09	Wind Turbine Design	5
WM0324LR	Ethics	3
Electives		
AE5055	Professional Training	6
WM1115TU	Elementary Course Dutch for Foreigners	3
AE4117	Fluid-Structure Interaction	4
OE44120	Offshore Wind Farms Design	4

** This course can be done in either the 2nd or 3rd semester*

Semester Three

15 ECTS courses + start 45 ECTS Thesis		
Mandatory		**ECTS**
AE4010	Research Methodologies (TU Delft)*	2
	One of the two following courses:	
46320	Loads, Aerodynamics and Control of Wind Turbines	10
46400	Wind Turbine Measurement Techniques	10
	Master Thesis (starting November 1st)	45
Electives		
41526	Fracture Mechanics	5
31200	Fundamentals of Acoustics and Noise Control	5
46200	Planning and Development of Wind Farms (January)	5
** In case you did not do this course in the 2nd semester*		

Semester Four

45 ECTS thesis (free mobility)**		
Compulsory DTU		
	Master Thesis	45
Compulsory TU Delft		
AE5912	Master Thesis	45
*** The master thesis is supervised by the two degree awarding universities*		

Classes for Rotor Design Track (Structures and Composites)

Semester One

30 ECTS courses @DTU

Click here to find information about the courses at DTU.

Mandatory		ECTS
46420	Composite Materials and Fibres	5
46300	Wind Turbine Technology and Aerodynamics	10
41525	FEM-Heavy (Programming the Finite Element Method)	10
Electives		
41526	Fracture Mechanics	5
31200	Fundamentals of Acoustics and Noise Control	5
46200	Planning and Development of Wind Farms (January)	5

Semester Two

30 ECTS courses @TU Delft

The 2nd semester at the TU Delft is divided in two quarters. Click here to find information about the courses at the TU Delft.

Mandatory		ECTS
AE4010	Research Methodologies*	2
AE4ASM506	Aeroelasticity	3
AE4W21-14	Wind Turbine Aeroelasticity	2
AE4ASM505	Non-linear modeling (using FEM)	3
AE4ASM109	Design & Analysis of Composite Structures I	5
AE4ASM105	Composite Trinity Exercise	4
AE4W09	Wind Turbine Design	5
WM0324LR	Ethics	3
Electives		
AE4ASM510	Design & Analysis of Composite Structures II	3
AE4ASM511	Stability & Analysis of Structures II	3
AE5055	Professional Training	6
AE4117	Fluid-Structure Interaction	4
WM1115TU	Elementary Course Dutch for Foreigners	3

** This course can be done in either the 2nd or 3rd semester*

Semester Three

15 ECTS courses + start 45 ECTS Thesis		
Mandatory		**ECTS**
AE4010	Research Methodologies (TU Delft)*	2
	One of the two following courses:	
46320	Loads, Aerodynamics and Control	10
46400	Wind Turbine Measurement Techniques	10
	Master Thesis (starting November 1st)	45
Electives		
41526	Fracture Mechanics	5
31200	Fundamentals of Acoustics and Noise Control	5
46200	Planning and Development of Wind Farms	5
46100	Introduction to Micro Meteorology for Wind Energy	5
41319	Computational Fluid Dynamics	10
** In case you did not do this course in the 2nd semester*		

Semester Four

45 ECTS thesis (free mobility)**		
Compulsory DTU		
	Master Thesis	45
Compulsory TU Delft		
AE5912	Master Thesis	45
*** The master thesis is supervised by the two degree awarding universities*		

Classes for Electric Power Systems Track

Semester One

30 ECTS courses @DTU

Click here to find information about the courses at DTU.

Mandatory		ECTS
46300	Wind Turbine Technology and Aerodynamics	10
31730	Electric Power Engineering, Fundamentals	10
31352	Power Electronics 1	10
Electives*		
31786	Wind Turbine Electrical Design	10
31750	Stability and Control in Electric Power Systems	10
31773	Transients in Power Systems	5
31783	Integration of Wind Power in the Power System	5

**Students can choose any Wind Energy related course or a course on general competences at DTU. Note that the choice has to be approved by the track coordinators.*

Semester Two

30 ECTS courses, incl. possible internship @TU Delft

The 2nd semester at the TU Delft is divided in two quarters. Click here to find information about the courses at the TU Delft. It is suggested that EWEM-students follow one of the three profiles given at the electives below in order to prepare themselves for the MSc thesis project.

Mandatory		ECTS
ET4108	Transients in Power Systems	4
Electives / specialization courses		
High Voltage		
EE4545	Electrical Power Systems of the Future	4
EE4550	Electromagnetic Modeling in Power Engineering	5
ET4108	Transients in Power Systems	4
ET4111	High-Voltage DC	3
ET4114	Power System Grounding and Protection	3
ET4116	Power Electronics	4
ET8020	High Voltage Testing and Diagnosis	4
Power Electronics and Electrical Machines		
EE4515	Advanced Power Electronics	4
EE4550	Electromagnetic Modeling in Power Engineering	5
ET4117	Electrical Machines and Drives (via Collegerama)	4
ET4116	Power Electronics	4
ET4121	A.C. Machines	4
ET4145	Power Electronic Components	4
ET4291	Control of Electrical Drives	5
ET4108	Transients in Power Systems	4
Smart AC Grids and DC Grids		
EE4536	DC and AC Microgrids	4
EE4545	Electrical Power Systems of the Future	4
ET4108	Transients in Power Systems	4
ET4113	Power System Dynamics	4
ET4117	Electrical Machines and Drives (via Collegerama)	4
ET4116	Power Electronics	4
SET3065	Intelligent Electrical Power Grids	4
Free electives (max 15 ECTS)		
WM1115TU	Elementary Course Dutch for Foreigners	3
ET5S	Internship**	6

***Students can choose do to an internship at industry and obtain ECTS for it. The faculty of Electrical Engineering at TU Delft offers an internship of 9 to 15 ECTS, depending on the time the students will stay at a company. EWEM students are allowed to use only 6 ECTS of the total amount of credits in their study programme. The remaining ECTS will be extra-curricular, i.e. the student will end up with >120 ECTS (for example, if the student takes an internship of 12 ECTS, the student will end up with 126 ECTS after completing the EWEM programme).*

Semester Three

15 ECTS courses + thesis @NTNU Click here tto find information about the courses at NTNU.		
Mandatory		**ECTS**
TET5505	Electric Power Engineering, Specialization Course	7.5
	You will start with your thesis research project	
Electives		
TET4160	Insulating Materials for High Voltage Applications	7.5
TET4190	Power Electronics for Renewable Energy	7.5
TET5100	Power Engineering Updates	7.5
TET4115	Power System Analysis	7.5

Semester Four

4th Semester – 45 ECTS thesis (free mobility)****		
Compulsory TU Delft		
ET4300	Master Thesis***	45
Compulsory NTNU		
TET4920	Electric Power Engineering, Master Thesis***	45

**** The specialization project TET5500 Electric power Engineering (15 ECTS) is part of the thesis work.*

***** The master thesis is supervised by the two diploma awarding universities and it is worth 45 ECTS.*

Classes for Offshore Engineering Track

Semester One

30 ECTS courses @DTU

Click here to find information about the courses at DTU.

Mandatory		**ECTS**
46300	Wind Turbine Technology and Aerodynamics	10
46211	Offshore Wind Energy	10
41111	Hydrodynamics 2	5
Electives		
41224	Linear Wave Dynamics	5
46100	Introduction to Micrometeorology for Wind Energy	5
46500	Probabilistic Methods in Wind Energy	5
11464	Advanced Soil Mechanics	5

Semester Two

30 ECTS courses @TU Delft

The 2nd semester at the TU Delft is divided in two quarters. Click here to find information about the courses at the TU Delft.

	3rd Quarter	
Mandatory		**ECTS**
CIE4140	Structural Dynamics	4
OE44095	Bottom Founded Structures	6
Electives		
OE44030	Offshore Geotechnical Engineering	4
OE44091	Structural Dynamics Practical	2
OE44115	Arctic Engineering	4
	4th Quarter	
Mandatory		
OE44100	Floating Structures & Offshore Moorings	6
OE44120	Offshore Wind Farms Design	4
OE44135	Offshore Wind Support Structures	4
Electives		
OE44055	Load Identification and Monitoring of Structures	4
OE44085	Fatigue & Fracture in Marine Structures	5
CIE4362	Soil Structure Interaction	3
CIE5340	Soil Dynamics	4

Semester Three

15 ECTS courses + 15 ECTS thesis/specialization project @NTNU Click here to find information about the courses at NTNU.		
Mandatory	**One of both**	**ECTS**
TMR4590	Wind Turbine Energy – Offshore Engineering, Specialization Project*	15
TBA4551	Marine Civil Engineering, Specialization Project**	15
Electives		
TMR4505	Marine Structures, Specialization Course***	7.5
	AT-327 Arctic Offshore Engineering	7.5
TMR4190	Finite Element Methods in Structural Analysis	7.5
TMR4215	Sea Loads	7.5
TMR4305	Advanced Analysis of Marine Structures	7.5
TMR4525	Marine Hydrodynamics, Specialization Course	7.5
TMR4235	Stochastic Theory of Sea Loads	7.5
TMR4200	Fatigue and Fracture of Marine Structures	7.5
TBA4116	Geotechnical Engineering, Advanced Course	7.5
TMM4195	Fatigue design	7.5
BA8304	Soil modeling (Ph.D. course)****	10

**The Specialization Project for EWEM students is part of the thesis project for those who will choose a professor from Department of Marine Technology as supervisor.*
***The Specialization Project for EWEM students is part of the thesis project for those who will choose a professor from Department of Civil and Environmental Engineering as supervisor.*
****Two modules of 3,75 ECTS each(or one of 7.5+ ECTS) shall be selected.*
*****This course is only taught once every two years. Besides the 7.5 ECTS courses offered at the NTNU, there is the alternative of combining two 3.75 ECTS courses into what is called a Specialization module.*

Semester Four

30 ECTS thesis (free mobility)		
Compulsory TU Delft		
OE54030	Master Thesis	30
Compulsory NTNU		
TMR5950	Wind Turbine Energy – Offshore Engineering, Master Thesis*	30
TBA4551	Marine Civil Engineering, Master Thesis **	30

**For those who will choose a professor from Department of Marine Technology as supervisor.*
***For those who will choose a professor from Department of Civil and Environmental Engineering as supervisor.*

DTU Alternative Electives

2393	Programming in C++
2450	Introduction to machine learning and data mining
2610	Optimization and data fitting
2619	Model predictive control
10336	Fundamental problems in fluid dynamics
31200	Fundamentals of acoustics and noise control
41129	Turbulence Theory
41207	Thin-walled beam structures
41215	Plate and shell structures
41291	Non-linear modelling and analysis of structures and solids
41319	CFD
41515	Computational multibody dynamics
41516	Anisotropy and fiber composites
41526	Fracture mechanics
41822	Experimental fluid dynamics
42003	Energy Economics, Markets and Policies
42004	Feasibility studies of energy projects
46100	Introduction to micro meteorology for wind energy
46200	Planning and design of wind farms
46211	Offshore wind energy
46320	Loads, aerodynamics and control of wind turbines
46400	Wind turbine measurement technique
46500	Probabilistic methods in wind energy
46800	Research immersion

TUDelft Alternative Electives

AE4115	Experimental Simulations
AE4117	Fluid structures interactions
AE4120	Viscous flows
AE4130	Aircraft aerodynamics
AE4133:	CFD II
AE4138	CFD 4: Uncertainty Quantification
AE4139	CFD 3: Large Eddy Simulation
AE4245	Advanced aircraft design II
AE4314	Helicopter Performance, Stability and Control
AE4314P	Helicopter Performance, Stability and Control Practical
AE4315	Advanced dynamics
AE4350	Bio-inspired Intelligence and learning for Aerospace Applications
AE4445	Introduction to aircraft noise
AE4509	Advanced design and optimisation of composite structures I
AE4628	Structural design of composite aircraft
AE4ASM106	Stability & analysis of structures I
AE4ASM109	Design & analysis of composite structures I
AE4ASM505	Non-linear modelling (using FEM)
AE4ASM510	Design & analysis of structures II
AE4ASM511	Stability & analysis of structures II
AE4T40	Airborne wind energy
AE4X04	Materials selection in mechanical design

AE4X09	Sensor and smart materials
AE5055	Professional training
ME46060	Engineering optimization: concepts and applications
ME46115	Compliant Mechanisms
OE44120	Offshore wind farm design
OE4680	Arctic engineering
UD9001	Creative problem solving
UD9002	Solar Energy
WI4019	Non-linear differential equations
WB1416	Numerical methods for dynamics
WB1424	Turbulence A
WM0355	Critical reflection on technology
WM0540	Successful leadership, innovation and entrepreneurship within the energy sector
WM0636	Duurzame energie-economie
WM1115	Elementary course Dutch for foreigners
WM1136	Written English for technologists

Appendix N Courses for the M.S. Program at Tufts University

Technical Core: Structural and Geosystems Engineering (choose 4 courses in consultation with program advisor)

1. Finite Element Analysis (CEE-105)
2. Structural Dynamics (CEE-106)
3. Advanced Structural Analysis (CEE-123)
4. Structural Health Monitoring (CEE-127)
5. Foundation Engineering (CEE-146)
6. Advanced Soil Mechanics (CEE-242)
7. Laboratory and In-situ measurements of Soil Properties (CEE-244)
8. Geomechanics (CEE-245)
9. Design and Analysis of Offshore Support Structures (CEE-294)

Energy Core: (required 1 course)

1. Clean Energy Engineering (CEE-120)

Technical Electives: (choose 3 courses in consultation with advisor)

1. Geographic Information Systems (CEE-187)
2. Building Information Modeling (CEE-188)
3. Applied Data Science I (CEE-294)
4. Energy & Infrastructure Systems (CEE-294)
5. Reliability (CEE-294)
6. CEE Courses from the Technical Core listed above and other CEE courses in consultation with advisor
7. Up to two courses from the ECE Department in consultation with advisor
8. Up to two courses from the ME Department in consultation with advisor
9. Up to two courses from the CS Department in consultation with advisor

Policy, Economics and Management Electives: (choose 2 courses in consultation with advisor)

1. Courses from the Fletcher School Diplomacy, History and Politics (DHP) Division:
    - Energy, Entrepreneurship & Finance (DHP-P251)
    - Climate Change and Clean Energy Policy (DHP-P254)
    - International Energy Policy (DHP-P255)
2. Course from the Economics Department:
    - Economics of Energy Markets (EC-132)
3. Courses from the Gordon Institute:
    - Project and Operations Management (MSEM Course 3)
    - Humanistic Perspectives on Leadership (MSEM Course 5)
    - Leading Teams and Organizations (MSEM Course 6)

Appendix O Courses for the University of Massachusetts Lowell Energy Engineering Graduate Program

- Well suited to technical majors such as Mechanical Engineering and Physics
- Required Courses (15 Credits)
  1. Chem Eng Thermodynamics
  2. Thermodynamics
  3. Fundamentals of Electricity
  4. Circuit Theory 1
  5. Power Systems Stability and Control
  6. Power Distribution Systems
  7. Physics II
  8. Engineering Economics
  9. Macroeconomics
  10. Intro to Environmental Politics
  11. Justice and Trade in the Global Economy
  12. Science and Technology in an Impoverished World
  13. Green Energy Engineering
  14. Design of Thermo-Fluid Systems
  15. Alternative Energy Sources
- Electives (6 Credit)
  1. Alternate Energy Sources
  2. Transport Process in Energy Systems
  3. Fuel Cell Fundamental
  4. Green Combustion and Biofuels
  5. Convective Heat/Mass transfer
  6. Materials for renewable Energy and Sustainability
  7. Integrated Power Systems
  8. Power electronics
  9. Nuclear Engineering
  10. Solar Fundamentals
  11. Aero/Wind Engineering
  12. Advanced Aerodynamics

Appendix P Courses for the Northeastern University Energy Systems Graduate Program

- Required Courses
    1. Economic Decision Making
    2. Fundamentals of Energy System Integration
    3. Mathematical Methods for Mechanical Engineering
    4. Financial Management for Engineers
    5. Foundations of Accounting and Finance
- Elective Courses
    1. Hydropower
    2. Electrochemical Energy Storage
    3. Wind Energy Systems
    4. Energy Storage Systems
    5. Smart Grid
    6. Electrochemical Energy Storage
    7. Sustainable Energy: Materials, Conversion, Storage, and Usage
    8. Special Topics in Energy Systems
    9. General Thermodynamics
    10. Engineering Project Management