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Identification of Curriculum Content for a Renewable Energy Graduate Degree Program

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IDENTIFICATION OF CURRICULUM CONTENT FOR A RENEWABLE ENERGY GRADUATE DEGREE PROGRAM

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Morehead State University, 2014

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There currently exists a disconnect between renewable energy industry workforce needs and academic program proficiencies. This is evidenced by an absence of clear curriculum content on renewable energy graduate program websites. The purpose of this study was to identify a set of curriculum content for graduate degrees in renewable energy. At the conclusion, a clear list of 42 content items was identified and statistically ranked. The content items identified were based on a review of literature from government initiatives, professional society's body of knowledge, and related research studies. Leaders and experts in the field of renewable energy and sustainability were surveyed, using a five-point Likert-Scale model. This allowed each item's importance level to be analyzed and prioritized based on non-parametric

statistical analysis methods. The study found seven competency items to be *very important*, 30 to be *important*, and five to be *somewhat important*. The results were also appropriate for use as a framework in developing or improving renewable energy graduate programs.

Accepted by: ______________________________, Chair
Ahmad Zargari

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Hans Chapman

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Nilesh Joshi

Dedication

This research is dedicated to Dr. Hans Chapman for his support and guidance throughout the project, Dr. Ahmad Zargari for his tireless encouragement and direction, Dr. Nilesh Joshi for his keen eye for details, and most importantly Cori and John Porter Haughery for their steadfast support and love.

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The following organizations and individuals were instrumental to the results of this study: the American Council On Renewable Energy's (ACORE) Ms. Turner Houston, Mr. Thomas Veague, Advisory Board, and Board of Directors; the Solar Energy Industries Association's (SEIA) Mr. Ken Johnson and employees; the North American Board of Certified Energy Practitioners' (NABCEP) Mr. Richard Lawrence and Board of Directors; the American Solar Energy Society's (ASES) Mr. Brian Allen, Board of Directors, and Technical Division Chairs; the Environmental and

Energy Study Institute's (EESI) Ms. Amaury Laporte, Board of Directors, and Advisory Board; the National Hydropower Association's (NHA) Ms. Linda Church Ciocci and staff; and the Hydro Research Foundation's (HRF) Ms. Deborah Linke, Board of Directors, and Steering Group. A profound thanks is made to these organizations and individuals. Without their participation this research could not have been accomplished.

A special thanks is given to Dr. Jim Menart, Director of Wright State University's Renewable and Clean Energy master's program. Mr. Menart's help at the outset of this research was instrumental. He generously gave his time for questions related to Wright State's graduate program and offered course syllabi from this degree as examples of renewable energy course content. His help was invaluable.

Lastly, Cori and John Porter Haughery (wife and son of the author) are acknowledged for their tireless love and care through the many late nights and long weekends. Without their support, this research would never have been completed.

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Chapter I – Introduction

General Area of Concern

Renewable energy is fast becoming a staple energy source, both in America and around the world. According to the International Energy Agency (IEA, 2013), renewable energy's total production increased by 8.2% from 2011 to 2012. To put this in context, the total global capacity of renewable energy produced in 2012 exceeded China's total electricity demand (4,860TWh). Furthermore, the IEA's report estimated that by 2018 renewable energy would account for 25% of gross energy generation worldwide (2013). Specifically in the United States, renewable energy technologies have garnered increasing support from government, academia, and industry.

In light of this growth, universities and colleges across the United States are striving to keep pace with renewable energy technology and policy. This has fostered an emerging conglomerate of renewable energy degree offerings, which, according to James Elder, Director of the Campaign for Environmental Literacy, are vital to the growth of the Nation. He says that universities and colleges have a critical responsibility to equip the future leaders of society to "understand the complex connections and interdependencies between the environment, energy sources, and the economy" (Elder, 2009, para. 3).

In step with Elder's comments, educational institutions are migrating towards an increased commitment to renewable energy usage, research, and education. This was exemplified by the 2009 statistic that colleges and universities were among the largest purchasers of wind energy in America (Elder, 2009). As further proof of this increased commitment, 680 university and college presidents across the United States have signed the *American College & University Presidents' Climate Commitment*. This is a highly visible commitment to promote the use of renewable and sustainable energy sources in conjunction with research initiatives and the promotion of renewable energy education. By signing this commitment, these members promised to (a) generate an emissions inventory, (b) set target dates and short-term milestones for climate neutrality, (c) take immediate action to reduce CO_2 emissions, (d) integrate sustainability into the course offerings, and (f) become transparent with the community about above issues (President's Climate Commitment, 2014).

However, according to Yildiz and Coogler (2012), universities and colleges need to go beyond a commitment. In order for educational institutions to effectively equip the future workforce for the multi-faceted issues related to energy and sustainability, they need to expose their students to renewable energy courses (Yildiz & Coogler, 2012). These course topics must go beyond merely campus utility issues and carbon footprint initiatives. Ultimately they should culminate in degree offerings that students can build a career around. This is supported by the *Curricula 2015: A Four Year Strategic Plan for Manufacturing Education* report, which cited sustainability as one of the emerging topics recommended to be included in manufacturing engineering curricula. This report represents the efforts of a combination of academic, industry, and service group professionals over a span of four years, with the goal of evaluating the state of manufacturing education and giving recommendations on best practices (Jack, et al., 2011).

It is apparent that education in renewable energy topics is garnering increased importance. Also, find a complete list of current renewable energy graduate degree offerings in the United States is increasing in difficulty. To facilitate database searches for these degrees, the search engines available through PhDs.org's website (2013) and the Association for the Advancement of Sustainability in Higher Education's (ASSHE) website (2012) are very helpful. These sites were used to generate Table 1-1, which shows an abridged list of renewable energy graduate programs offered across the country. These degrees are related specifically to renewable energy, alternative energy, and sustainability.

Table 1-1. Abridged list of related graduate degree programs in the United States.

Quantity	*Graduate Degree Type*
8	Alternative Energy
6	Renewable Energy
20	Energy
9	Energy Management
43	Total

It should be noted that Table 1-1 intentionally contains only graduate's level degree programs. This was in line with the intent of this study, which specifically emphasized research related to graduate level renewable energy degrees. This explicit focus on graduate programs was due to the multi-disciplinary nature of the renewable energy field, which has broad educational feeders across a wide variety of traditional degree programs. Completing one of these traditional undergraduate degrees in science, technology, engineering, mathematics, or business lays a strong foundation upon which an advanced degree in renewable energy can be built. Also, renewable energy careers require high levels of cognitive analysis, evaluation, and creativity, which span a wide variety of fields. These broad and advanced cognitive abilities are usually beyond the scope of an undergraduate degree. Consequently, when considering renewable energy degrees, there is significant merit to focusing on graduate level programs.

Purpose of the Research

In spite of the burgeoning number of renewable energy graduate degrees in the United States, there is currently a lack of clearly defined program competencies for these degrees. Even though many such program websites claim to prepare their graduates for the multi-disciplinary requirements of the green energy workforce, it is hard to find a list of curriculum content that can be directly tied to knowledge, skills, or attributes needed by graduates as required by industry. There are examples of these competencies compiled by both industry and government (ISSP, 2013; ETA, 2010), but as yet there has not been a clear connection between these competencies and academic curriculum content. Bridging this gap will benefit industry, academia, and students. To accomplish this, a body of curriculum content for a renewable energy graduate program was identified. This content was based on competencies appropriate to the field of renewable energy and sustainability. Lastly, professional and academic experts were surveyed to prioritize each item.

Objectives of the Research

Two research objectives were selected to satisfy the purpose stated above. Objective 1 was to determine an appropriate list of curriculum content for a renewable energy degree. This determination was conducted through a literature review of existing programs, scholarly publications, industry reports, government *Green Job* training initiatives, and consultation with renewable energy practitioners and academics. The deliverable that was produced at the completion of this first research objective was a proposed list of competencies that could be included in a renewable energy program.

Objective 2 was to prioritize the list of curriculum content based on importance level. This prioritization was accomplished through statistical analysis of the response data obtained from a survey sent to industry experts in the field of renewable energy and sustainability. In this survey, the respondents were asked to rate each proposed program competency on a 5-point Likert-Scale. The rated results were then analyzed to determine priority rankings of each item. The deliverable from this second objective was a list of competencies grouped according to *very important, important, somewhat important, unimportant,* and *very unimportant.*

Significance of the Research

It is becoming more important for engineering and technology programs to offer courses and degrees linked to renewable energy (Yildiz & Coogler, 2012). This is due in part to the increased push by federal and state policymakers to advance

America's renewable energy capabilities. Also, this technology is increasing in viability. According to Bari and Ferdousi (2012), renewable energy courses and degrees are needed to prepare future engineering and technology graduates for the multi-disciplinary energy workforce. To compound the issue, Batterman, Martins, Antunes, Freire and Gameiro da Silva (2011) state in their paper titled *Development and Application of Competencies for Graduate Programs in Energy and Sustainability*, "transitioning to a sustainable energy system is one of society's greatest challenges. Existing energy systems must confront many immediate issues, including energy security, aging infrastructure, capacity constraints but growing demands, and shifting investment responsibilities under competitive energy markets" (p. 199).

This challenge of "transitioning to a sustainable energy system" can be combated by degree programs that have clearly defined program competency items, which are related to the specific renewable energy knowledge, skills and attributes needed for successful careers in this field (Batterman, et. al., 2011). With these clearly defined and vetted content items, students are given the proper tools to succeed in the renewable energy industry. These program competencies represent a catalog of knowledge, skills, and attributes that are needed for a professional to succeed in industry and therefore should be at the core of any program seeking to trend with this industry. Curriculum content can further serve to "[address] that important gap between academia and practice" (Batterman, et. al., 2011, p. 199). Earnest (2005) echoes this need for clearly defined and industry assessed proficiencies, but also cautions that they should be reviewed and modified in an ongoing manner to stay abreast with the changes of industry, policy, and technology.

In light of the importance and benefits of clearly defined competency items, it has become evident that there is a lack of definition in the majority of current graduate degrees in renewable energy and sustainability. A specific case of this was Batterman, et. al. (2011) who, after reviewing more than 2-dozen universities and colleges in the United States and Europe, were unable to find an adequate list of items for a Master of Science degree related to renewable energy or sustainability. Furthermore, Woodruff (2006) found that only a few institutions have been able to integrate sustainability into their engineering curriculum in a sufficient manner. The conclusions reached by these authors exemplify an apparent disconnect between industry and academia. There is no clear connection between industry vetted competencies and academia's curriculum content specific to renewable energy graduate programs. In the same way that a project needs a clear goal, a program of study should have a clear list of competencies that can be tied to measurable knowledge, skills, and attributes that are relevant to industry.

In addition to the benefit of bridging the gap between academia and industry, clearly defined program competencies can also be a requirement of accreditation bodies. Organizations such as the Association of Technology, Management and Applied Engineering (ATMAE) and the Accreditation Board for Engineering and Technology (ABET), require accredited programs to define specific competencies and learner outcomes as part of their accreditation processes (ATMAE, 2013; ABET, 2013). For example, in Standard 7.2 of ATMAE's *2011 Outcomes Assessment Accreditation Handbook*, an institution seeking accreditation must have competencies that are "measurable…identified and validated for each program/option" (ATMAE, 2013, p. 4). Similarly, ABET's *Self-Study Questionnaire: Template For A Self-Study Report 2014-2015 Review Cycle*, requires that programs "list the student outcomes" as part of its Criterion 3 requirements for accreditation (ABET, 2013, p. 11). As these sources indicate, defining curriculum competencies is an integral part of the accreditation process.

The preceding paragraphs have illustrated a number of significant motivations for conducting this research. The importance of this study only grows as government, industry, and society increase their support for renewable energy and sustainable practices. As this support grows so does the need to meet the multi-disciplinary challenges related to energy sustainability. Meeting these challenges can be accomplished through clearly defined and vetted competencies. Unfortunately it has become evident that a gap exists between academia and industry. As renewable energy programs move toward accreditation, these competencies will be a requirement. In light of these issues, it is apparent that there is a pronounced significance for further research to identify curriculum content for renewable energy graduate programs.

Assumptions

The following assumptions were critical to interpreting and analyzing the results of this research.

1. It was assumed the survey respondents answered each question in an unbiased and accurate manner.
2. The selection criterion for the target population was appropriate and accurately representative of the overall renewable energy industry population.

Limitations

There were four inherent limitations related to conducting this research. They were as follows,

1. The findings and analysis of the research were related to graduate degrees in renewable energy.
2. The research was not intended to draw conclusions about non-graduate degrees.
3. The research was not intended to draw conclusions about graduate degrees in environmental sustainability, policy, or law.
4. The results and conclusions of this study were to be viewed as temporary in nature because they were based on survey results, which represented a snapshot of the opinions of those surveyed. Therefore,

> continual review and re-evaluation of the findings herein are required to guard against obsolescence.

Definition of Terms

The following terms are here defined as they relate to this research study:

Curriculum Content. According to Nicholls and Nicholls (1978) the content of a program's curriculum are the knowledge, skills, attitudes, and values that make up the core of what the teacher imparts to his/her students (as cited by Zargari, 1994). In this research study, this content will encompass the competencies that make up a program's curriculum.

Renewable Energy. The United States Environmental Protection Agency (EPA) (2013) defines *renewable energy* to,

> [Include] resources that rely on fuel sources that restore themselves over short periods of time and do not diminish. Such fuel sources include the sun, wind, moving water, organic plant and waste material (eligible biomass), and the earth's heat (geothermal) (para. 3).

Degree Program. Princeton University's WordNet (2010) lexicon defines *degree program* as "a course of study leading to an academic degree" (para. 1).

Competency. Earnest (2005) defines *competency* as "a statement which describes the integrated demonstration of a cluster of related knowledge, skills and attitudes that are observable and measurable, necessary to perform a job independently at a prescribed proficiency level", as illustrated by Figure 1-1.

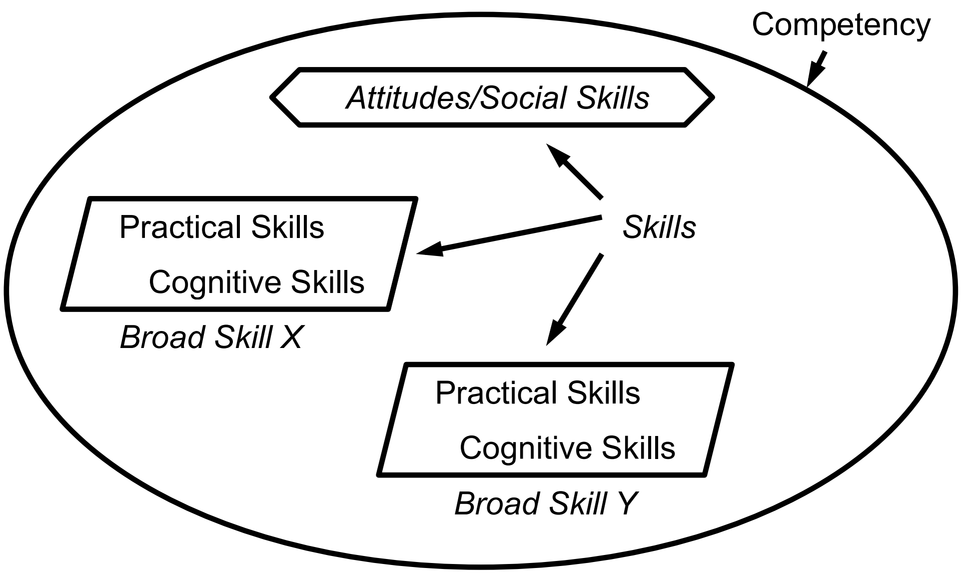

Figure 1-1. Conceptual illustrations of a competency.

Energy. Floyd and Buchla (2010) define *energy* as the ability to do work, specifically electrical energy used to power a piece of equipment, heat an environment or generate other forms of energy.

Sustainability. The International Society of Sustainability Professionals (ISSP) (2014) defines sustainability as the "implementation of sustainable strategies and methodologies to assist communities, organizations and individuals to prosper while honoring the laws and limits of natural systems as well as the needs of community members to thrive" (para. 3).

Summary

Chapter I began with a brief overview of the recent growth in renewable energy. This was followed by an introduction to the current trends in graduate level renewable energy degrees. Next, a rationale for focusing the research specifically on graduate level renewable energy degrees was presented, along with a clear statement of the purpose of the research. This purpose was to identify an appropriate body of curriculum content for a renewable energy graduate degree. Two research objectives were additionally presented, each supportive of the research purpose. Furthermore, a case was made for the significance of conducting this research, which included preparing graduates for the multi-disciplinary nature of the renewable energy field, bridging the gap between academia and industry, and satisfying requirements of relevant accreditation bodies. Finally, this chapter closed with a list of assumptions inherent to this study, limitations delineating the scope of the research, and definitions of significant terms used in this paper.

Chapter II – Literature Review

Historical Background

Graduate programs. Graduate level education in the United States can be traced back to German style universities of the 1800's. As these European universities increased in reputation and influence, colleges in the United States felt the pressure to keep pace with them. Speaking to this dynamic, Storr (1953) wrote that, "the need, as distinct from the demand, for graduate education had been declared loudly and repeatedly" (p. 35). In response to this pressure, graduate programs in American began to spring up.

In 1886 John Hopkins University responded to this pressure by establishing what has been considered the first modern style graduate degree program in the United States. At its inception, it was lauded as a "German-style" university program and required a student to complete a set amount of courses before a degree was awarded (Geiger, 1997). This degree was in juxtaposition to other American "graduate" programs, which awarded honorary degrees to alumni only after a certain number of years had passed since their undergraduate degree (Stroupe, 1966).

Brown University was one such institution, which had established this style of honorary graduate degree as far back as 1850. At that time, they offered a 4+1 graduate degree in which students were awarded a graduate diploma 1-year post undergraduate degree completion. This program was discontinued in 1857 and reinstituted in 1887 as a full-fledged 2-year graduate program (Brown University, 2014).

Wake Forest was yet another university with an honorary graduate program prior to John Hopkins. This graduate degree was announced in 1866 as a Masters of Art, but it was not until 1871 that Wake Forest awarded its first diploma to a graduate (Stroupe, 1966).

The growth of graduate education in the United States grew rapidly after these graduate programs were established. Moving into the 20th century, the demand for this level of education only increased. By 1900 there were 150 institutions that had started or committed to start graduate education, with a total of 1,600 candidates for these graduate degrees. By 1940, this number increased by 1,840 (Stroupe, 1966).

Renewable energy graduate programs. Fast-forwarding sixty years, it was not until the 21st century that graduate programs related to renewable energy (as depicted in Table 1-1) began to surface. It is important to appreciate this contrast between traditional and renewable energy graduate programs in the United States. Viewed in the larger landscape of advanced education, these renewable energy programs are still infantile. They have only been in existence for about a decade; traditional programs have been graduating students for more than one hundred years.

One of the first renewable energy degrees established was at Stanford University. In 2004 the Department of Civil and Environmental Engineering started offering a Master of Science in Atmosphere/Energy that was intended to bridge the gap between these two disciplines. Its intent was to show students the interdisciplinary connections between energy, the atmosphere and the environment. Since the establishment of this degree, Stanford University has added four more graduate programs related to renewable energy and sustainability. These include Sustainable Design & Construction Programs, Environmental Engineering & Science, Environmental Fluid Mechanics and Hydrology Program, Structural Engineering and Geomechanics (Stanford University, 2014).

Four years later, in 2008, the University of Maryland unveiled an online Master of Engineering in Sustainable Energy Engineering program, which was entirely online. This degree was developed by faculty from the departments of mechanical, nuclear, reliability, chemical & bio-molecular, and systems engineering and was operated out of the Clark School. It focused on core topics in renewable energy applications, energy conversion, environmental risk analysis, advanced fuel cells/batteries, and photovoltaic (University of Maryland, 2008). In response to the introduction of this degree, Stephen Treado, adjunct faculty at the University of Maryland and associate coordinator of the White House's Task Force on Energy, Security and Climate Change, was quoted as saying,

> The advent of this program comes at a time when practicing engineers are needed in the rapidly developing field of Sustainable Energy Engineering. The program allows engineers the opportunity to supplement and develop their current knowledge through a multi-disciplinary curriculum without ever needing to step foot on campus (University of Maryland, 2008, para. 5).

Also in 2008, the University of Dayton (UD) and Wright State University (WSU), in conjunction with Central State University, the Air Force Institute of Technology, and the Dayton Area Graduate Studies Institute announced a consortium graduate degree program in Renewable and Clean Energy (Runyon, 2010). This degree officially began in January of 2009 with eleven students enrolled. By the fall of 2010, 26 students were attending classes and 42 were enrolled (Menart, 2011). The program was conducted through UD's aerospace engineering department and WSU's mechanical and materials department. The focus of the degree was that of energy-reducing designs, renewable energy and manufacturing systems, solar, fuel cell, and biofuel technologies. Eric D. Fingerhut, former Chancellor of the Ohio Board of Regents, was quoted by Runyon (2010) as stating, "[s]tudents will graduate from this graduate program with the leadership, management, research and technical skills needed to help grow one of the most critical industries of the 21st century – clean and renewable energy and advanced energy systems" (para. 8).

Most recently, Pennsylvania State University (PSU) has established an online Intercollege Master of Professional Studies (iMPS) in Renewable Energy and Sustainability Systems. This degree is offered through PSU's World Campus and brings together faculty and instructors from around the world to teach the courses in an online format. The College of Agricultural Sciences is the leading academic unit offering this degree, but is also supported by the College of Earth and Mineral Sciences, the College of Engineering, and the Liberal Arts. This program focuses on giving its graduates a foundational knowledge of renewable energy and sustainability with specific courses in energy markets, policy and regulation; and further technical knowledge through specializations in Sustainable Management and Policy, Bioenergy, Solar Energy, and Wind Energy (Pennsylvania State University, 2013).

In addition to those mentioned above, many other universities and colleges have established graduate programs related to renewable energy and sustainability within the past 10 years. An abridged list of these institutions is given in Table 2-1, which has been compiled base on search engine queries using PhD.org (2013), the ASSHE (2012), Google Scholar, and Google. Surprisingly none of these programs publicly published competencies on their websites that clearly define what graduates are expected to learn upon graduation. This issue will be discussed in further detail in the Review of Related Content section of this chapter. For now, a list of additional graduate degrees related to renewable energy is presented in Table 2-1.

Table 2-1. Additional universities offering renewable energy graduate degrees.

Universities	
Appalachian State University	University of Delaware
Rochester Institute of Technology	University of Florida
George Washington University	University of Houston
Johns Hopkins University	University of Miami
University of Illinois, Chicago	Illinois State University
Oregon Technical Institute	Northeastern University
New York Institute of Technology	University of Oregon
Pace University	University of the Pacific
Santa Clara University	Villanova University
University of Michigan	NC State University

Competency-Based Curriculum Content

As academic institutions endeavor to bolster educational excellence in light of dwindling fiscal budgets, competency-based program development can increase benefits over course-based development strategies. According to Klein-Collins (2012), using competency-based curriculum development methods lead to increased program quality. This increased quality is realized through clearly defined competency goals, which communicate a clear message to all stakeholders as to the intent and expectations of a degree (Klein-Collins, 2012). Furthermore, Earnest (2005) indicates that competency-based development approaches will increase the “rationalization of the curricula” (p. 8). In their study focusing on curriculum content for renewable energy programs, Batterman, et. al. (2011) stated that competencies “…promote the development and evaluation of curricula…” (p. 200). They go on to posit that competencies “…are an essential part of educational planning and assessment processes” (p. 207).

Additionally, Batterman, et. al. (2011) added, by way of warning, that proficiencies within a competency-base curriculum should be regarded as goals to aim for, not minimum requirements of graduation. When they are viewed as minimum requirements, their potency is weakened and the rigor of the program in question is subsequently weakened. This is especially applicable in a typical thirty-three credit hour renewable energy graduate program, which can be comprised of a large number of cross-disciplinary competencies that each compete for attention. In contrast, competencies should be regarded as guidelines to aspire to. They should help to orient, plan, evaluate, and revise a degree (Batterman, et. al., 2011).

Synopsis of a Competency

The definition of competencies presented in Chapter I was a simplistic one. This was intended to give the reader a condensed explanation of the term. A more nuanced definition of this term is appropriate for the research herein. Therefore, this term will be unpacked in greater detail below.

As Earnest's (2005) definition states, a competency is an observable and measureable group of knowledge, skills and attitudes. This forms a fundamental statement that encapsulates what is necessary to perform a specific job at a specific level of proficiency. This can be viewed graphically in Figure 1-1 of Chapter I. A similar definition, as given by Ewell (2001), expresses a competency as "the particular levels of knowledge, skills, and abilities that a student has attained at the end (or as a result) of his or her engagement in a particular set of collegiate experiences" (p. 6). Furthermore, Klein-Collins (2012) asserts that a competency is a tangible, measureable set of knowledge, skills and abilities that an individual acquires, which can be applied in a diversity of circumstances.

It is clear that each definition above clearly indicates that a competency is first and foremost observable and measurable. Therefore it cannot be loosely or ambiguously defined. It must be an overt cluster of knowledge, skills and abilities that can be measured. The measurement can be conducted in "terms of quantity, quality, time, cost, or a combination of any of these, for which ‘action’ or ‘performance’ oriented verbs are to be used in writing competency statements” (Earnest, 2005, p. 10).

Another important connection that is represented by these definitions is that a competency forms a conduit between education (academia) and job performance (industry). This should not be overlooked. According to Batterman, et. al. (2011), competencies “should provide core knowledge, skills, abilities, and values that will serve an individual throughout his or her career” (p. 199). In this statement, the word *career* indicates that the competencies a student acquires during his/her education will be carried forward into a job by giving them the necessary knowledge, skills, and abilities to perform their job and succeed in a career. It is clear, therefore, that competencies bridge the gap between academia and industry, as illustrated by the Venn diagram in Figure 2-1.

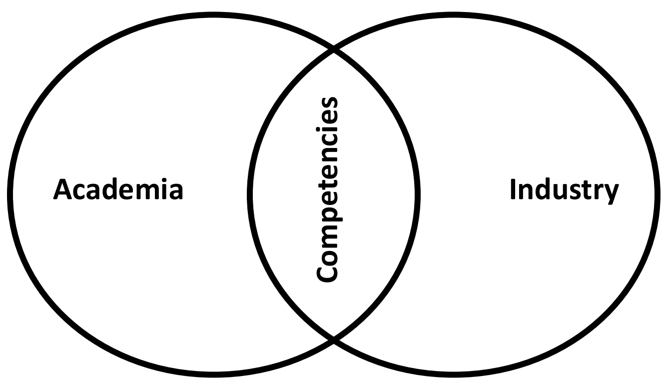

Figure 2-1. Venn diagram of academia, competencies, and industry.

Additionally, Batterman, et. al. (2011) indicates that these competencies should be dynamic and keep pace with advancements in technology and industry.

Jack, Mott, Stratton, Waldrop, and Wosczyna-Birch (2012) echo this sentiment in the Society of Manufacturing Engineers' 2012 update to their *Curricula 2015,* "In this endeavor educators and practitioners are partners. If academia and industry communicate, education will be more relevant to practice, and industry will be able to use the knowledge the graduates possess" (p. 5). Furthermore, Seybert (2010) posits that it is very important to listen to the voice of industry during the process of competency development. The importance of this voice stems from the reality that it carries: concrete job opportunities for graduates. These jobs, and the financial stability they bring, are an integral part of education, industry and society. Listening to the voice of industry is priceless, and thus should be a key contributor to any curriculum competency development (Seybert, 2010).

To this end, as part of the accreditation process, ABET and ATMAE strongly recommend or require industry input during curriculum development (ABET, 2013; ATMAE, 2013). These requirements highlight the shared responsibility that academia and industry have in defining educational competencies. It is therefore important for these two entities to foster strong, long-term relationships that are centered on curricula designed around competencies.

Finally, when formulating competency statements, it is helpful to make use of a consistent set of "…'action' or 'performance' oriented verbs…" to describe dimensions of knowledge, skill and attribute (Earnest, 2005, p. 10). This will lead to clear and consistent competency statements. As a source of reference in this process, Bloom's taxonomy is very helpful. The International Society of Sustainability

Professionals (ISSP) included a revised version of this taxonomy in their *Sustainability Practitioner's Body of Knowledge* in order to help define specific verbs associated with knowledge, skills and attributes used in their list of professional competencies (ISSP, 2013). This revised matrix of Bloom's taxonomy is depicted in Table 2-2 and is divided into three categories. Each category has corresponding action verbs that can be used when writing competencies that describe each category.

Table 2-2. Bloom's taxonomy of knowledge, skills and attributes.
(Source: ISSP, 2013)

	Category	*Suggested Verbs*
Knowledge	**Remembering**: can the practitioner recall or remember the information?	define, duplicate, list, memorize, recall, repeat, reproduce, state
	Understanding: can the practitioner explain ideas or concepts?	classify, describe, discuss, explain, identify, locate, recognize, report, select, translate, paraphrase
Skills	**Applying**: can the practitioner use the information in a new way?	choose, demonstrate, dramatize, employ, illustrate, interpret, operate, schedule, sketch, solve, use, write
	Analyzing: can the practitioner distinguish between the different parts?	appraise, compare, contrast, criticize, differentiate, discriminate, distinguish, examine, experiment, question, test
	Evaluating: can the practitioner justify a stand or decision?	appraise, argue, defend, judge, select, support, value, evaluate
	Creating: can the practitioner create new product or point of view?	assemble, construct, create, design, develop, formulate, write
Attributes	**Possessing**: does the practitioner possess characteristics that facilitate successful job performance?	open minded, observant, logical, flexible, resilient, self-reliant.
	Relating: Can the practitioner work effectively with teams and individuals?	empathize, listen, feedback
	Acting: does the practitioner act in a way that lends credibility and integrity to the profession?	ethical, reliable, honest, fair, proactive

Need for Competencies

Going beyond the synopsis above, literature clearly indicates there is a real need for competencies to be an integral component in educational curriculum content. This need is multi-faceted and goes beyond the need for academia and industry to foster a symbiotic relationship.

According to Klein-Collins (2012), having lucidly defined program competencies sends a clear message to outsiders (e.g. students) who are investigating a program. These competencies help inform these students as to the curriculum and goals of the degree in question. They also help the “students understand what they are expected to learn and how they are expected to apply that learning” (Klein-Collins, 2012, p. 8). Additionally, Earnest (2005) states, “the more occupation specific and competency-based the curriculum is, the better it is understood by all stakeholders without any ambiguity” (p. 9). This clarity helps students by giving them a well-defined road map of degree expectations.

It should be noted these stakeholders are more than just students. They can also include industry representatives in the form of businesses and hiring entities. These industry stakeholders are very interested in the quality of graduates and put a high value on knowledge, skills and abilities that can be transferred directly to the workforce. The ability for graduates to seamlessly integrate into jobs after graduation can be realized when curricula are developed around industry relevant competencies. As Earnest states, “these explicit [content] statements tend to prepare [graduates] to develop the requisite occupation specific competencies to be "work ready" for immediate employment on graduation" (2005, pp. 8-9).

In addition to industrial and student stakeholders, curriculum developers, teachers and administrators can also benefit from clearly defined program competencies. According to Earnest (2005) these stakeholder groups will benefit in the following ways,

- *Curriculum developers* - as to which curriculum design philosophy to adapt during curriculum planning, design, implementation and evaluation
- *Teachers* - as to what and where to develop and assess these competencies
- *Administrators* - as to what resources need to be provided to develop these competencies (p. 12)

Lastly, competencies help clarify questions related to transfer course credits. When competencies are defined, there is a clear understanding of the educational curriculum. This clarity lends itself to increased articulation of transfer credits between institutions and/or across degrees. Additionally, using curricula built around competencies increases the ability to normalize life experiences with degree and certification requirements and, in some situations, satisfy these requirements without coursework (Klein-Collins, 2012). This has increased benefits, as more individuals pursue non-traditional and part-time educations, which may not be completed at the same institution. Being able to easily transfer courses between institutions can have great benefit to students. Also, if these individuals bring with them extensive career experiences that are associated to the degree being pursued, competencies can facilitate the process of granting credit for these experiences.

Review of Related Content

As implied in the Historical Background section above, there are limited resources and officially published materials related to degree competencies of renewable energy graduate programs in the United States. During the review of these programs of study, contact was made with program directors and department chairs with the purpose of obtaining official and/or unofficial lists of competencies, but with no avail. In light of this, and in order to compile a list of competencies to satisfy the first research objective, literature beyond these educational institutions was reviewed, namely government initiatives, professional societies and related research studies.

These alternative research avenues proved fruitful and resulted in three clear lists of competencies related to renewable energy and sustainability. Each of these lists are presented below and represent the competencies that were analyzed in this study. They include the Employment and Training Administration's (ETA) competency model for renewable energy careers, the ISSP's Body of Knowledge (BoK) competencies, and a study by Batterman, et. al. (2011) on renewable energy degree competencies.

ETA's competency model. The ETA, which is under the umbrella of the Department of Labor has developed multiple competency models for a wide range of specific industries and career paths. The ETA's specific model for renewable energy careers was developed in collaboration with the Department of Energy (DoE), the Office of Energy Efficiency and Renewable Energy (EERE), the National Renewable Energy Laboratory (NREL), The North American Board of Certified Energy Practitioners (NABCEP), the California Regional Consortium For Engineering Advances In Technological Education (CREATE) and the Interstate Renewable Energy Council (IREC). This model "supports workforce preparation for jobs in energy technologies that strengthen the economy, protect the environment, and diversify the U.S. energy system" (ETA, 2010). The purpose of this model was to illustrate competencies required for careers specifically related to the production of renewable energy; not those related to renewable energy for transportation. Additionally, the ETA points out that this model should progress alongside the evolving skills requirements of energy technology and policy (ETA, 2010).

The ETA's model for renewable energy careers, as depicted in Figure 2-2, is divided into six separate tiers. These tiers are not to be viewed as a hierarchy of importance (e.g. Tier 3 is not more important than Tier 2), but should be viewed as a hierarchy of increasing "specialization and specificity in the application of skills" (ETA, 2010). A brief description of each tier follows Figure 2-2, and was borrowed from the ETA's (2010) model.

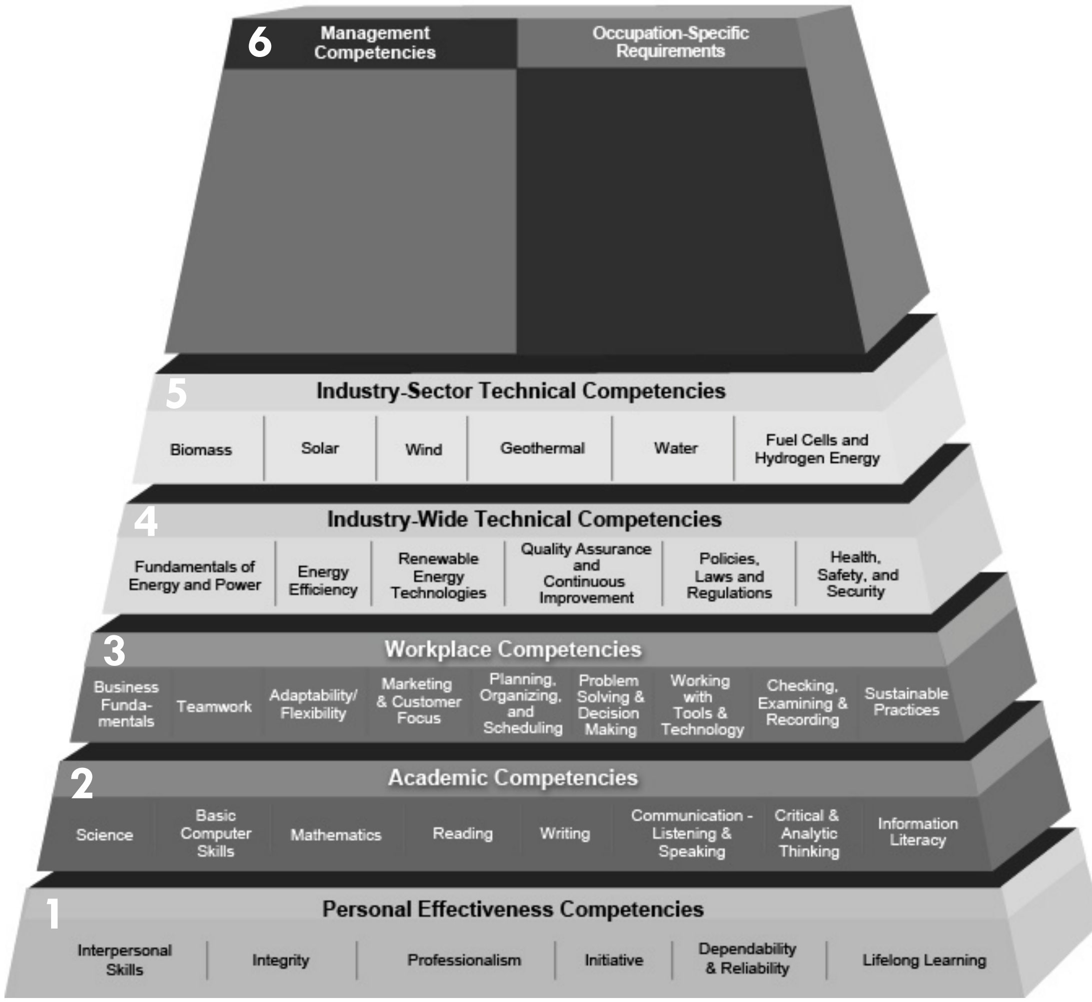

Figure 2-2. ETA's Model of Competencies.
(*Source:* ETA, 2010)

- *Tier 1:* Personal soft skills that are most often gained in a home or social environment.
- *Tier 2:* Foundational cognitive and critical thinking abilities that apply to a wide range of career paths and are primarily gained in undergraduate education.

- *Tier 3:* Workplace motivations and traits that are gained in a wide variety of careers during day-to-day job functions.
- *Tier 4:* Knowledge and skills common to all sectors of the renewable energy industry.
- *Tier 5:* Skills that are critical to specific sectors within the fields of renewable energy and are acquired on the job.
- *Tier 6:* Competencies determined by specific companies for specific job positions within that company.

Not all of the tiers above related directly to the research objectives of this study. The competencies listed in Tiers 1 – 3, and 6 were related to skills that are gained outside of a graduate degree and therefore were not pertinent to this study. Furthermore, Figure 2-2 indicates Tier 5 as being subdivided into the six energy sectors of biomass, solar, wind, geothermal, water, and fuel cell/hydrogen. The competencies in this tier were not considered in this research because the intent was to find curriculum content relevant to the overall field of renewable energy, not one focused on a specific sector(s).

The competencies within Tier 4, however, related specifically to this study and were used to satisfy Objective 1. According to the ETA (2010), this tier "represent[s] the knowledge and skills that are common across the sectors within the broader energy industry. These technical competencies build on, but are more specific than, competencies represented on lower tiers" (2010, p. 4). It was the broad scope of these competencies, across all sectors of renewable energy, which warranted their relevance to this study. A detailed list of each of the Tier 4 competencies is outlined in Table 2-3. This list provides a more comprehensive synopsis of each item than was depicted in Figure 2-2.

Table 2-3. ETA's Tier 4 competencies for careers in renewable energy. (*Source:* ETA, 2010)

Category	*Competency*
Fundamentals of Energy and Power	Knowledge of the basic and emerging principles and concepts that impact the generation, transport, installation, operation, and maintenance of technologies and related equipment used to produce energy
Energy Efficiency	Knowledge of the basic and emerging principles and concepts that promote energy conservation and efficiency while reducing the dependency on fossil fuels
Renewable Energy Technologies	Producing sustainable, clean energy from sources such as the sun, earth's heat, wind, plants, and water
Quality Assurance and Continuous Improvement	Ensure product and process meets quality system requirements as defined by customer and product specifications.
Policies, Laws, and Regulations	Compliance with applicable local, state, and federal laws and regulations that impact the energy industry
Health, Safety, and Security	Compliance with the procedures necessary to ensure a safe and healthy work environment, as appropriate

ISSP's BoK competencies. The ISSP is a non-profit international professional organization that endeavors to promote sustainability and professional development for practitioners in careers related to sustainability. This organization recently released a draft version of their *Sustainability Practitioners Body of Knowledge* (2013), which was intended to clearly define a set of core competencies that were expected of professionals working with sustainability initiatives. This BoK was also intended to serve future accreditation bodies by providing them with recommendations of observable criteria for individual credentialing. The ISSP arranged these competencies into six categories, which include (a) Core Sustainability Concepts, (b) Stakeholder Engagement, (c) Plan, (d) Implement, (e) Evaluate, and (f) Adjust. As illustrated in Figure 2-3, these categories are hierarchical (i.e. they build on each other). Additionally, each competency within these six categories had corresponding knowledge, skills, and attributes listed, as described in Table 2-4.

The first category, Core Sustainability Concepts, was intended to embody those core competencies necessary for a professional to develop sustainable initiatives within organizations and communities. The second category, Stakeholder Engagement, defined soft skills necessary for involving, effecting, and connecting applicable stakeholders associated with sustainable initiatives. The last four competency categories were lumped under the subheading Sustainable Strategy & Management. This lumping of the last four categories was intended to mirror the Plan, Do, Check, Act (PDCA) continuous improvement process championed by the philosophy of total quality management (ISSP, 2013). The cyclical relationship of these categories is illustrated in Figure 2-3.

Finally, each competency within the ISSP's BoK was directly applicable to the research herein. In light of this, each category and competency was considered during the process of satisfying Objective 1.

Table 2-4. ISSP's BoK categories and competencies.
(*Source*: ISSP, 2013)

Concept Category	*Number*	*Competency*
1. Core Sustainability Concepts	1	Explain ideas and concepts of sustainability to various audiences
	2	Choose appropriate third-party sustainability resources
2. Stakeholder Engagement	3	Identify, map and prioritize stakeholders and their primary interests or concerns
	4	Develop a strategy and means of engaging with each stakeholder
	5	Implement and institutionalize procedures for engaging and communicating with internal stakeholders (e.g. senior management, functional leads, line employees)
	6	Implement procedures for engaging and communicating with external stakeholders (e.g. suppliers, industry partners, NGO's community members)
	7	Build relationships across organizational functions
	8	Prepare communications with input from key stakeholders
3. Plan	9	Develop a high level, long- term sustainability road map
	10	Articulate the business case for sustainability
	11	Create an overarching project framework to support the higher level framework, that can be operationalized and implemented
	12	Identify material issues and the relevant key indicators, specific metrics and targets
	13	Identify the critical components of a Sustainable Management System

Table 2-4. Continued.
(*Source*: ISSP, 2013)

Concept Category	*Number*	*Competency*
4. Implement	14	Establish effective support and governance structures for the implementation of sustainability strategies and initiatives
	15	Articulate a long term vision of sustainability for the organization and a strategy to achieve it
	16	Implement a Sustainable Management System in alignment with accepted standards and protocols
	17	Integrate sustainability principles into organizational functions, policies and practices
	18	Manage complex projects
	19	Communicate sustainability plans and concepts and choose strategies for buy-in from all members and levels of an organization
	20	Launch and support teams and work groups
	21	Drive innovation, improvement and continuous learning
	22	Distribute communication and process for gathering feedback
5. Evaluate	23	Conduct an impacts assessment of organizational or community inputs, operations, outputs and stakeholder relationships
	24	Design, implement and maintain data systems for collecting accurate, timely and reliable data (maximally integrated with other data collection systems of the organization)
	25	Analyze data and draw conclusions about progress
	26	Gather data, case studies, examples, and logically compile and order them
6. Adjust	27	Maintain and continuously refine management systems
	28	Prioritize actions based on analysis and set targets

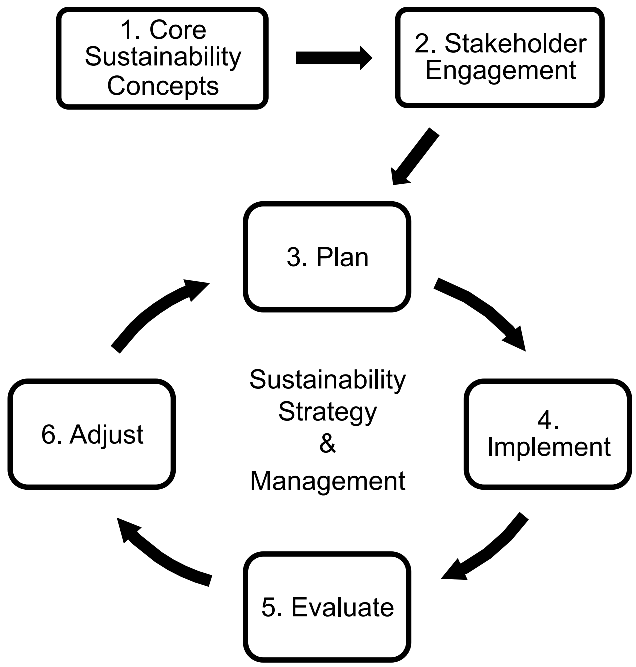

Figure 2-3. ISSP's BoK interrelated competency categories.
(*Source:* ISSP, 2013)

Batterman, et. al.'s competencies. In their paper titled *Development and Application of Competencies for Graduate Programs in Energy and Sustainability*, Batterman, et. al. (2011) conducted an extensive review of more than 2-dozen universities with the expressed intent of finding a list of distinct curriculum content for renewable energy and sustainability graduate programs. Unfortunately, they were unable to find such a list. Therefore, these authors set out to compile a model of their own. This list was based on a review of renewable energy course syllabi, course descriptions, program overviews, and brainstorming sessions. After reviewing these literature streams, they compiled their list of competencies. This list was divided into three main categories, as described below (Batterman, et. al., 2011).

The first category that Batterman, et. al. (2011) chose was Core, as illustrated by Table 2-5. This category included basic engineering and environmental principals, a multi-disciplinary view of renewable energy, and an understanding of the relationship between institutions and communities. These competencies were intended to have a broad relation to renewable energy and sustainability programs of study. Within this category, Batterman, et. al. (2011, p. 204) further organized the list into five domains. These include (a) Sustainability Context and Challenges (e.g. Sustainable Development), (b) Design and Analysis (e.g. industrial ecology), (c) Energy and the Environment (e.g. energy planning), (d) Decision/Policy-making (e.g. operations research), and (e) Communication, Implementation, and Innovation.

The second category listed was that of Specialty, as indicated by Table 2-6. This category included the knowledge, skills, professional practices and case studies related specifically to a focus area in Energy Systems and Policy (ESP). These competencies were intended to form the specialization within a degree. Furthermore, this category was subdivided into two domains, (a) Technical Expertise, and (b) Social & Institutional Context (Batterman, et. al., 2011, p. 204).

Table 2-5. Batterman, et. al.'s core competency categories and domains. (*Source*: Batterman, et. al., 2011)

Category	*Domain*	*Number*	*Competency*
Core	Sustainability challenges facing society	1A	Broad understanding of environmental issues including climate change, pollution, resource depletion, environmental health, and environmental risks
		1B	Knowledge of sustainable development and underlying key concepts, including environmental science, social issues, economic development, and key stressors/drivers
	Design and analysis principles, including sustainability metrics	2A	Basic energy concepts, including thermodynamics and heat transfer
		2B	Understanding of economics for energy and environmental analyses, including project evaluation, cost estimating, accounting, discounting, externalities, and markets
		2C	Familiarity with environmental impact and risk assessment methods and applications, including case studies and scenario analysis
		2D	Working knowledge of industrial ecology and sustainability indicators, including life- cycle analysis, material flow analysis, input-output analysis, life-cycle management, and relevant ISO standards
		2E	Knowledge of decision support/operations research/systems analysis including ability to formulate and solve decision problems, decision support techniques, and relevant software

Table 2-5. Continued.
(*Source:* Batterman, et. al., 2011)

Category	*Domain*	*Number*	*Competency*
Core	Energy and the environment	3A	Understanding of consumer behavior and household energy consumption
		3B	Knowledge of technical, economic, and environmental factors associated with fossil and nuclear fuels
		3C	Knowledge of technical, economic, and environmental factors associated with renewable energy including biofuels, wind, wave, tidal and solar energy; opportunities and energy potential; and key challenges and constraints
		3D	Knowledge of energy and environmental aspects of passenger and freight transportation systems including transportation policy, local and regional transportation planning, risk and siting of transport facilities, investment and operations, and new technology development and deployment
		3E	Knowledge of information sources that allow continuous updating of relevant data and design/assessment techniques, including technologies, and performance benchmarking

Table 2-5. Continued.
(*Source:* Batterman, et. al., 2011)

Category	*Domain*	*Number*	*Competency*
Core	Decision/policy making	4A	Familiarity with EU directives, national laws/regulations, and institutions relevant to energy management, including energy conversion, consumption, pollution, recycling, and waste management
		4B	Knowledge of techniques and practices that promote sustainability, including commercial and management techniques, strategic planning, procurement/supply chain management, clean production, life-cycle product design (minimization of impacts from production, operational/use/maintenance, end-of-life decommissioning), consumption and demand management, audits and performance evaluations
		4C	Ability to formulate, conduct, and interpret quantitative studies of energy technologies that address technical, economic, environmental, and institutional considerations
	Communication, implementation, and innovation	5A	Experience and ability to work and communicate effectively in a multidisciplinary team
		5B	Knowledge of energy and environmental management organizational practices, including accounting, financing, and reporting related to energy and environmental performance
		5C	Mastery of innovation and entrepreneurism in the energy sector, development of commercial products and services, diffusion of technology, barriers and incentives, managing the innovation process, business models, and case studies of successes and failures

The third and final category listed by Batterman, et. al. (2011) was that of Research. This category simply involved items related to the practice of academic research and was subdivided into two domains, (a) Research Methods, and (b) Examples of Research Activities (p. 204). This category was not pertinent to the research herein because it was common to most graduate degrees, regardless of a specific field of study. Therefore these competencies were not considered in this research.

According to Batterman, et. al. (2011), the intent of the above competency categories were to “address energy systems (e.g. electrical, transportation, and renewable), industrial energy management, environmental impacts of energy conversion, and energy markets” (p. 199). Additionally, these competencies were intended as outcome-based criteria for evaluating student’s multi-disciplinary education in a renewable energy systems degree. They were thus used as curriculum content intended to be implemented in a master’s and doctoral degree program in Energy for Sustainability (EfS) at the University of Coimbra, Portugal. These degrees were a collaboration between Coimbra and the sustainable energy systems graduate program at the Massachusetts Institute of Technology (MIT) – Portugal. (Batterman, et. al., 2011).

Table 2-6. Batterman, et. al.'s specialty competency categories and domains. (*Source*: Batterman, et. al., 2011)

Category	*Domain*	*Number*	*Competency*
Specialty (ESP)	Technical expertise in energy systems	1A	Knowledge of conventional, renewable, and emerging energy sources, including fossil fuels, nuclear, solar, wind, wave, and hydrogen
		1B	Knowledge of energy transmission, storage, conversion and end use, including efficiencies, key use sectors, and energy-efficient technologies
		1C	Knowledge of the design and operation of electrical energy networks, including centralized and decentralized generation, transmission systems, stability, loads, and storage
		1D	Ability to utilize and interpret systems models for energy engineering including process modeling/simulation/optimization, design/analysis of integrated energy systems, process/technology selection/evaluation using a life-cycle framework, and forecasting with uncertainty
	Institutional understanding of energy systems and policy	2A	Understanding of energy markets including energy supply, demand/demand management, markets/market competition, and regulation for key sectors including buildings, industry (manufacturing, agriculture), and transport
		2B	Mastery of activities related to environmental and energy management in companies and enterprises, including energy/environmental management systems
		2C	Understanding of strategic planning and management for energy systems, including regional and global energy needs
		2D	Knowledge of case studies of energy successes and failures

After reviewing Batterman, et. al.'s (2011) content list, it was apparent that not all the competencies therein applied explicitly to this study. Specifically, those in the Research category, which included broad competencies that feasibly relate to all graduate degrees, not exclusively renewable energy graduate degrees were not considered. It is important to note that these competencies are still vital for graduate level curricula, but were not unique to renewable energy degrees. The rest of Batterman, et. al.'s (2011) curriculum content items were used to satisfy Objective 1 of this study and were presented in Table 2-5 and Table 2-6.

Summary

Chapter II presented a backdrop for this study. First, the juxtaposition of the longevity of traditional graduate programs to the infancy of renewable energy graduate programs was presented. Next, the importance and benefits of curriculum content development based on competencies were presented. This was done to validate this approach. Following this was an in-depth synopsis of a competency, namely a clearly defined, observable, and measurable set of knowledge, skills, and attributes. The need for competencies in curriculum content development was also presented. This included the stakeholder interests of the educational institution, graduates, industry, and government. This chapter ended with a detailed review of three related competency models germane to renewable energy careers and graduate programs. These models included those of the ETA (2010), ISSP (2013), and Batterman, et. al. (2011). Each of these models was non-educational degree sources, which was due to a lack of clearly defined program competencies available from current renewable energy degree offerings in the United States. Consequently, this lack of definition was the single most significant reason to proceed with the research purposed in Chapter I.

Chapter III – Methodology

Restatement of the Purpose

Currently there is an absence of curriculum content publicly available on renewable energy graduate program websites. The purpose of this research was to identify a body of curriculum content that was based on items appropriate to the field of renewable energy and vetted by industry and academic experts. It was also the purpose of this study to prioritize these content items based on importance level.

Restatement of the Objectives

As stated in the first chapter, Objective 1 was to determine an appropriate list of curriculum content for a renewable energy degree. Objective 2 was to prioritize this list of content based on importance level. In this chapter the methodologies used to accomplish each of these objectives are presented.

Methodology of the Objectives

Towards satisfying the two objectives of this research, the methodology was divided into six distinct components. These components, as depicted in Figure 3-1, included Proposed List, Research Instrument, Target Population, Validation, Data Collection, and Data Analysis. Additionally, Figure 3-1 illustrates which component(s) were used to satisfy which research objective. The details of these components and how they were used to satisfy the objectives are presented in the following sections.

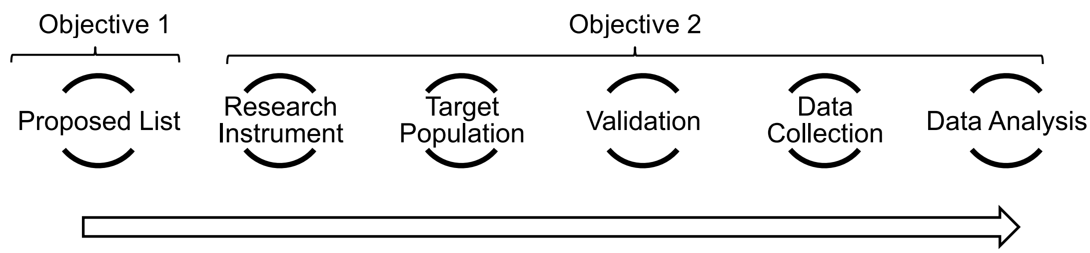

Figure 3-1. Main components of the research methodology.

Objective 1. In order to satisfy the first research objective, one methodology component was used. This was embodied in a Proposed List of competencies that was then carried forward to aid in satisfying the second objective.

Proposed List. The first component of the research methodology was to compile a Proposed List of competencies based on a review of secondary data in the form of related literature. The main sources of literature that were reviewed included government initiatives, professional society's bodies of knowledge, and related academic research studies. These sources were used secondarily due to the relevance they had to the research topic and primarily due to the scarcity of available competency lists at related university graduate programs. Based on these three literature streams, three clear lists of competencies relevant to renewable energy and sustainability were gleaned. These lists were presented in detail in the Review of Related Content section of Chapter II and represented the competencies that were analyzed in this study. These lists included the ETA's competency model, the ISSP's

BoK, and a study by Batterman, et. al. (2011) on renewable energy degree competences.

From these three lists, a single Proposed List of 42 competency items, as illustrated in Table 3-1, was compiled to satisfy Objective 1. As indicated by this table, the competencies were separated into two broad types: General and Focused. These types were intended to clearly delineate which items could be included in suggested *core* and which could be included in the suggested *specialization* components of a renewable energy program. Specifically, the items grouped as General types could be used for suggested core content and those grouped as Focused types could be used for suggested specialization content.

Further organization of this content was made within the two broad components stated above. Seven category headings, borrowed from Batterman, et. al. (2011), were used to sort the competencies into logical groups within each component section. The first five of these categories included (a) Sustainability Challenges & Society, (b) Design & Analysis, (c) Energy & Environment, (d) Decision & Policy Making, and (e) Communication, Implementation & Innovation. These categories were organized within the General component section and comprised suggested core content of a renewable energy degree. Next, the Focused component section included the categories of (a) Technical Expertise and (b) Social and Institutional. Similarly, these comprised suggested specialization component competencies.

It is important to note that the *research* component of a graduate degree's curriculum content, while very important, was not included in the Proposed List of content. This was due to the broad nature of research competencies, which can be applied to both core and specialization components of a curriculum and do not vary drastically from graduate degree type to degree type. Therefore, these were withheld from the Proposed List because the focus of this study was on suggested *core* and *specialization* content specific to renewable energy degrees, not on established *research* competencies.

As illustrated by Table 3-1, a Source and Number column were included for each competency item. First, the Source heading was used to indicate the originating author of each content item. For example, the competencies denoted by "Validation Review" were added as part of the Validation phase of the methodology. Specifically, these additional competencies were added to the Proposed List by the validation review team because they were deemed appropriate to the research. Second, the Number column did not indicate levels of priority at this stage of the research, but only the coded numbering scheme that was used to assist in the data analysis process.

This Proposed List of competencies was the deliverable used to satisfy Objective 1, which was to determine an appropriate set of program competencies for a renewable energy degree. The purpose of Objective 2 was to prioritize these content items.

Table 3-1. Proposed List of competencies items.

Type	***Category***	***Number***	***Competency***	***Source***
General	Sustainability Challenges & Society	1	Broad understanding of environmental issues including climate change, pollution, resource depletion, environmental health, and environmental risks	Batterman et. al., 2011
		2	Knowledge of the basic and emerging principles and concepts that impact the generation, transport, installation, operation, and maintenance of energy technologies	ETA, 2012
		3	Knowledge of the impacts (positive and negative) of renewable energy sources including fossil fuels, nuclear, solar, wind, wave, and hydrogen	Internal Review
		4	Knowledge of factors impacting the appropriateness of renewable energy technologies for a given situations/environmental settings	Internal Review
		5	Knowledge of the basic and emerging principles and concepts that promote energy conservation and efficiency while reducing the dependency on fossil fuels	ETA, 2012
		6	Knowledge of sustainable development and underlying key concepts including environmental science, social issues, economic development, and key stressors/drivers	Batterman et. al., 2011

Table 3-1. Continued.

Type	Category	Number	Competency	Source
General	Design & Analysis	7	Understand economics for energy and environmental analyses including project evaluation, cost estimating, accounting, discounting, externalities, and markets	Batterman et. al., 2011
		8	Familiarity with environmental impact and risk assessment methods and applications including case studies and scenario analysis	Batterman et. al., 2011
		9	Understand importance that quality system requirements as defined by customer and/or product specifications have on product and process design	ETA, 2012
		10	Knowledge of industrial ecology and sustainability indicators including life-cycle analysis, material flow analysis, input-output analysis, life-cycle management, and relevant ISO standards	Batterman et. al., 2011
		11	Understand compliance requirements necessary to ensure a safe and healthy work environments, as appropriate to regulator agencies	ETA, 2012
		12	Apply qualitative and quantitative research methodologies on data, case studies and examples with the intent of statistically analyzing the results to draw conclusions and make recommendations	ISSP, 2013

Table 3-1. Continued**.**

Type	***Category***	***Number***	***Competency***	***Source***
General	Design & Analysis	13	Demonstrate an ability to analyze & design energy conversion devices for electric energy, thermal energy, chemical energy, etc.	Internal Review
		14	Design and analyze energy efficient lighting systems based on technical and economic criteria	Internal Review
		15	Design a needs assessment, system sizing and equipment selection for various energy systems including hydroelectric, solar PV, geothermal, wind, hydrogen cell	Internal Review
		16	Perform a site analysis appraisal of potential locations for the installation of energy systems including hydroelectric, solar PV, geothermal, wind, hydrogen cell	Internal Review
		17	Design and analyze appropriate grid-tie equipment for AC 1-phase/3-phase and DC systems to included technical, safety, and code requirements	Internal Review
		18	Knowledge of decision support, operations research and systems analysis including ability to formulate and solve decision problems, decision support techniques, and relevant software	Batterman et. al., 2011

Table 3-1. Continued.

Type	*Category*	*Number*	*Competency*	*Source*
General	Energy & Environment	19	Understand consumer and industrial behavior and energy consumption	Batterman et. al., 2011
		20	Knowledge of technical, economic, and environmental factors associated with fossil fuels	Batterman et. al., 2011
		21	Knowledge of technical, economic, and environmental factors associated with nuclear fuels	Batterman et. al., 2011
		22	Knowledge of technical, economic, and environmental factors associated with renewable energy including biofuels, wind, wave, tidal and solar energy; opportunities and energy potential; and key challenges and constraints	Batterman et. al., 2011
		23	Knowledge of energy and environmental aspects of passenger and freight transportation systems including local/regional planning, risk assessment, sit planning, investment & operations, and new technology development & deployment	Batterman et. al., 2011
		24	Knowledge of information sources that allow continuous updating of relevant data and design/assessment techniques including technologies, and performance benchmarking	Batterman et. al., 2011

Table 3-1. Continued.

Type	*Category*	*Number*	*Competency*	*Source*
General	Decision & Policy Making	25	Familiarity with national, state and local laws/regulations and institutions relevant to energy management including energy conversion, consumption, pollution, recycling, and waste management	Batterman et. al., 2011
		26	Knowledge of techniques and practices that promote sustainability including strategic planning, procurement/supply chain management, clean production, life-cycle product design, consumption and demand management, audits, and performance evaluations	Batterman et. al., 2011
		27	Ability to formulate, conduct, and interpret quantitative studies of energy technologies that address technical, economic, environmental, and institutional considerations	Batterman et. al., 2011
	Communication, Implementation & Innovation	28	Experience and ability to work and communicate effectively in a multidisciplinary team	Batterman et. al., 2011
		29	Communicate ideas, plans and concepts of sustainability to various audiences and articulate the business case for sustainability to various audiences	ISSP, 2013
		30	Knowledge of energy and environmental management organizational practices including accounting, financing, and reporting related to energy and environmental performance	Batterman et. al., 2011
		31	Understand innovation and entrepreneurism in the energy sector including development of commercial products and services, diffusion of technology, barriers and incentives, managing innovation, business models, and case studies of successes/failures	Batterman et. al., 2011

Table 3-1. Continued.

Type	*Category*	*Number*	*Competency*	*Source*
Focus	Technical Expertise	32	Knowledge of conventional, renewable, and emerging energy sources including fossil fuels, nuclear, solar, wind, wave, and hydrogen	Batterman et. al., 2011
		33	Basic energy concepts, including thermodynamics and heat transfer	Batterman et. al., 2011
		34	Knowledge of energy transmission, storage, conversion and end use including efficiencies, key use sectors, and energy-efficient technologies	Batterman et. al., 2011
		35	Knowledge of the design and operation of electrical energy networks including centralized and decentralized generation, transmission systems, stability, loads, and storage	Batterman et. al., 2011
		36	Ability to utilize and interpret systems models for energy engineering including process modeling/simulation/optimization	Batterman et. al., 2011

Table 3-1. Continued**.**

Type	***Category***	***Number***	***Competency***	***Source***
Focus	Social & Institutional	37	Understand energy markets including energy supply, demand management, market competition, and regulation for key sectors including buildings, industry (manufacturing, agriculture), and transport	Batterman et. al., 2011
		38	Knowledge of activities related to environmental and energy management in companies and enterprises including energy/environmental management systems	Batterman et. al., 2011
		39	Ability to develop and articulate a high level, long-term vision for sustainability for an organization, industry or society and strategies to achieve this vision	ISSP, 2013
		40	Understand strategic planning and management for energy systems including regional and global energy needs	Batterman et. al., 2011
		41	Identify the critical components of a Sustainable Management System (SMS)	ISSP, 2013
		42	Knowledge of case studies of energy successes and failures	Batterman et. al., 2011

Objective 2. Objective 2 was accomplished by using a survey instrument to prioritize each listed competency into groupings of *very important, important, somewhat important, unimportant,* and *very unimportant* ranking levels. This methodology followed others who have conducted similar research related to ranking program competencies, namely Zargari (1994), Zegwaard and Hodges (2003), and Stepp (2010). Furthermore, because the second research objective was to determine a ranked list of discrete non-continues items, the survey's results were considered ordinal and non-parametric statistical analysis was appropriate to perform as part of the data analysis process (Leedy, 2013). The following sections, previously depicted by Figure 3-1, explain this methodology in greater detail.

Research instrument. The instrument that was used to collect data for the prioritization of program competencies was a 45-item, nine-page survey. This survey, which can be referred to in Appendix A, employed a five-point Likert-Scale. The structure of the survey was similar to Zargari (1994), Zegwaard and Hodges (2003), and Stepp (2010). The methodological use of a five-point scale differed most significantly from Zegwaard and Hodge's methodology, which used a seven-point scale. The intent behind using a five-point scale was to give the respondents a simpler set of options without removing excessive precision from the results. Additionally, a Likert-Scale model was used because of its application to descriptive research, specifically rating opinions and attitudes (Leedy, 2013).

When looking at the phrasing used for each rating value, this study's survey instrument differed slightly from Zargari (1994). The phrasing that was used is depicted in Table 3-2. This scale was arranged from 1 to 5 in a left to right orientation and had weights equal to each scale value. Also, a "No Opinion" option was made available for each competency item on the survey. This gave respondents an option to forgo rating a question if they so desired. A weight of 0 was given to this option, which kept these responses from affecting the statistical results of the survey. In this way, these responses were removed from the overall median calculations. This statistical removal of the "No Opinion" response was clearly stated on the survey so that the respondents understood the effect of choosing this option.

Table 3-2. Survey instrument's Likert-Scale phrasing, scale, and weights.

	Very Unimportant	*Unimportant*	*Somewhat Important*	*Important*	*Very Important*	*No Opinion*
Scale	1	2	3	4	5	0
Weight	1	2	3	4	5	0

Moving to the content of the survey, the first question included informed consent information. This question was placed at the beginning of the survey and was required to be answered affirmatively before the rest of the survey could be completed. In this way an informed consent was documented for each survey without connecting that survey to a specific individual, which allowed for further anonymity of the results. Also, it was indicated to the respondents that the survey could be terminated at any moment during the course of its completion. If terminated, the survey was labeled as "Incomplete" and deleted from the survey results.

The next two questions of the survey were demographic questions asking for the respondent to indicate their employment sector and employment duration as it related to the field of renewable energy and sustainability. These two questions were included so that the results could be validated against employment sector and employment duration.

The remaining 42 questions represented each individual competency item, as indicated in Table 3-1. The respondents were asked to rate each competency item based on the rating scale presented in Table 3-2. In addition to the listed competencies, the respondents were given the ability to suggest additions or subtractions to the survey's list and rate each. Finally, all 42 items were presented to the respondents in a randomized order. This was done to further strengthen the results and guard against bias of questions being asked at the beginning of the survey verses those asked at the end, where respondents may get tired of the questions and be more inclined to answer more quickly or with less sincerity.

Target population. The target population of the study was comprised of leadership members of seven United States based professional organizations focused on renewable energy and sustainability. These members held positions on Boards of Directors, Executive Board, Advisory Board, Management Team, and Technical Division Chairs from each of these seven organizations. Additionally, each of the individuals in this population held high-level professional positions of leadership in industry, the military, government, and academia and each had extensive expertise in renewable energy and sustainability. These qualifications of leadership and experience were the primary criteria in the selection process of this target population. The importance of these criteria stemmed from the intent of the research, which was to gauge the opinions of leading experts in the field of renewable energy in relation to curriculum content for a renewable energy degree. The following list represents the organizations that made up the study's target population.

- American Council On Renewable Energy (ACORE)
- Solar Energy Industries Association (SEIA)
- The North American Board of Certified Energy Practitioners (NABCEP)
- American Solar Energy Society (ASES)
- Environmental and Energy Study Institute (EESI)
- National Hydropower Association (NHA)
- Hydro Research Foundation (HRF)

Validation. Prior to the survey instrument being administered to the target population, it went through two validation review rounds. The research committee members, Dr. Ahmad Zargari, Dr. Hans Chapman, and Dr. Nilesh Joshi, conducted the first validation review round. This involved reviewing and completing the survey instrument while considering the following questions and making any applicable comments: (a) survey was appropriate to research objective, (b) survey question wording was clear and unbiased, (c) survey content was presented plainly, (d) survey was formatted cleanly, (e) page subcategories enhance or distract, and (f) overall comments or suggestions for additional questions/competencies.

During this review phase, a number of comments and edits were made to the survey. These changes included adding a “Comments” field to the end of each section, changing the job sector option of “Educational services” to “Educational/Academia services”, re-wording the professional experience question to included verbiage indicating “involvement” in renewable energy and sustainability, and adding additional competencies 13 – 17 (refer to Table 3-1) to the Design and Analysis section of the survey. All the comments given by the research committee members were incorporated into the survey instrument after the first validation review round.

The second validation review round involved sending the revised survey instrument to a second review team comprised of two faculty members from Morehead State University (MSU), one faculty member from the Kentucky Community and Technical College System, and two industry members of MSU’s Department of Applied Engineering and Technology’s Advisory Board. Each of these members had extensive experience in renewable energy and sustainability projects. Similar to the first review round, this team asked the following questions as part of their review process. Is the survey appropriate to the research objectives? Are the questions presented clearly? Are the questions worded clearly and in an unbiased way? Is the survey formatted in a clear/helpful way? Are there suggestions/questions to add or delete?

During this phase, more comments were made by way of revising the survey instrument. First, two competency items were suggested and added to the

Sustainability Challenges & Society category, namely items number three and four (refer to Table 3-1). These items were related to the positive and negative impacts of renewable energy technologies and the appropriate usages of these technologies related to specific environment situations. Second, it was suggested that a competency item in the Energy & Environment category related to the technical, economic, and environmental factors of fossil fuels and nuclear fuels be split into two separate items (items 20 and 21). This separation was suggested due to the multifaceted and divergent environmental implications of these two fuel technologies. Finally, the review team suggested rewording competency item 25 to include "state and local" laws and regulations instead of simply "national" laws in order to reflect the importance of local regulations affecting renewable energy technologies. A few other comments were made related to shortening the wording of specific competency items, removing the "No Opinion" option, and rewording the rating scales to include an even balance of negative and positive options. These last few suggestions were considered but not incorporated into the final survey instrument, though, due to additional discussion and overriding recommendations by the research committee members.

Lastly, by way of conforming to federal regulations, which require institutional review of human subject research, the survey instrument and methodology were reviewed by MSU's Institutional Review Board (IRB). After this review, the survey instrument and methodology were deemed "Exempt" based on federal regulation 46.101(b)(2). This meant that the research instrument and methodology herein were not required to produce formal, continuation, or final review reports. The formal approval letter from MSU's IRB, indicating exemption qualifications, can be seen in detail in Appendix B.

After the survey passed through the above validation review rounds, the corresponding revisions, and the MSU IRB review, it was deemed ready to be administered to the target population. During this administration process, a cover letter was also sent with each survey. This letter identified the reason for the survey, the importance of the survey, why the individual was being asked to respond, how the results would be used, the confidentiality of the results, and the time commitment necessary to complete the survey. Appendix C shows this cover letter in its entirety.

Data collection. To facilitate the collection of the survey results, a SurveyMonkey web link was embedded in the cover letter and sent to each member of the survey population. This link was active for a 4-week period starting on 21 February 2014 and ending on 21 March 2014. The web link directed each respondent to a secure website in which they could complete the survey. Due to policy requirements, none of the organizations granted the researcher direct access to their member's email addresses. To circumvent this issue, the survey link and cover letter were sent to a representative at each organization who then forwarded the link and cover letter on to their respective constituents. Three weeks after the survey was sent a follow-up email was sent to all the recipients reminding them to complete the survey (if they had not) and thanking those who had submitted already. In this way, all the responses were anonymous to the researcher and were kept on a secure database by SurveyMonkey.

Furthermore, no survey results could be directly linked to any individual respondent's identity. This anonymity of the responses also included the informed consent information, as detailed in the Research Instrument section above. Access to the raw data results were obtained by downloading them from SurveyMonkey's database after the completion of the survey period. These results were then used during the data analysis process, as discussed in the next section.

Data analysis. Upon completion of the survey period, the raw data results were downloaded from SurveyMonkey's database and evaluated using Excel and MiniTab. These software packages were used to perform the functions of (a) graphically represent the demographic information related to the respondent's job sector and professional experience, (b) generate and test the normalcy of the distribution of the aggregate survey results, (c) calculate the median for each competency item, and (d) generate a single box-plot graph of all items. The following paragraphs indicate the details of each of these functions.

By analyzing the demographic data collected from the survey instrument, the sector and employment durations relative to the results were presented. This allowed the subsequent data analysis to be framed by a clear picture of the makeup of the respondents. This also helped to further substantiating the research results.

Next, a histogram and descriptive statistics of the aggregate survey responses were plotted. The histogram was generated by plotting the frequencies of each of the scale values (i.e. No Opinion, 1, 2, 3, 4, 5). The descriptive statistics of the entire data set that were calculated were minimum value, maximum value, mean, median, mode, first quartile, third quartile, and interquartile range. The histogram and descriptive statistics were used to analyze the distribution of the entire data set.

As stated by Jamieson (2004), Likert-Scale survey results have a tendency to be skewed in the affirmative direction (e.g. towards *important* or *very important*). Due to this skew, non-parametric statistical analysis methods are appropriate. To determine if the data was skewed (or non-normally distributed), the histogram and descriptive statistics motioned above were generated and analyzed. By confirming the non-normality of the data, the use of non-parametric statistical analysis methods below was validated.

Median values of each competency item were used as the indicator of central tendency of the survey results. The reason for using these median values, as opposed to mean values, was due to the ordinal, discrete, and non-normally distributed nature of the response data. Specifically, with ordinal data, there is inherently no explicit measurement value between each scale value (e.g. the interval between *important* and *very important* may not be equal to the interval between *somewhat important* and *important*). According to Pett (1997), Blaikie (2003) and Hansen (2003), Likert-Scale results return ordinal measurements that indicate the ordered opinions of respondents (as cited by Jamieson, 2004), not continuous values. Therefore, non-parametric statistical analysis must be used without mean and standard deviation calculations (Jamieson, 2004). As Cohan, Manion, and Morrison (2000) state, calculating means (and corresponding standard deviations) of these survey responses is meaningless. The reason is that the mean of *important* and *very important* cannot be *important-and-a-half* (Jamieson, 2004). For this reason, median values were used as measures of central tendency.

All competency items listed in the survey were then ranked into five groupings, from *very unimportant* to *very important*. These groupings were based on median values, as indicated by Table 3-3. The competencies within each of these groupings were not rank ordered, due to the reasons stated above. This unranked lumping of competencies was not regarded detrimental to the conclusions of the research, as Batterman et. al. (2011) stressed, items should be goals to aim for, not minimum requirements. Therefore, have a lumped grouping of *very important* content is ok, as it will be a starting point from which to focus the curriculum development on. Finally, the overall priority rankings of each item were presented in both tabular and graphical formats, organized by coded competency number as well as calculated rank groupings.

Table 3-3. Ranking levels and associated median values.

Rank Level	*Median Value*
Very Important	5
Important	4
Somewhat Important	3
Unimportant	2
Very Unimportant	1

The final data analysis instrument that was used was a box-plot graph. This tool was used to display the data variation within and between each competency item.

The box-plot provided a clear visual representation of each content item and how it corresponded to the other items. The variation within each competency included the median value, the spread of the data (range), and the interquartile range. By plotting all content items on one single graph, the variation between items was illustrated graphically (Montgomery, 2013). In this way the variations between competencies could be analyzed.

Summary

Chapter III began with a brief restatement of the research purpose and objectives. This was follow by a detailed explanation of the methodology components used to satisfy each objective. Objective 1 was satisfied by generating a proposed list of competencies constructed from a review of related literature. Objective 2 was satisfied using a survey instrument to prioritize each listed competency. This second and final phase of the methodology involved five components, including designing a research instrument, selecting a target population, validating the research instrument, collecting the data, and analyzing the data. This was the balance of the methodology employed to satisfy both research objectives, which in turn achieved the purpose of the study.

Chapter IV – Findings

Restatement of the Objectives

As stated previously, Objective 1 was to determine an appropriate list of program competencies for a renewable energy graduate degree. This objective was accomplished through a Review of Related Curriculum Content, as presented in Chapter II. Objective 2 was to rank order this list of program competencies based on importance level. This ranking was accomplished by surveying experts in the field of renewable energy and sustainability. The results were statistically analyzed to form a ranked list of competencies. This analysis and prioritization are presented in the subsequent sections.

Response Rate

The survey collection process occupied a four-week period from 21 February 2014 to 21 March 2014. During this timeframe the survey instrument was sent to and viewed by 50 individuals via email. These persons each held various leadership positions across seven national organizations, as detailed in Chapter III. At the conclusion of the four-week period the collection process was terminated. Six surveys were returned incomplete and nine were not returned at all. The remaining 35 surveys were completed, which represented a response rate of 70.00%. This was considered an excellent rate of return and no further data collection was performed.

Demographics

Given the nature of survey data, it was very important to substantiate the perspectives, experiences, and backgrounds of the survey population. This was due to the survey results being based on the opinions of the population, which were inevitably influenced by the biases of each respondent (Leedy, 2013). Analyzing the demographic data of the respondents allowed the perspectives of the results to be appropriately framed. With this goal, the demographic data of employment sector and professional experience were collected as part of the survey instrument.

The employment sector data, depicted in Table 4-1, revealed a diverse population of respondents. These individuals held professional leadership positions in sectors relevant to renewable energy. This population was comprised primarily of individuals employed in the sectors of *Professional/Business Services, Non-Profit/Research,* and *Solar PV*, which represented 17.14%, 14.29%, and 11.43% respectively. These were followed by the sectors of *Educational/Academic, Utilities, Independent Consultant, Policy, Manufacturing,* and *Renewable Energy (General),* which represented 8.57%, 8.57%, 8.57%, 5.71%, 5.71%, and 5.71% respectively. The remaining five sectors accounted for the balance of the population, each representing 2.86%. Additionally, Table 4-1 clearly indicates that nearly half the population was employed in the top four job sectors. Beyond this, the distribution of sectors is fairly well spread across the remaining areas. This diverse cross-section of respondents supports the validity of the data collected in this study.

Table 4-1. Distribution of the survey population's employment sectors.

Job Sector	*%*	*Cumulative %*
Professional/Business Services	17.14	17.14
Non-profit/Research	14.29	31.43
Solar PV	11.43	42.86
Educational/Academic	8.57	51.43
Utilities	8.57	60.00
Independent Consultant	8.57	68.57
Policy	5.71	74.29
Manufacturing	5.71	80.00
Renewable Energy	5.71	85.71
Agriculture	2.86	88.57
Construction	2.86	91.43
Federal government	2.86	94.29
Financial activities	2.86	97.14
Trade Association	2.86	100.00

The second type of demographic data that was captured was professional experience. This data represented the employment duration of each respondent specific to the renewable energy field and did not include experience related to other fields. As illustrated by Figure 4-1, almost one quarter (22.86%) of the survey population had 30+ years of experience, while almost one quarter (22.86%) had 0 – 5 years of experience. This represented close to half the experience being held at either end of the spectrum. The remaining 54.28% of the population were spread across 5 – 25 years, with the smallest amount having 10 – 15 years of experience. Again, this demographic data supported a diverse experience level of the survey population, which further validated the data collected in this study.

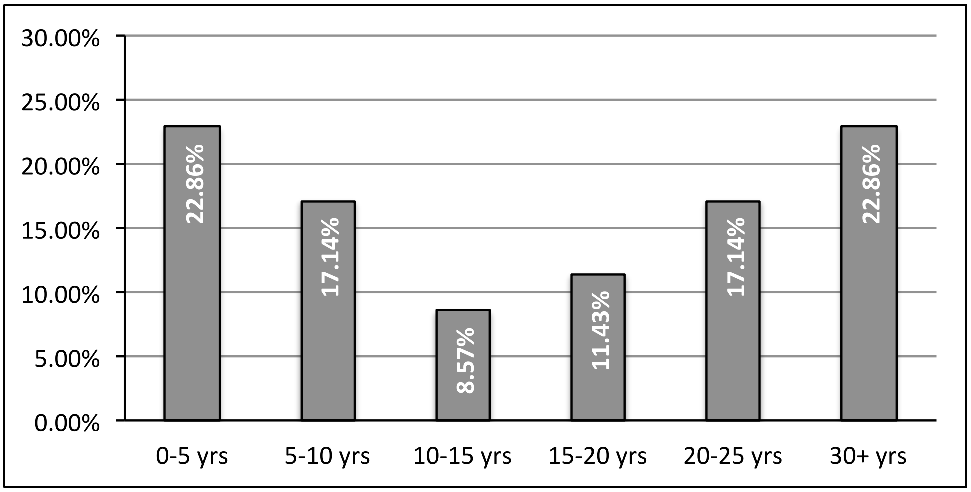

Figure 4-1. Distribution of the survey population's professional experience.

Data Distribution

The survey instrument used in this study employed a Likert-Scale, which is prone to return results skewed towards the affirmative direction of the scale (Jamieson, 2004). When a distribution of data is skewed, it may be considered non-normal and non-parametric statistical analysis methods should be used to calculate the statistics of the population. Therefore, the first step in the data analysis process was to analyze the survey data to determine if it was non-normally distributed.

In order to analyze the overall distribution of the data, a histogram was plotted, accompanied by descriptive statistics. Both of these were used to analyze the normality of the results. As Figure 4-2 illustrates, the distribution was negatively skewed (i.e. shifted towards *important* and *very important*). Specifically, the mean value of 3.82, the median value of 4.00, and the interquartile range of 3.00 – 5.00, confirmed Jamieson's (2004) postulation of non-normally distributed survey data.

This analysis confirmed a non-normal distribution of the data and validated the use of non-parametric analysis methods (i.e. analysis of central tendency based on median values) used in this research.

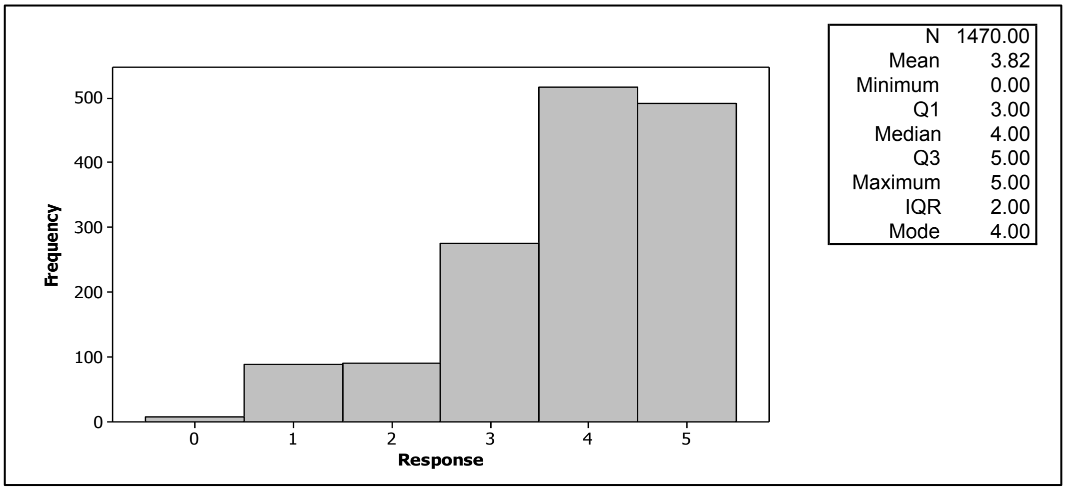

Figure 4-2. Histogram and descriptive statistics of the aggregate response data.

Data Analysis

After the use of non-parametric data analysis methods was confirmed to be appropriate, the median values of each of the 42 competency items were calculated. These median values were used to rank the importance level of each competency item into five ranking levels, as previously indicated in Table 3-3. Once these values were calculated they were graphed against each competency item. This graph is shown in Figure 4-3 and was sorted based on coded competency numbers. This graph illustrates all items had a median value of at least 3 or higher. There was no single competency item with a median value below 3, which was in line with the negative skew of the data. Furthermore, the majority of the items were ranked with a median value of 4, which was in line with the central tendency of the aggregate data having a median value of 4.

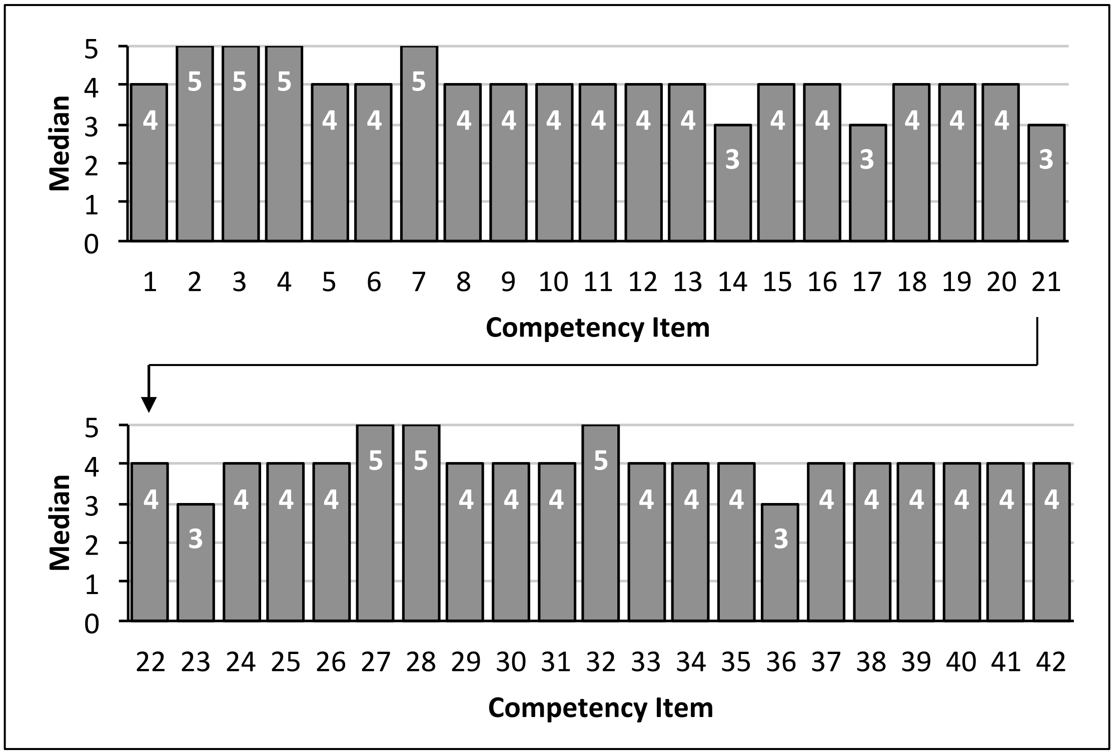

Figure 4-3. Survey results sorted by coded competency number.

The next analysis performed was sorting the data by median value. This can be seen in Figure 4-4, which again clearly illustrates that the majority of the items scored a median value of 4. It is important to note the ordering of competency items within each median value grouping did not indicate levels of important. Rankings within each group (e.g. *very important, important,* and *somewhat important*) could not be calculated due to the ordinal nature of the data. Again, this is in line with previous analysis. Additionally, there were seven items that scored a median value of

5 and only five items that scored a median value of 3. Again, this is was congruent with the negative skew of the survey results.

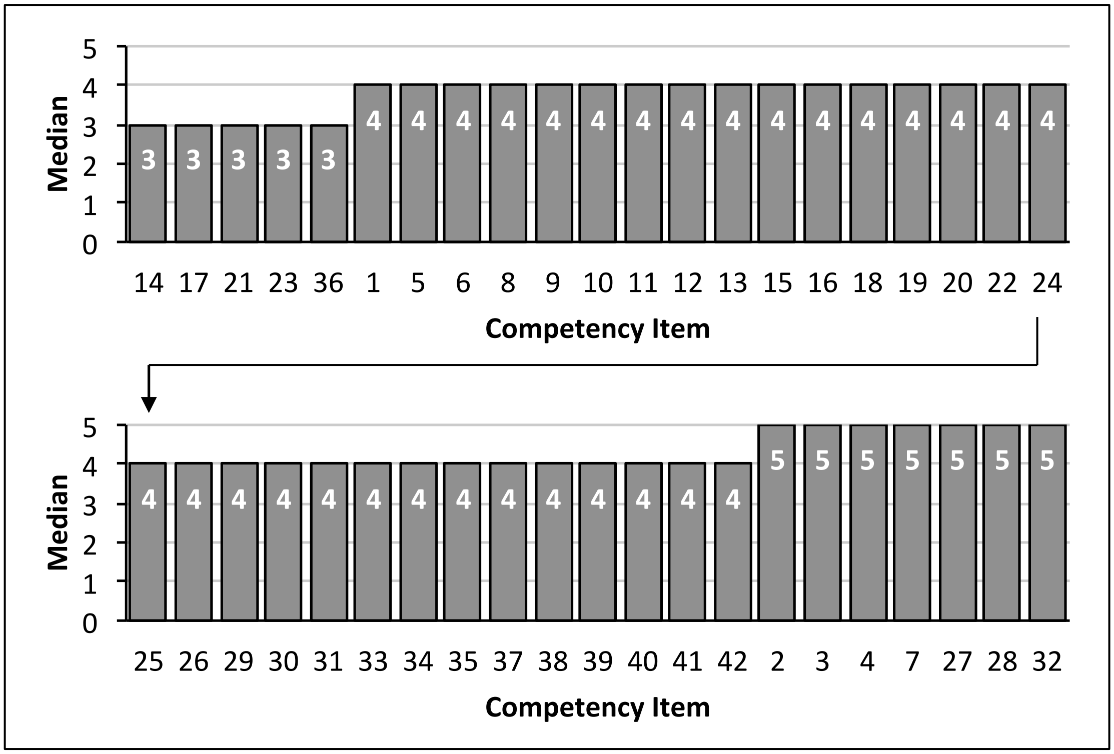

Figure 4-4. Survey results sorted by median value.

The median values of each competency item identified in this study were used to rank their importance level. This ranking split the competencies into three groupings: *very important* (median = 5), *important* (median = 4), and *somewhat important* (median = 3). It was evident from the results that no items were ranked into *unimportant* (median = 2) or *very unimportant* (median = 1) groupings. Once again, this pointed to the negative skew of the data, but also validated the significance of each item included in the survey. For a more detailed list of the rankings of each competency item, refer to the Conclusion or Appendix D. These sections provide a tabular format of the information included in Figure 4-3 and Figure 4-4 with specific verbiage of each competency item along with its ranking level and category designation.

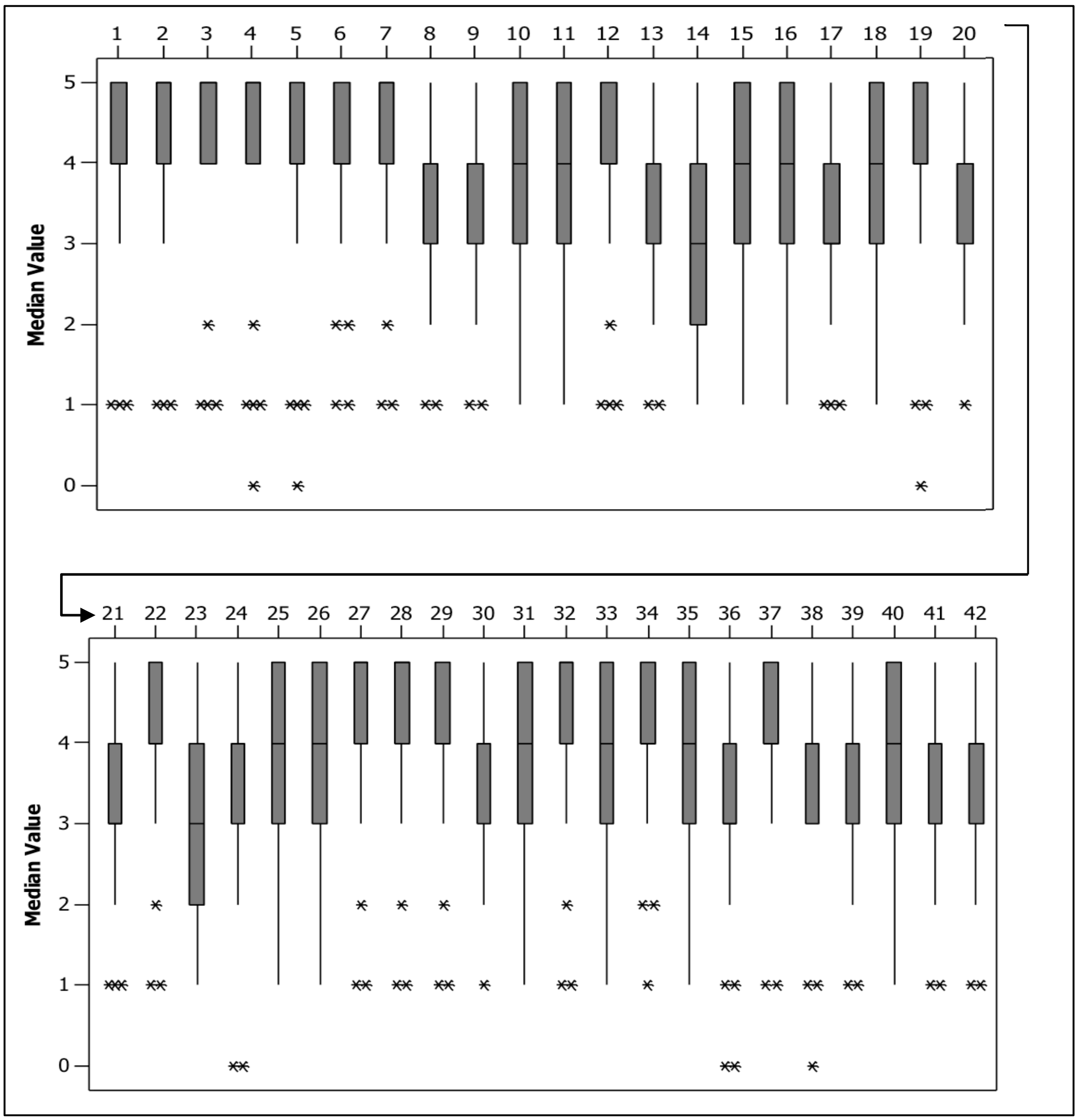

Figure 4-5. Box-plot of survey results sorted by median value.

Finally, a box-plot of all competency items is illustrated in Figure 4-5. This graph illustrates the variation within each competency, including the median, data spread, and interquartile range.

Summary

In this chapter an analysis of the survey data was presented. First, the response rate of the survey instrument was analyzed, which was found to be 70.00%. This high percentage was an excellent rate of return and eliminated the need for further survey responses. Next, demographic data related to the survey population was examined. The importance of this data lay in the framing of the results in light of the inevitable biases inherent in survey data. It was found that the survey population was employed in a wide range of job sectors and had experience levels that ranged widely across a 0 – 30+ year spectrum. This diversity in demographics further validated the data collected in this study. The distribution of the data was also found to be non-normal, with a negative skew towards the positive direction of *important*. This was to be expected with survey data and was confirmed by generating a histogram and calculating descriptive statistics of the entire data set. Lastly, the median values of each competency were calculated and presented graphically to show the ranked importance levels of each.

Chapter V – Conclusion, Recommendations, and Summary

Conclusion

The conclusions reached by this study were based on both secondary and primary data. The first source, secondary data, was collected from a review of related government, professional, and academic literature centered on competencies for renewable energy careers and academic programs of study. By analyzing this data, a survey instrument was generated that included 42 competency items. Industry and academic experts in the field of renewable energy were surveyed to collect their input on the importance level of each item. The results of this survey, which represented primary data, were then used to statistically prioritize all 42 competencies.

Objective 1. Objective 1 was to generate a proposed list of curriculum content appropriate for a renewable energy graduate degree. This was accomplished by reviewing secondary data, in the form of related literature. This Proposed List formed the body the survey instrument used in this study. The main sources of this literature were government initiatives, professional society's body of knowledge, and related academic research studies. These sources were used primarily for their relevance to the research topic and secondarily due to the scarcity of available competency listings at related university graduate programs. The Employment and ETA's competency model, the ISSP's BoK, and a study by Batterman, et. al. (2011) comprised the three sources used to generate the Proposed List of this study. A detailed list of these competencies was presented in Table 3-1 and included 42 items. This list satisfied Objective 1.

Objective 2. Objective 2 was accomplished by statistically prioritizing the 42 curriculum content items. This ranking was based on importance level, as determined by industry and academic experts in the field of renewable energy and sustainability. In order to arrive at a statically sound ranked list, a 5-point Likert-Scale survey instrument was used. This survey asked respondents to rate all 42 items on a scale of *very important, important, somewhat important, unimportant,* or *very unimportant*. The results of this survey were then analyzed with non-parametric statistical methods to determine a ranked list based on median scores of each item.

This ranking of competencies was indicated in Figure 4-3 and Figure 4-4. It is important to note that the ordering of each competency within each median value grouping was arbitrary and did not indicate levels of importance. The ordinal nature of the data prohibited ranking of the items within each median value grouping. This was because calculating fractional values was meaningless and invalid.

From the results of Figure 4-4, seven items rose to the top with a median value of 5. These items, which spanned five of the seven categories, were ranked as *very important* and are detailed in Figure 5-1. As Batterman, et. al. (2011) indicated, competency items should be goals to aim for, not a list of minimum requirements. Therefore, out of the 42 competencies to consider including in a program, these top seven should be of first priority. With the median value of 5, they were identified as the most important competency items of the entire list. Also, given the finite resources available to institutions and the limits of student's schedules, focusing efforts on a handful of items was recommended. As continuous program improvements are made, additional competencies from the other importance level groups could be added or removed, as deemed appropriate.

Table 5-1. Competency items ranked by survey population as *very important*.

Category	*Competency*	*Median*
Sustainability Challenges & Society	Knowledge of the basic and emerging principles and concepts that impact the generation, transport, installation, operation, and maintenance of energy technologies	5
	Knowledge of the impacts (positive and negative) of renewable energy sources including solar, wind, wave, and hydrogen	5
	Knowledge of factors impacting the appropriateness of renewable energy technologies for a given situation/environmental settings	5
Design & Analysis	Understand economics for energy and environmental analyses including project evaluation, cost estimating, accounting, discounting, externalities, and markets	5
	Ability to formulate, conduct, and interpret quantitative studies of energy technologies that address technical, economic, environmental, and institutional considerations	5
Communication, Implementation & Innovation	Experience and ability to work and communicate effectively in a multidisciplinary team	5
Technical Expertise	Knowledge of conventional, renewable, and emerging energy sources including fossil fuels, nuclear, solar, wind, wave, and hydrogen	5

There were a total of 30 additional items ranked as *important,* with a median value of 4. These items, as illustrated by Table 5-2, spanned the entire spectrum of competency categories and made up the largest grouping of items. It was not unexpected that the majority of the competencies were ranked in this grouping, as the central tendency of the entire data set had a median of 4. This was also congruent with Jamieson's (2004) postulation that survey results are predominately shifted toward the positive direction of Likert-Scales. The results of the study supported this theory. These items should be incorporated into a renewable energy graduate program only after the *very important* items have been solidified. It is cautioned though, that these *important* items only be incorporated as appropriate. Institutional resources, student scheduling restraints, and stakeholder needs should drive the decision weather to include of each of these items.

Table 5-2. Competency items ranked by survey population as *important*.

Category	*Competency*	*Median*
Sustainability Challenges & Society	Broad understanding of environmental issues including climate change, pollution, resource depletion, environmental health, and environmental risks	4
	Knowledge of the basic and emerging principles and concepts that promote energy conservation and efficiency while reducing the dependency on fossil fuels	4
	Knowledge of sustainable development and underlying key concepts including environmental science, social issues, economic development, and key stressors/drivers	4
Design & Analysis	Familiarity with environmental impact and risk assessment methods and applications including case studies and scenario analysis	4
	Understand importance that quality system requirements as defined by customer and/or product specifications have on product and process design	4

Table 5-2. Continued.

Category	*Competency*	*Median*
Design & Analysis	Knowledge of industrial ecology and sustainability indicators including life-cycle analysis, material flow analysis, input-output analysis, life-cycle management, and relevant ISO standards	4
	Understand compliance requirements necessary to ensure a safe and healthy work environments, as appropriate to regulator agencies	4
	Apply qualitative and quantitative research methodologies on data, case studies and examples with the intent of statistically analyzing the results to draw conclusions and make recommendations	4
	Demonstrate an ability to analyze & design energy conversion devices for electric energy, thermal energy, chemical energy, etc.	4
	Design a needs assessment, system sizing and equipment selection for various energy systems including hydroelectric, solar PV, geothermal, wind, hydrogen cell	4
	Perform a site analysis appraisal of potential locations for the installation of energy systems including hydroelectric, solar PV, geothermal, wind, hydrogen cell	4
	Knowledge of decision support, operations research and systems analysis including ability to formulate and solve decision problems, decision support techniques, and relevant software	4
Energy & Environment	Understand consumer and industrial behavior and energy consumption	4
	Knowledge of technical, economic, and environmental factors associated with fossil fuels	4
	Knowledge of technical, economic, and environmental factors associated with renewable energy including biofuels, wind, wave, tidal and solar energy; opportunities and energy potential; and key challenges and constraints	4

Table 5-2. Continued.

Category	*Competency*	*Median*
Energy & Environment	Knowledge of information sources that allow continuous updating of relevant data and design/assessment techniques including technologies, and performance benchmarking	4
Decision & Policy Making	Familiarity with national, state and local laws/regulations and institutions relevant to energy management including energy conversion, consumption, pollution, recycling, and waste management	4
	Knowledge of techniques and practices that promote sustainability including strategic planning, procurement/supply chain management, clean production, life-cycle product design, consumption and demand management, audits, and performance evaluations	4
Communication, Implementation & Innovation	Communicate ideas, plans and concepts of sustainability to various audiences and articulate the business case for sustainability to various audiences	4
	Knowledge of energy and environmental management organizational practices including accounting, financing, and reporting related to energy and environmental performance	4
	Understand innovation and entrepreneurism in the energy sector including development of commercial products and services, diffusion of technology, barriers and incentives, managing innovation, business models, and case studies of successes/failures	4
Technical Expertise	Basic energy concepts, including thermodynamics and heat transfer	4
	Knowledge of energy transmission, storage, conversion and end use including efficiencies, key use sectors, and energy-efficient technologies	4

Table 5-2. Continued.

Category	*Competency*	*Median*
Technical Expertise	Knowledge of the design and operation of electrical energy networks including centralized and decentralized generation, transmission systems, stability, loads, and storage	4
Social & Institutional	Understand energy markets including energy supply, demand management, market competition, and regulation for key sectors including buildings, industry (manufacturing, agriculture), and transport	4
	Knowledge of activities related to environmental and energy management in companies and enterprises including energy/environmental management systems	4
	Ability to develop and articulate a high level, long-term vision for sustainability for an organization, industry or society and strategies to achieve this vision	4
	Understand strategic planning and management for energy systems including regional and global energy needs	4
	Identify the critical components of a Sustainable Management System (SMS)	4
	Knowledge of case studies of energy successes and failures	4

The remaining five items were ranked as *somewhat important* with median values of 3. These items, depicted in Table 5-3, should be considered the last items to include in a renewable energy graduate program. Again, Batterman, et. al. (2011) supports this by cautioning against trying to implement a wide range of cross-disciplinary competencies all at once. These items should only be implemented into a mature renewable energy program if they do not overextend resources or students.

Table 5-3. Competency items ranked by survey population as *somewhat important*.

Category	*Competency*	*Median*
Design & Analysis	Design and analyze energy efficient lighting systems based on technical and economic criteria	3
	Design and analyze appropriate grid-tie equipment for AC 1-phase/3-phase and DC systems to included technical, safety, and code requirements	3
Energy & Environment	Knowledge of technical, economic, and environmental factors associated with nuclear fuels	3
	Knowledge of energy and environmental aspects of passenger and freight transportation systems including local/regional planning, risk assessment, sit planning, investment & operations, and new technology development & deployment	3
Technical Expertise	Ability to utilize and interpret systems models for energy engineering including process modeling/simulation/optimization	3

Finally, no competency items received rankings of *unimportant* or *very unimportant*. It was concluded that the lack of median values of 2 and 1, respectively, were a function of the positive shift in the survey data's distribution, as supported by Jamieson (2004). It was also concluded that this points to the legitimacy of each competency item's inclusion in the survey instrument.

Furthermore, by way of full disclosure, competency item number three was reworded. The terms "fossil fuels" and "nuclear" were removed from this item based on the following two survey comments: (a) "Renewable energy sources including 'fossil fuels', 'nuclear' makes no sense." and (b) "On question 2, fossil fuels and nuclear power are listed as 'renewable energy sources.' I vehemently disagree with this characterization, and hope anyone graduating from this future MS in Renewable Energy would, too." It was not the intent of this study to insinuate *fossil fuels* and *nuclear* as sources of renewable energy. Therefore, they were removed from competency item number three, as seen in Appendix D.

Recommendations

The following recommendations were germane to future research related to curriculum development towards renewable energy graduate programs. These recommendations were intended to indicate how and where this study could be advanced.

1. When developing a renewable energy graduate program, focus on the competency items ranked as *very important*. As the program matures, items ranked as *important* can be integrated as is appropriate to best meet the needs of the institutional resources, students, and professional stakeholders. Items ranked as *somewhat important* should be the last to implement.
2. The results of this study should be re-evaluated on a continual basis. As technologies and policies in the renewable energy industry change, it is increasingly important for degree offerings to stay relevant. This is especially crucial for the prioritized list in Appendix D. Re-evaluation of these results is necessary due to the transitory nature of survey data, which represents a snapshot in time of the survey population's

opinions. Due to this, it is recommended that this review be integrated into a curriculum's recurring review process. This re-evaluation of the research results will guard against obsolescence of the conclusions and help to keep the curriculum on trend with industry and policy.

3. Review all survey comments cataloged in Appendix E. At the end of each page of the survey, the respondents were given the opportunity to submit comments related to the survey's competency items. These comments, while anecdotal in nature, hold value to the implementation of the conclusions of this study. Therefore, these should be referenced during curriculum development.
4. Another recommendation was to conduct further evaluate of the survey population's professional experience levels. As illustrated by Figure 4-1, this data was bimodal, with a peak at 0 – 5 years and another peak at 30+ years. Analyzing the cause(s) of this abnormal distribution, and the effect it had on the content item rankings, could yield additional insight into the results of this study.
5. It is also recommended that the results of this study be used to develop a curriculum framework for a graduate program in renewable energy. To accomplish this, a Delphi Method should be used to further investigate the findings of this research. The objective of this further research would be to solidify the suggested curriculum content of this study into a fully formed program offering. This program framework

could include content areas made up of corresponding competency items. The content areas of core, specialization, and research are suggested and illustrated in Figure 5-4. In addition to these areas, course titles and corresponding competency items could be identified. The use of a Delphi methodology would lend itself to the objective of this further investigation by allowing an expert panel to give expert input into the development process. Multiple rounds would be used to alleviate possible leading of the content items or survey questions. As the time commitment necessary for this methodology was beyond the scope of this study, it was recommended for future research.

Table 5-4. Curriculum content areas for a renewable energy degree.

Suggested Curriculum Content Area	*Credit Hours*
Core	12
Specialization	12
Research (Synthesis)	9
Total	33

6. Finally, future research towards the development of a complete renewable energy degree program should answer the question, “Is there a significant need for a renewable energy graduate program?” This question should be of first importance in a complete program development process and is recommended to be incorporated as part of the first round of the Delphi methodology described above. Answering this question will validate the significance of the proposed degree

program and could serve as the first research objective in future research.

Summary

The purpose of this study was to identify a set of curriculum content for graduate degrees in renewable energy. At the conclusion, a clear list of 42 content items was identified and statistically ranked. The content items identified were based on a review of literature from government initiatives, professional society's body of knowledge, and related research studies. Leaders and experts in the field of renewable energy and sustainability were surveyed, using a five-point Likert-Scale model. This allowed each item's importance level to be analyzed and prioritized based on non-parametric statistical analysis methods. The study found seven competency items to be *very important*, 30 to be *important*, and five to be *somewhat important*. The results were also appropriate for use as a framework in developing or improving renewable energy graduate programs.

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Appendix A: Survey Instrument Final Version

Renewable Energy Degree Competencies Survey

Informed Consent

Please fill in the answers that best applied to you.

***You have been specifically invited, based on your unique experience and position of leadership, to participate in this survey, the objective of which is to determine appropriate curriculum content for a Master of Science in Renewable Energy degree. Current research has shown there is a lack of clearly defined degree competencies related to renewable energy and sustainability graduate programs in the United States. Your input will help codify and prioritize these competencies, which will be able to be used by educational institutions.**

The survey's length is 5-10 minutes. Please answer each question as completely and accurately as possible. You will be presented a list of proposed competencies and then asked to rate each individually on a scale from 1-5.

The researcher promises to keep all survey responses 100% anonymous and the results will be stored in a secure data center by SurveyMonkey. Your responses will be processed confidentially and only aggregate data will be made available at the end of the study. If you would like a copy of the study results please contact the researcher at the address below.

This study is part of the thesis research of Mr. John Haughery, who is pursuing an MS in Engineering & Technology Management at Morehead State University. He is planning to complete this study in time for a May 2014 graduation. As such, the results of this study will be published in academic publications. If you have any questions regarding the survey or would like a copy of the survey results, please contact John at jrhaughery@moreheadstate.edu.

Completion of this survey is 100% voluntary and can be terminated at any time.

Thank you for your contribution to this important research.

○ I voluntarily agree to complete the following survey and understand the information above (survey termination can be performed at any time by closing browser window).

Renewable Energy Degree Competencies Survey

*Which job sector are you currently employed in?

- Mining
- Construction
- Utilities
- Wholesale trade
- Retail trade
- Transportation and warehousing
- Information
- Financial activities
- Professional and business services
- Educational/Academic services
- Health care and social assistance
- Leisure and hospitality
- Federal government
- State and local government
- Agriculture wage and salary
- Agriculture self-employed and unpaid family workers
- Nonagriculture self-employed and unpaid family worker
- Military
- Other (please specify)

*Professional experience

	0-5 yrs	5-10 yrs	10-15 yrs	15-20 yrs	20-25 yrs	30+ yrs
How many years have you been employed or involved in a renewable energy or sustainability capacity?						

Renewable Energy Degree Competencies Survey

Please rate EACH of the following competency statements in terms of their importances to be included in a Masters of Science in Renewable Energy program.

RATING SCALE:
1 = Very Unimportant
2 = Unimportant
3 = Somewhat Important
4 = Important
5 = Very Important

"NO OPINION" RESPONSES WILL BE EXCLUDED FROM SURVEY RESULT CALCULATIONS

* Competencies related to Sustainability Challenges & Society

	1	2	3	4	5	No Opinion
Knowledge of the impacts (positive and negative) of renewable energy sources including fossil fuels, nuclear, solar, wind, wave, and hydrogen	○	○	○	○	○	○
Knowledge of sustainable development and underlying key concepts including environmental science, social issues, economic development, and key stressors/drivers	○	○	○	○	○	○
Knowledge of the basic and emerging principles and concepts that promote energy conservation and efficiency while reducing the dependency on fossil fuels	○	○	○	○	○	○
Knowledge of the basic and emerging principles and concepts that impact the generation, transport, installation, operation, and maintenance of energy technologies	○	○	○	○	○	○
Broad understanding of environmental issues including climate change, pollution, resource depletion, environmental health, and environmental risks	○	○	○	○	○	○
Knowlege of factors impacting the appropriateness of renewable energy technologies for a given situations/environmental settings	○	○	○	○	○	○

Comments (please specify & rate)

Renewable Energy Degree Competencies Survey

Please rate EACH of the following competency statements in terms of their importances to be included in a Masters of Science in Renewable Energy program.

RATING SCALE:
1 = Very Unimportant
2 = Unimportant
3 = Somewhat Important
4 = Important
5 = Very Important

"NO OPINION" RESPONSES WILL BE EXCLUDED FROM SURVEY RESULT CALCULATIONS

Renewable Energy Degree Competencies Survey

*Competencies related to Design & Analysis

	1	2	3	4	5	No Opinion
Apply qualitative and quantitative research methodologies on data, case studies and examples with the intent of statistically analyzing the results to draw conclusions and make recommendations						
Design and analyze energy efficient lighting systems based on technical and economic criteria						
Perform a site analysis appraisal of potential locations for the installation of energy systems including hydroelectric, solar PV, geothermal, wind, hydrogen cell						
Knowledge of industrial ecology and sustainability indicators including life-cycle analysis, material flow analysis, input-output analysis, life-cycle management, and relevant ISO standards						
Design and analyze appropriate grid-tie equipment for AC 1-phase/3-phase and DC systems to included technical, safety, and code requirements						
Design a needs assessment, system sizing and equipment selection for various energy systems including hydroelectric, solar PV, geothermal, wind, hydrogen cell						
Demonstrate an ability to analyze & design energy conversion devices for electric energy, thermal energy, chemical energy, etc.						
Understand importance that quality system requirements as defined by customer and/or product specifications have on product and process design						
Understand compliance requirements necessary to ensure a safe and healthy work environments, as appropriate to regulator agencies						
Familiarity with environmental impact and risk assessment methods and applications including case studies and scenario analysis						
Knowledge of decision support, operations research and systems analysis including ability to formulate and solve decision problems, decision support techniques, and relevant software						
Understand economics for energy and environmental analyses including project evaluation, cost estimating, accounting, discounting, externalities, and markets						

Comments (please specify & rate)

Renewable Energy Degree Competencies Survey

Please rate EACH of the following competency statements in terms of their importances to be included in a Masters of Science in Renewable Energy program.

RATING SCALE:
1 = Very Unimportant
2 = Unimportant
3 = Somewhat Important
4 = Important
5 = Very Important

"NO OPINION" RESPONSES WILL BE EXCLUDED FROM SURVEY RESULT CALCULATIONS

*** Competencies related to Energy & Environment**

	1	2	3	4	5	No Opinion
Knowledge of technical, economic, and environmental factors associated with renewable energy including biofuels, wind, wave, tidal and solar energy; opportunities and energy potential; and key challenges and constraints	○	○	○	○	○	○
Knowledge of technical, economic, and environmental factors associated with nuclear fuels	○	○	○	○	○	○
Knowledge of technical, economic, and environmental factors associated with fossil fuels	○	○	○	○	○	○
Knowledge of energy and environmental aspects of passenger and freight transportation systems including local/regional planning, risk assessment, sit planning, investment & operations, and new technology development & deployment	○	○	○	○	○	○
Understand consumer and industrial behavior and energy consumption	○	○	○	○	○	○
Knowledge of information sources that allow continuous updating of relevant data and design/assessment techniques including technologies, and performance benchmarking	○	○	○	○	○	○

Comments (please specify & rate)

Renewable Energy Degree Competencies Survey

Please rate EACH of the following competency statements in terms of their importances to be included in a Masters of Science in Renewable Energy program.

RATING SCALE:
1 = Very Unimportant
2 = Unimportant
3 = Somewhat Important
4 = Important
5 = Very Important

"NO OPINION" RESPONSES WILL BE EXCLUDED FROM SURVEY RESULT CALCULATIONS

* Competencies related to Decision & Policy Making

	1	2	3	4	5	No Opinion
Familiarity with national, state and local laws/regulations and institutions relevant to energy management including energy conversion, consumption, pollution, recycling, and waste management	○	○	○	○	○	○
Knowledge of techniques and practices that promote sustainability including strategic planning, procurement/supply chain management, clean production, life-cycle product design, consumption and demand management, audits, and performance evaluations	○	○	○	○	○	○
Ability to formulate, conduct, and interpret quantitative studies of energy technologies that address technical, economic, environmental, and institutional considerations	○	○	○	○	○	○

Comments (please specify & rate)

Renewable Energy Degree Competencies Survey

Please rate EACH of the following competency statements in terms of their importances to be included in a Masters of Science in Renewable Energy program.

RATING SCALE:
1 = Very Unimportant
2 = Unimportant
3 = Somewhat Important
4 = Important
5 = Very Important

"NO OPINION" RESPONSES WILL BE EXCLUDED FROM SURVEY RESULT CALCULATIONS

* Competencies related to Communication, Implementation & Innovation

	1	2	3	4	5	No Opinion
Knowledge of energy and environmental management organizational practices including accounting, financing, and reporting related to energy and environmental performance	○	○	○	○	○	○
Experience and ability to work and communicate effectively in a multidisciplinary team	○	○	○	○	○	○
Understand innovation and entrepreneurism in the energy sector including development of commercial products and services, diffusion of technology, barriers and incentives, managing innovation, business models, and case studies of successes/failures	○	○	○	○	○	○
Communicate ideas, plans and concepts of sustainability to various audiences and articulate the business case for sustainability to various audiences	○	○	○	○	○	○

Comments (please specify & rate)

Renewable Energy Degree Competencies Survey

Please rate EACH of the following competency statements in terms of their importances to be included in a Masters of Science in Renewable Energy program.

RATING SCALE:
1 = Very Unimportant
2 = Unimportant
3 = Somewhat Important
4 = Important
5 = Very Important

"NO OPINION" RESPONSES WILL BE EXCLUDED FROM SURVEY RESULT CALCULATIONS

* Competencies related to Technical Expertise

	1	2	3	4	5	No Opinion
Knowledge of conventional, renewable, and emerging energy sources including fossil fuels, nuclear, solar, wind, wave, and hydrogen	○	○	○	○	○	○
Knowledge of the design and operation of electrical energy networks including centralized and decentralized generation, transmission systems, stability, loads, and storage	○	○	○	○	○	○
Knowledge of energy transmission, storage, conversion and end use including efficiencies, key use sectors, and energy-efficient technologies	○	○	○	○	○	○
Ability to utilize and interpret systems models for energy engineering including process modeling/simulation/optimization	○	○	○	○	○	○
Basic energy concepts, including thermodynamics and heat transfer	○	○	○	○	○	○

Comments (please specify & rate)

Renewable Energy Degree Competencies Survey

Please rate EACH of the following competency statements in terms of their importances to be included in a Masters of Science in Renewable Energy program.

RATING SCALE:
1 = Very Unimportant
2 = Unimportant
3 = Somewhat Important
4 = Important
5 = Very Important

"NO OPINION" RESPONSES WILL BE EXCLUDED FROM SURVEY RESULT CALCULATIONS

* Competencies related to Social & Institutional

	1	2	3	4	5	No Opinion
Understand energy markets including energy supply, demand management, market competition, and regulation for key sectors including buildings, industry (manufacturing, agriculture), and transport	○	○	○	○	○	○
Identify the critical components of a Sustainable Management System (SMS)	○	○	○	○	○	○
Ability to develop and articulate a high level, long-term vision for sustainability for an organization, industry or society and strategies to achieve this vision	○	○	○	○	○	○
Knowledge of activities related to environmental and energy management in companies and enterprises including energy/environmental management systems	○	○	○	○	○	○
Knowledge of case studies of energy successes and failures	○	○	○	○	○	○
Understand strategic planning and management for energy systems including regional and global energy needs	○	○	○	○	○	○

Comments (please specify & rate)

Appendix B: MSU IRB Exempt Approval Notification and Memorandum

MSU Institutional Review Board for the Protection of Human Subjects in Research
NOTIFICATION OF EXEMPT PROTOCOL REVIEW

Principal Investigator/Researcher:

Name: John Haughery Title: Student

Campus Address: 210 LC Campus Phone: 717-587-6506

Department: Department of Applied Engineering and Technology

Purpose:

Title of Project/Course: Determining and Analyzing program Competencies for a Master of Science in Renewable Energy Engineering Technology

Funding Source/Agency: NA

Period of Project/Course: From: 2/21/14 To: 2/20/20

Protocol Review Number: 14-02-50

Initial Review X Continuing Review ____

The human subject use protocol described above has been reviewed by the MSU Institutional Review Board for the Protection of Human Subjects in Research with the following results:

The IRB determined the project, as stated, is exempt based on federal regulation 46.101(b)(2). Federal regulations require that the IRB be notified if anything in the research changes, as additional review may be necessary.

Yes ☒ No ☐ Approved, may proceed as written

2/21/14 Approval Date

In accordance with new procedures instituted by the IRB, **and because your study is exempt**, you are not required to complete continuation or final review reports. **However, it is your responsibility to notify the IRB prior to making any changes to the study. Please note that changes made to an exempt protocol may disqualify it from exempt status and may require an expedited or full-board review.**

Yes ☒ No ☐ N/A ☐ Regulatory requirements have been met for the waiver of documentation of consent

Yes ☐ No ☐ N/A ☒ Regulatory requirements have been met for the waiver of informed consent

Yes ☐ No ☐ N/A ☒ Criteria for use of children has been met

Signed: [signature] **Date:** 2/21/14
Chair, Institutional Review Board for the Protection of Human Subjects in Research

Please refer to the protocol review number in any future references to this protocol. If *any* revisions are made to a project or if *any* unforeseen risks arise during an investigation, the principal investigator must submit Form H to the IRB, fully explaining all changes or unexpected risks.

pc: Protocol File

Institutional Review Board
Office of Research and Sponsored Programs
901 Ginger Hall
(606) 783-9370

MUCH MORE

MEMORANDUM

DATE: February 21, 2014
TO: John Haughery

FROM: Institutional Review Board (IRB)
c/o Office of Research and Sponsored Programs

SUBJECT: **Exempt Protocol #14-02-50**

On February 21, 2014 the IRB determined that your project entitled, ***Determining and Analyzing program Competencies for a Master of Science in Renewable Energy Engineering Technology,*** meets the criteria to qualify as an exempt study.

In accordance with new procedures instituted by the IRB, **and because your study is exempt**, you are not required to submit Part H (Annual Continuing Review) or a Part H (Final Report). **However, if any revisions are made to a project or if any unexpected risks arise during an investigation the principal investigator must submit Part H (Change of Status) to the IRB, fully explaining all changes or unexpected risks. It is your responsibility to notify the IRB prior to making any changes to the study. Please note that changes made to an exempt protocol may disqualify it from exempt status and may require an expedited or full-board review.**

The Office of Research and Sponsored Programs will hold your exemption application for six years. Before the end of the sixth year, you will be notified that your protocol will be closed. If your project is still ongoing, you will need to contact the Office of Research and Sponsored Programs upon receipt of that letter and follow the instructions for completing a new exemption application. *It is important that you keep your address current with the Office of Research and Sponsored Programs.*

If you have any questions, contact the Office of Research and Sponsored Programs at (606)-783-2010.

pc: IRB File

Appendix C: Survey Cover Letter

MOREHEAD STATE
UNIVERSITY

DEPARTMENT OF APPLIED ENGINEERING AND TECHNOLOGY

210 LLOYD CASSITY BLDG.
MOREHEAD, KENTUCKY 40351-1689
TELEPHONE: 606-783-2013
FAX: 606-783-5030

<date>

Re: Renewable Energy Degree Competencies Survey

Dear *<organization>* Member,

As a member of *<organization>*, you have been specifically invited, based on your unique experience, to participate in a national research study to determine the appropriate educational content for a Masters of Science in Renewable Energy. Current research has shown there is a lack of clearly defined degree competencies related to renewable energy and sustainability graduate programs in the United States. Your input will help codify and prioritize appropriate competencies that can be used by educational institutions.

Please take **5-10 minutes** today to answer each question on the survey as completely and accurately as possible. The survey will present a list of proposed competencies and you will be asked to rate each individually on a scale from 1-5. Your responses will be processed confidentially and only aggregate data will be made available. Completed online surveys are **100% anonymous** and will be stored on a secure server by *SurveyMonkey*.

Please link to the survey at the address below. This link is uniquely tied to this survey and does not track your email address or personal information. Please do not forward this link.

<web link>

This study is part of the thesis research of Mr. Haughery, who is pursuing an MS in Engineering & Technology Management at Morehead State University. He is planning to complete this study in time for a May 2014 graduation. As such, the results of this study will be published in academic publications. If you have any questions regarding the survey or would like a copy of the survey results, please contact Mr. Haughery at the address below. Thank you for your contribution to this important survey and I wish you the best in your future endeavors.

Please note: If you do not wish to participate in this survey, kindly reply with “not interested” and your name will be removed from the mailing list.

Sincerely,

John Haughery
Graduate Assistant
Department of Applied Engineering and Technology
E-mail: jrhaughery@moreheadstate.edu

Appendix D: Ranked List of Curriculum Competency Items

Rank	*Category*	*Competency*	*Median*
Very Important	Sustainability Challenges & Society	Knowledge of the basic and emerging principles and concepts that impact the generation, transport, installation, operation, and maintenance of energy technologies	5
	Sustainability Challenges & Society	Knowledge of the impacts (positive and negative) of renewable energy sources including fossil fuels, nuclear, solar, wind, wave, and hydrogen	5
	Sustainability Challenges & Society	Knowledge of factors impacting the appropriateness of renewable energy technologies for a given situation/environmental settings	5
	Design & Analysis	Understand economics for energy and environmental analyses including project evaluation, cost estimating, accounting, discounting, externalities, and markets	5
	Decision & Policy Making	Ability to formulate, conduct, and interpret quantitative studies of energy technologies that address technical, economic, environmental, and institutional considerations	5
	Communication, Implementation & Innovation	Experience and ability to work and communicate effectively in a multi-disciplinary team	5
	Technical Expertise	Knowledge of conventional, renewable, and emerging energy sources including solar, wind, wave, and hydrogen	5

Rank	*Category*	*Competency*	*Median*
Important	Sustainability Challenges & Society	Broad understanding of environmental issues including climate change, pollution, resource depletion, environmental health, and environmental risks	4
	Sustainability Challenges & Society	Knowledge of the basic and emerging principles and concepts that promote energy conservation and efficiency while reducing the dependency on fossil fuels	4
	Sustainability Challenges & Society	Knowledge of sustainable development and underlying key concepts including environmental science, social issues, economic development, and key stressors/drivers	4
	Design & Analysis	Familiarity with environmental impact and risk assessment methods and applications including case studies and scenario analysis	4

Rank	*Category*	*Competency*	*Median*
Important	Design & Analysis	Understand importance that quality system requirements as defined by customer and/or product specifications have on product and process design	4
	Design & Analysis	Knowledge of industrial ecology and sustainability indicators including life-cycle analysis, material flow analysis, input-output analysis, life-cycle management, and relevant ISO standards	4
	Design & Analysis	Understand compliance requirements necessary to ensure a safe and healthy work environments, as appropriate to regulator agencies	4
	Design & Analysis	Apply qualitative and quantitative research methodologies on data, case studies and examples with the intent of statistically analyzing the results to draw conclusions and make recommendations	4
	Design & Analysis	Demonstrate an ability to analyze & design energy conversion devices for electric energy, thermal energy, chemical energy, etc.	4
	Design & Analysis	Design a needs assessment, system sizing and equipment selection for various energy systems including hydroelectric, solar PV, geothermal, wind, hydrogen cell	4
	Design & Analysis	Perform a site analysis appraisal of potential locations for the installation of energy systems including hydroelectric, solar PV, geothermal, wind, hydrogen cell	4
	Design & Analysis	Knowledge of decision support, operations research and systems analysis including ability to formulate and solve decision problems, decision support techniques, and relevant software	4
	Energy & Environment	Understand consumer and industrial behavior and energy consumption	4
	Energy & Environment	Knowledge of technical, economic, and environmental factors associated with fossil fuels	4
	Energy & Environment	Knowledge of technical, economic, and environmental factors associated with renewable energy including biofuels, wind, wave, tidal and solar energy; opportunities and energy potential; and key challenges and constraints	4
	Energy & Environment	Knowledge of information sources that allow continuous updating of relevant data and design/assessment techniques including technologies, and performance benchmarking	4

Rank	*Category*	*Competency*	*Median*
Important	Decision & Policy Making	Familiarity with national, state and local laws/regulations and institutions relevant to energy management including energy conversion, consumption, pollution, recycling, and waste management	4
	Decision & Policy Making	Knowledge of techniques and practices that promote sustainability including strategic planning, procurement/supply chain management, clean production, life-cycle product design, consumption and demand management, audits, and performance evaluations	4
	Communication, Implementation & Innovation	Communicate ideas, plans and concepts of sustainability to various audiences and articulate the business case for sustainability to various audiences	4
	Communication, Implementation & Innovation	Knowledge of energy and environmental management organizational practices including accounting, financing, and reporting related to energy and environmental performance	4
	Communication, Implementation & Innovation	Understand innovation and entrepreneurism in the energy sector including development of commercial products and services, diffusion of technology, barriers and incentives, managing innovation, business models, and case studies of successes/failures	4
	Technical Expertise	Basic energy concepts, including thermodynamics and heat transfer	4
	Technical Expertise	Knowledge of energy transmission, storage, conversion and end use including efficiencies, key use sectors, and energy-efficient technologies	4
	Technical Expertise	Knowledge of the design and operation of electrical energy networks including centralized and decentralized generation, transmission systems, stability, loads, and storage	4
	Social & Institutional	Understand energy markets including energy supply, demand management, market competition, and regulation for key sectors including buildings, industry (manufacturing, agriculture), and transport	4
	Social & Institutional	Knowledge of activities related to environmental and energy management in companies and enterprises including energy/environmental management systems	4
	Social & Institutional	Ability to develop and articulate a high level, long-term vision for sustainability for an organization, industry or society and strategies to achieve this vision	4

Rank	*Category*	*Competency*	*Median*
Important	Social & Institutional	Understand strategic planning and management for energy systems including regional and global energy needs	4
	Social & Institutional	Identify the critical components of a Sustainable Management System (SMS)	4
	Social & Institutional	Knowledge of case studies of energy successes and failures	4

Rank	*Category*	*Competency*	*Median*
Somewhat Important	Design & Analysis	Design and analyze energy efficient lighting systems based on technical and economic criteria	3
	Design & Analysis	Design and analyze appropriate grid-tie equipment for AC 1-phase/3-phase and DC systems to included technical, safety, and code requirements	3
	Energy & Environment	Knowledge of technical, economic, and environmental factors associated with nuclear fuels	3
	Energy & Environment	Knowledge of energy and environmental aspects of passenger and freight transportation systems including local/regional planning, risk assessment, sit planning, investment & operations, and new technology development & deployment	3
	Technical Expertise	Ability to utilize and interpret systems models for energy engineering including process modeling/simulation/optimization	3

Appendix E: Survey Comments

Comments from Sustainability Challenges & Society items:

1. "Hydroelectric needs to be identified in the mix. It is by far, the largest and most reliable renewable in the world."

2. "Believe strong mechanical and electrical engineering skills critical."

3. "The last question (while rarely addressed,) is very important because it gets to an essential metric which must be used on all energy options - and that is life cycle costs (economic, environmental, health, etc.)."

4. "I teach two interdisciplinary courses on sustainable energy, and you need to focus less on individual technologies and address energy risk in the entire cradle-to-grave including water, land, emissions, waste, and failure (terrorism, human error, geologic, weather and climate events) (5)."

5. "ALL of these are critical competencies for earning an MS in RE."

6. "Renewable energy sources including fossil fuels, nuclear" makes no sense."

7. "On question 2, fossil fuels and nuclear power are listed as 'renewable energy sources.' I vehemently disagree with this characterization, and

hope anyone graduating from this future MS in Renewable Energy would, too."

8. "It is difficult to do a true cost-benefit analysis without a well rounded knowledge of the areas impacted financially."

Comments from Design & Analysis items:

9. "The relative importance of these depends upon your job. Do you plan on being an engineer or something else and what field?"

10. "The lighting systems question should address - in addition to technical & economic criteria - but also the social impact: Fewer absent days by workers, more/longer shopping in commercial bldgs, etc. There are many studies on these values."

Comments from Energy & Environment items:

11. "Another caveat, it depends upon what field (transport, elec. Generation, energy efficiency, thermal, etc.) You plan to work in."

12. "Would like to see hydropower included in all of the curriculum due to needs for engineers and technicians."

13. "Knowing enough to compare all energy options is critical. To making choices that meet all of the life cycle costs I mentioned earlier this."

14. “Again from cradle-to-grave, including liability (and liability limits) and risk.”

15. “Biofuels/transportation systems ... Interesting questions that I hadn't considered. Within a Renewable Energy program, biofuels certainly fits, but transportation fuels are an entirely different field than electricity generation. I'd structure it as a track or concentration, but wouldn't attempt to teach all courses with an eye toward both fuels and electricity. It's too complicated.”