Oregon Power Engineering Education Project:

Filling the Workforce Pipeline Gaps

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Preamble

OESTRA felt compelled to fund this study as a way of verifying revelations made during two separate meetings with executives from the power industry regarding available talent in the power engineering sector:

1. When speaking of human resources risks, an executive with the Bonneville Power Administration emphasized the imminent loss of "institutional memory" due to retirement attrition of engineering and technical talent, estimated to be over 40% within the next five years.

2. A Program Manager from a local Investor Owned Utility remarked that the industry considers this loss of talent a "silent crisis" that is compounding due to a shortfall of locally educated engineers and a lack of action from the regional higher education institutions.

These statements reveal the power industry's apprehension regarding the shortcomings of the engineering workforce pipeline. The industry's major customers, Oregon's manufacturing and high technology sectors, are also at risk. Both sectors benefit significantly from the low rates and high reliability that are maintained by the region's electric utilities and power engineering consultancies. These competitive advantages are underpinned by the talented and innovative people of the power industry. If Oregon hopes to continue advancing its high tech and manufacturing sectors and to maintain its leadership in providing world-class power engineering services, it is imperative that the state invest in engineering education to ensure a well-educated and experienced power engineering talent pool.

Executive Summary

Examination of national, as well as Oregon-specific, engineering employment needs within the electric power industry shows two concurrent and disconcerting trends: the power industry engineering workforce is on the verge of a major contraction while simultaneously experiencing escalating employee demand.[1, 2, 3, 4] This is a result of large-scale retirements, paired with operational expansions due to renewable portfolio standards, updates to aging infrastructure, enlargement of regulatory compliance and increasing power requirements on the bulk electric grid.[5, 6, 7, 8, 9] Education programs for power engineers currently do not have the ability to meet projected industry needs by the year 2020.[10, 11] Mechanisms for recruitment and education must advance in the immediate future in order to maintain a stable power industry.

The regional power industry is represented by a diverse array of over 100 companies, all of whom are subject to this employment trend. Considering only Bonneville Power Administration, Portland General Electric and PacifiCorp, around 500 engineers will be eligible for retirement by 2020.[6, 7] In order for Oregon to meet its renewable portfolio standard, maintain environmental quality, keep customer rates low, move towards greater energy independence and meet increasing electricity demand, an additional 1,300 or so new power engineering positions may be needed by 2020.[12, 13, 14, 15, 16, 17] The current graduation rates of engineering students from Oregon's universities are insufficient; only around 490 engineering students versed in power engineering may graduate by 2020.[18, 19]

Oregon's power engineering education programs will provide only slightly more than one-third of the demand for power engineers over the 2013-2020 period; creating a talent deficiency for meeting the needs of industry, government mandates, and the Governor's Ten Year Energy Action Plan.[20] Educational reform must be applied in power engineering to attract large numbers of dedicated local talent, and provide employee professionalization for immediate efficacy in the workforce. Oregon stands to greatly benefit through maintaining high standards in the electrical power industry. This excellence stems from a large pool of local power engineering companies; and these companies should assist Oregon's universities in creating a model engineering education program. Furthermore, low power rates attract business in

manufacturing and high technology industries, thus creating a stronger and more diverse state economy. Allying power engineering education with industry will help fill the gaps in the industry's workforce pipeline, impacting the state through:

1. Expanded job growth and creation.
2. Achieving affordable, fair, and reasonable energy costs for stakeholders.
3. Building a sustainable energy future.
4. Creating energy independence in Oregon.
5. Providing skilled and "work-ready" graduates for a major Oregon Industry.
6. Meeting legislative standards for renewable energy.
7. Fulfilling goals of Oregon's Ten Year Energy Action Plan.

This report analyzes the current and projected workforce needs for electrical power engineers in Oregon. Based on these findings, we detail a framework for collaborative unification of the three existing power engineering programs in the State; those at Oregon Institute of Technology, Portland State University and Oregon State University. The Oregon Power Engineering Education Project will leverage existing resources, eliminate redundant educational investments, and evolve the educational paradigm for power engineering in Oregon. Its incorporated pedagogy is meant to revolutionize teaching methods; with built-in accountability, experiential learning, close collaboration between universities and industry, and measured ROI outcomes. These practices enhance graduate retention rates and foster innovative thinking.[21, 22, 11, 23] Necessary to the successful function of this plan are autonomous governance, strategic public and private sector funding, and industry collaboration to establish development priorities. Main deliverables will be an internship program for all power engineering bachelor students; a Power Engineering Project Center in Portland and expanded teaching laboratories at Oregon State University; improvements in engineering pedagogy; and, collaborative undergraduate projects.

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1 Introduction

The Pacific Northwest hosts a large and diverse power industry, with a number of major industry contributors located in Portland, OR. This document pays reference to the Portland Power Pool (PPP), which consists of local utilities, consultancies, federal entities, developers, manufacturers and engineering service firms, as well as companies within the high-tech cluster moving into the smart grid domain (Appendix A). The Portland Power Pool represents a sizable fraction of the regional economy. Investment in new generation and transmission, innovations in communications and IT, and rapidly-decreasing prices for renewable resources are all contributing to the industry's growth. These combined factors, along with a comparatively rare abundance of natural hydro and wind generation resources, create a unique advantage for the Pacific Northwest. If developed with thoughtful intent, the region stands to gain international recognition for innovative and sound practices in power engineering; thereby setting a global precedent and becoming a model for practical implementation.

Table 1: Eligible and projected retirements of engineers in 2015 and 2020 at the two local investor owned utilities and BPA. Data were collected by the Oregon and SW Washington Energy Consortium, of which PGE, PacifiCorp and BPA are members.[6]

By 2020, these companies anticipate 59%, 28% and 61% retirements of their current workforce, respectively.

	Current Workforce	Eligible for Retirement 2015	Projected to Retire 2015	Eligible for Retirement 2020	Projected to Retire 2020
PGE	95	44	68%	42	62%
PacifiCorp	200	27	80%	38	90%
BPA	450	144	66%	216	84%

The impending large-scale retirement of power engineers has long been forecast.[2, 3] Several recent publications echo these projections for nation-wide, large-scale retirements from the power industry.[1, 4] A 2011 survey by the Center for Energy Workforce Development (CEWD) projects a 38% turnover of engineers to occur between 2010 and 2015, with an additional 15% turnover in the ensuing five years, amounting to a national need for nearly 15,000 replacements by 2020.[5] Regionally, three employers of power engineers, Portland General Electric (PGE), PacifiCorp and the Bonneville Power Administration (BPA), project short-term, 2015-2020, retirement of 52% of their current workforce (Table 1).[6, 7] In addition, technological, regulatory and political changes are resulting in increased investment in power systems planning and capital investment, further driving the demand for power engineers.

2 Findings: Oregon Workforce Gaps

Putting Table 1 in real terms, there will be approximately 390-510 power engineer retirees between PGE, BPA and PacifiCorp by 2020. Graduation rates from the Oregon Institute of Technology (OIT), Portland State University (PSU) and Oregon State University (OSU) power engineering programs from prior years indicate that Oregon could produce an estimated 40-70 new engineers annually.[18, 19] These graduation rates would provide the industry with just 280-490 new power engineers by 2020. Consequently, there is a projected deficit in maintaining engineering staffing levels at just PGE, BPA and PacifiCorp. This shortfall does not even consider the employment needs of the wider Portland Power Pool, nor does it account for forecasted power engineering employment growth due to Renewable Portfolio Standards (RPS) compliance, investment in energy efficiency and smart grid technologies, expansion of the electric vehicle infrastructure, impending carbon restrictions, or upgrades and expansion of generation, transmission and distribution assets. It is also important to note that this industry turn-over replaces knowledgeable veterans with entry-level engineers, who take up to fifteen years to fully professionalize.[6]

2.1 Compliance With Legislative & Public Utility Commission Mandates

The 2007 enactment of Senate Bill 838 began Oregon's Renewable Portfolio Standards, which require that electrical power utilities supply yearly increasing percentages of total power from renewable resources.[24] Regionally, Oregon Public Utility Commission (PUC) mandates such as UM 1573 for energy efficiency power purchase agreements and UM 1460 for smart grid, as well as Oregon legislation like ORS 757.370 mandating solar capacity and ORS 469A introducing Oregon's Renewable Portfolio Standards, are placing pressure on the regional power industry to incorporate new technologies and implement renewable generation.[25, 26, 27, 24] Nationally, recent FERC Orders are providing regulatory framework for wholesale market interactions, demand response and ancillary service compensation, transmission planning and cost allocation of transmission infrastructure.[28, 29, 30, 31, 32]. Concurrently, twenty-four U.S. states have passed RPS legislation or Alternative Energy Portfolio Standards (APS), which are spurring investment in technologies such as wind, solar and geothermal generation; carbon-capture & storage technology; and, the transmission and distribution infrastructure required to support these new resources.[33] The extra engineering work required by these mandates is increasing the demand for additional power engineers and the effects of these mandates have already become apparent. Notably, the number of electrical engineers in the U.S. power industry has experienced a 43.8% growth rate in the span between 2004 and 2012, an unprecedented excess over the DOE-predicted 8.1% growth over the 2004-2014 period.[8, 9]

2.1.1 Renewable Portfolio Standards

ORS 469A, Oregon's RPS, requires electrical power utilities supply yearly increasing percentages of total power from renewable resources.[24] The requirements by utility size and year are listed in Table 2.[34] Large utilities are required to begin meeting RPS standards in 2011; and small utilities in 2025. Three utilities in Oregon qualify under the "large" category: PGE, PacifiCorp, and Eugene Water and Electric Board (EWEB).[35] Mandates of RPS statute ORS 469A, along with Public Utility Commission rules listed under OAR 860-083 and Oregon Department of Energy (ODOE) rules OAR 330-160, dictate that each large utility provide yearly reports on compliance efforts.[35, 36]

Table 2: Annual percentage target of qualifying electricity per year.

Utility Class	Supplied Power to Oregon (%)	2011 Renewables (%)	2015 Renewables (%)	2020 Renewables (%)	2025 Renewables (%)
Large	3 or More	5	15	20	25
Smaller	1.5 - 3	N/A	N/A	N/A	10
Smallest	Less than 1.5	N/A	N/A	N/A	5

For the compliance year of 2012, PGE released a supplemental integrated resource plan (IRP) which voiced concerns over long-term compliance limitations.[37] The dependence on dwindling renewable energy credits (RECs) and forecast cost increases for investment in renewable generation facilities were paralleled in other utilities.

PacifiCorp reported using the maximum allowable unbundled RECs to meet their targets, and EWEB filed exemptions to RPS for BPA tier 1 and legacy hydro facilities within their service territory.[38, 34] Even with successful implementation of all upgrades proposed in PGE's IRP, they expect continuing yearly deficits in RECs beginning in 2015.[37] PGE asserts that immediate investment in renewable energy generation resources, energy efficiency, and smart grid are imperative to meet future RPS without raising electricity prices.[37]

2.1.2 Carbon Restrictions

The growing need for power engineers is exacerbated by increasingly stringent worldwide carbon restrictions. A study conducted by Greenpeace International and the European Renewable Energy Council predicted the creation of 300,000 extra jobs in the U.S. energy sector between 2010-2020, in response to limiting carbon emissions.[12] According to the Bureau of Labor Statistics (BLS), 3.7% of current energy sector employees in the U.S. are electrical engineers.[9] This forecasts an additional 11,100 electrical power engineering jobs for carbon restrictions alone in the U.S. by 2020. However, this figure does not account for engineering growth rates, or the non-utility and other-discipline engineers working in the power industry. The actual number for general power engineering job creation would reflect a much more expansive growth.

Projected workforce expansion is not solely attributable to the carbon restriction economy; but also to impending demands from industrial upgrades. It is important to remember that, regardless of future carbon market effects, the U.S. power industry will require major overhauls to equipment that is presently decades past its designed lifetime.[39, 40] This being said, it is probable that power engineering workforce demands will be exacerbated by carbon regulation in the United States. Regulations depend on country politics, as evidenced through Australia's recent economically-driven reduction of carbon restrictions.[41] This example relates to a carbon-intensive economy, which does not carry the same emphasis in the U.S.; and is particularly absent in the state of California, which carries global precedence in the movement. Furthermore, many carbon motives in the U.S. are driven by international competition in progressive environmental measures.[42] The risk associated with future carbon restrictions is leading to investment apprehension in new coal generation resources, thereby forcing system upgrades to target growth in renewable energy and the smart grid.

2.2 Economic and Industrial Growth in Oregon

Challenges of meeting RPS requirements, FERC Orders, PUC mandates and carbon limits are issues of national concern; every state is under pressure to comply with mandates of some form or another. This creates a compelling interstate competition opportunity, because the first state to develop the educated talent to address these issues will become the national leader in power engineering expertise. This carries very large economic implications for that state, as others look to them for answers and ideas by hiring power engineers from consultancies based in that lead state. New business opportunities will compound, further increasing that state's power engineering expertise.

Oregon has a unique advantage in seizing this lead role because of the Portland Power Pool, which consists of over two dozen consultancies that serve national and international clients. As large amounts of highly skilled engineers are produced, these PPP companies will hire Oregon graduates, allowing regional businesses to grow and become stronger. Other states around the nation will outsource their compliance and engineering work to Oregon companies and the region will experience an economic snowball effect. Oregon will thus develop a self-sustaining cycle between industry and university sectors, becoming economically robust and recognized for excellence in power engineering careers and education. This can be shown with a parallel case: the Oregon green building industry. Unique policy initiatives have fueled Oregon green building business and educational investment since 2000, fostering vast economic growth as national industry leaders locate operations in Oregon. The green building industry employs home-grown talent and supports 168 organizations with headquarters in Oregon. The national presence of these Oregon-based companies employs four million people and generates $27 billion in annual revenue.[43]

3 Resource & Investment Evaluation: Oregon Power Engineering Talent Needs

Defining the strategy for advancing the power engineering workforce in Oregon requires assessment of current strengths and needs within the state. This includes surveys of university resources; consideration of returns on investment (ROI) for education in science, engineering, technology and math (STEM) programs; as well as investigation into the power industry workforce needs in Oregon.

3.1 Oregon University System Power Engineering Education Resources

Three Oregon universities have educational programs in power engineering. Degree offerings relating to power engineering at each university are itemized below. Specific courses within these programs are listed in Appendix B. Supplemental departments for diversifying curriculum are also listed, as they apply to creation of a comprehensive power industry education.

- Oregon Institute of Technology: BS and MS in Renewable Energy Engineering
- Portland State University: Electrical & Computer Engineering, MS ECE and BS EE programs with power engineering foci; Engineering & Technology Management
- Oregon State University: MS and BS ECE programs with power engineering foci; Wallace Energy Systems & Renewables Facility
- Oregon State University, Cascades: Energy Systems Engineering
- General Supplemental Departments for Consideration: Computer Science, Mechanical Engineering, Civil Engineering, Economics, Public Policy & Administration, Electrical Engineering Management

3.2 ROI for STEM Program Funding

The U.S. has fallen behind the global average in STEM education in proportion to other industrialized nations. In 2008, 15% of U.S. college graduates held STEM-related degrees, compared to a world average of 23%.[22] In 2010, only 5% of U.S. graduates majored specifically in engineering.[10] Approximately 14% of college freshmen declare STEM majors in the U.S., and only 50% of these students actually complete these degrees, double the attrition rate for majors outside of STEM.[22, 44]

A 2013 study published by the McKinsey Global Institute reported the immediate need for investment in STEM education programs.[22] It predicted a "possible $1.7 trillion annual increase in GDP by 2030 through improving the US talent development pipeline."[22] In 2012, the President's council of advisers on science and technology surmised that one million extra STEM graduates would be needed within the next decade.[21] The power industry is a primary source of impact on future GDP, especially with development of shale oil and renewable energy markets.[22] If the power industry is to succeed in such rapid progression, a significant fraction of the new STEM workforce will need to be directed into the power industry. This creates an issue, considering that most STEM investments to date have not been power-related.[11]

The federal government gave $2.9 billion to STEM programs in 2012, and is budgeting for an additional $3.1 billion in 2014.[22] In contrast, between the years spanning 2003-2010, $37 million was invested in workforce training for the electric power industry.[45] The total fraction of annual federal STEM investment in the energy industry in 2011 was less than 1% of the educational budget and 5% of the workforce training budget.[11] This minuscule fraction of total STEM investment has resulted in a scarcity of power-related education programs. As a result, recipients for additional funding simply do not exist. This decrease in power-related education programs evolved from power program cancellations after a major industry decline in the late 1980s and early 1990s.[10] Educational recovery has been unable to keep pace with drastic increases in workforce demand.[10] Development and approval for new degree offerings at conventional universities take years to complete; and many institutions become stymied in the process due to competition and objection from other geographically close programs over curriculum similarities. For decades, this competition has set a dangerous precedent of pitting universities against each other and degrading educational opportunities due to perceived threats to enrollment. Consequently, many STEM programs are shoehorned to fit within existing education norms, and so new ideas are not able to flourish.[10, 11]

Efforts to curtail the existing and projected dearth of STEM education in the United States have not yet returned compelling results on a national level.[22] Many programs are not structured in a sense for providing measurable results within a short time-frame. This observed gap between STEM investment and results is also highly attributed to the lack of practical skills development in education.[21, 22, 44] Private-sector involvement for university-industry integration is vital to bridge this gap. Necessary involvement includes skill set evaluation, lab development, intern sponsorship, and course design consulting. Funding for tuition and undergraduate research can also help student retention.[21, 22, 46]

Though large-scale results from STEM education investment have not been produced, it is estimated that if the U.S. were to meet the world average 23% STEM graduate rate by 2020, it would correspond with a $25 billion increase in GDP.[22] If this coincided with an educational shift, which gave college graduates better workforce outcomes, it could potentially contribute an additional $95 billion towards GDP by 2020.[22]

In 2012 the Oregon Department of Education held a meeting for board members of the STEM Education Initiative to discuss methods for delivering optimized ROI for state investments in STEM.[23, 46] Particular emphasis was placed on collaborative partnerships and appropriate educational context in lesson design.[23] It was noted that worthwhile investments would allow multiple different agencies to benefit from shared funding on a common project.[46] Their summarized components to effective learning core objectives are shown in Figure 1.[46]

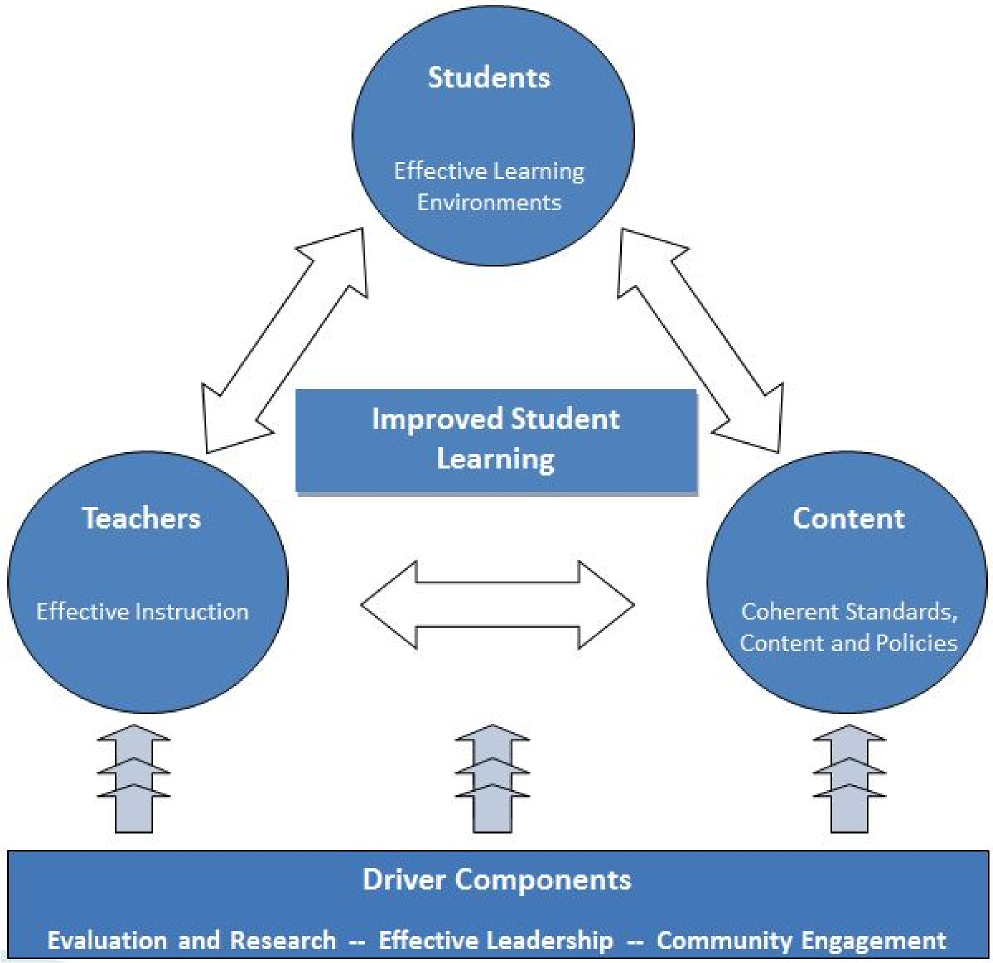


Figure 1: Oregon Department of Education STEM advancement objectives. The driving force behind necessary upgrades includes an experiential context to learning. *Image Source [46]*

The core objectives asserted by the Oregon STEM Education Initiative are repeated by numerous publications on the matter. According to the McKinsey Global Institute,

"Several successful examples show that STEM attrition can be reduced by injecting research, real-world projects, and creativity into the standard curriculum. The EXPRESS program at the University of Missouri, for example, provides research experience to freshmen and sophomores; those in the program have a 90 percent retention rate, higher than the university mean. Other universities are trying different

approaches, from replacing large section classes with courses on creative problem solving to designing an engineering course on numerical methods around a racing simulation. And outside the university setting, the RoboAcad programa partnership of NASA, academics, and industry challenges summer interns to create highly technical engineering deliverables."[22]

The necessary steps for maximizing STEM investment are clearly defined and outlined by multiple different vested parties. One significant approach has been to provide an experiential context to learning. The path forward for reaching these goals within the Oregon electric power industry is a thorough examination of specific needs, followed by the creation of an educational framework for meeting them.

3.3 Oregon Power Workforce Study

In terms of net power production, the Pacific region including the states of WA, OR and CA together rank comparably with Texas: both territories produce more power than any other region in the country. According to U.S. Energy Information Administration (EIA) approximations for May 2013, the combined Pacific states produced 31,060 thousand MWh and Texas produced 36,854.[47]

Though Oregon ranks lowest of the Pacific states in energy production, it boasts a high renewable energy production percentage (including hydro).[47, 48] This gives the state a unique advantage with a reputation for progressive generation abilities and low rates. The EIA ranked Oregon with the 6th lowest power rates per state in the U.S. residential sector for May 2013.[49] However, these low rates come as a result of Oregon's purchase of inexpensive out-of-state coal power.[50] In fact, Oregon only produces 40% of its consumed power.[50] The increased investment demand for RPS compliance, paired with attempts to become electrically independent, have caused a trend of heightened yearly increases in Oregon electricity rates since 2006 (Figure 2).[50, 51]

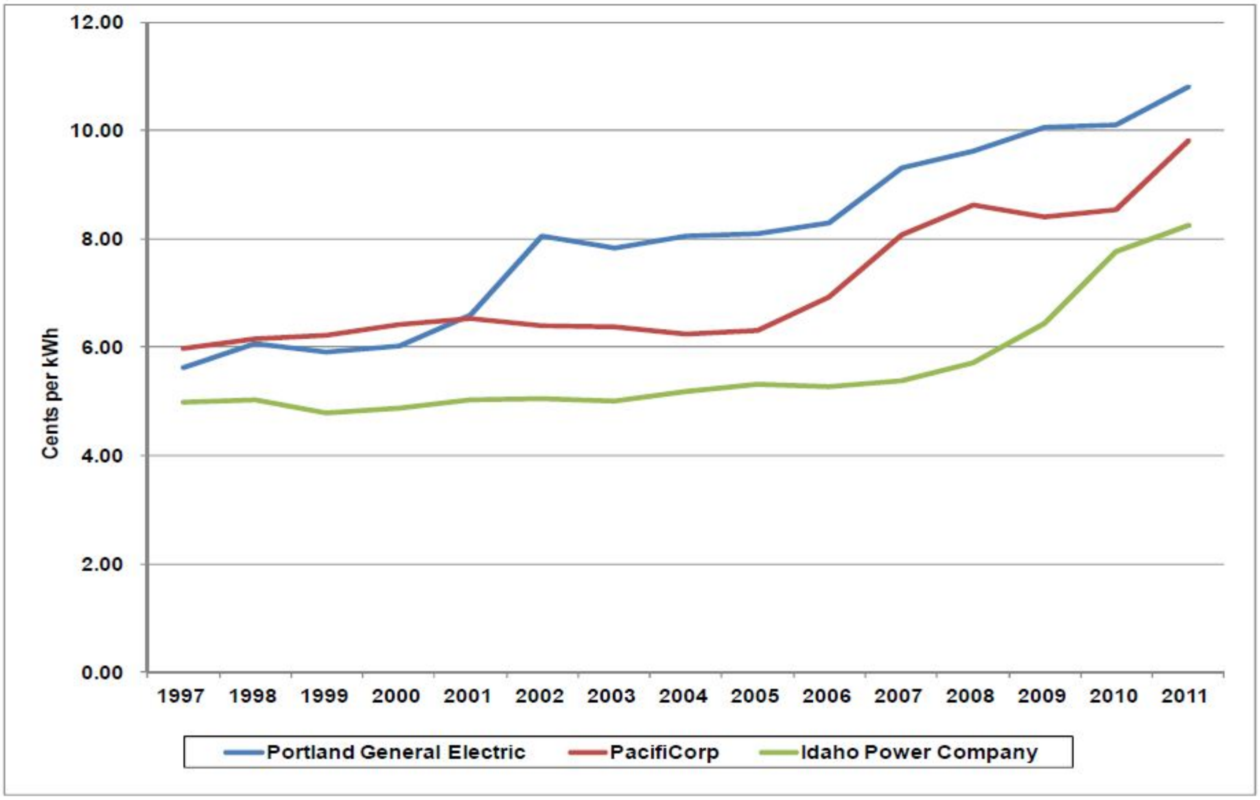


Figure 2: Rising electricity rates for Pacific Northwest utilities. Note the sharp increase trend beginning in 2006; when REC banking began, in preparation for RPS mandate compliance. *Image Source [50]*

In order to retain a low electricity price portfolio in the state, Oregon power resource investments must be analyzed on a least-cost basis. Figure 3 illustrates the price per kWh for installing new generation in the U.S.[50] Notably, investments in energy efficiency, which includes smart grid, are the least expensive of all new generation techniques. This is likely to consume the majority of new investments because it will carry the lowest impact on electricity rates. These upgrades are also financially attractive because their costs are not entrenched with unpredictable subsidies, like those of renewables. The required upgrades for energy efficiency are almost purely a matter of engineering. Many new engineers will be required with backgrounds in electrical, systems science, regulatory, and computational programming fields. Beyond this, ending incentives for solar and limited available site locations for wind are creating rate increase forecasts, and promoting urgency for investment in these technologies within the five-year time horizon.[37] This indicates an immense upcoming demand for power engineers in the near term.

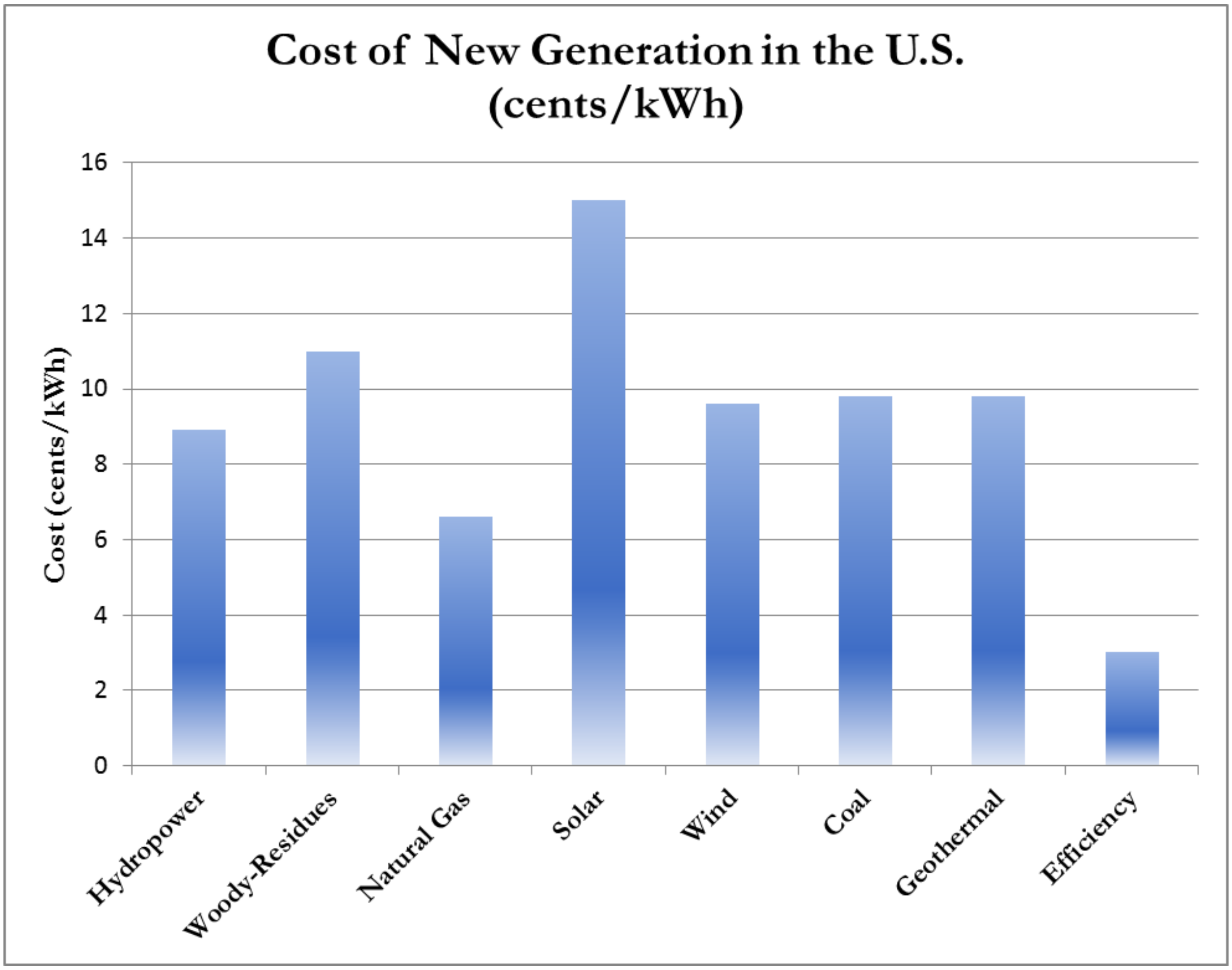


Figure 3: Cost of new generation in the U.S. Note that efficiency efforts rank lowest, meaning that these investments are the most beneficial to the PUC mission of maintaining low electricity rates.[50]

Oregon is situated as the tie between the two major power production territories directly to the north and south, and as such, must maintain a stable backbone for transmission, power management and real-time arbitrage. The state plays a vital role in load shaping transmission services for price stability between all three pacific states. With operational expanses looming, Oregon will need progressively-minded and expertly educated engineers to continue a prosperous energy outlook and maintain low electrical power rates.

The Bureau of Labor statistics projects the national employment rate for electric power generation, transmission and distribution to experience a 0.9% *decline* over the 2010-2020 time frame.[13] The study credits "new technologies, along with newer and larger facilities" for enhancing plant efficiency to the extent that fewer workers are necessary for operations.[13] Declining employment rates are thus affecting operations staff most severely, and run counter to the increasing employment trend for engineers. This is to say that major investments in community college and trade certificate programs run a clear risk of saturating the market with unemployable skilled trade-workers.

Referencing BLS growth figures in comparison with carbon market predictions made by Greenpeace, there will be an expected additional growth in the number of electrical power engineers of 16%-94% in the U.S. over the time frame of 2012-2020.[12, 13, 14] This is only a portion of the actual engineering talent requirement, which additionally spans mechanical, civil, environmental, planning, policy and management fields. A separate BLS survey predicts that rapid technological advancement will create a large demand for research and development engineers in upgrading distribution systems.[14] This is to say that a comprehensive power engineering education must encompass elements of multiple disciplines in order to create adaptable graduates useful for any industry need.

The BLS forecasts national growth in real power output by $63.2 billion over the 2010-2020 period, implying that the power industry is concurrently expanding and experiencing employment reductions.[12] However, these assertions are misleading in light of the fact that they pay sole reference to the utilities sector, which has resorted to outsourcing engineering work to consultancies for two main reasons. First, as seasoned industry veterans retire, they are returning as consultants because the expertise they take with them is not being replaced fast enough; and second, it is less expensive for a utility to use outside contractors for single project functions than employ their own permanent staff.[14] BLS statistics on the electrical power industry fail to account for the massive growth boom in power engineering consultancies; as evidenced by a major Portland Power Pool consultancy, *POWER Engineers*, which experienced a 212% growth from 2010-2013.[52] Half of the new hires within this time frame were entry-level Power Engineering graduates with bachelor degrees.[52]

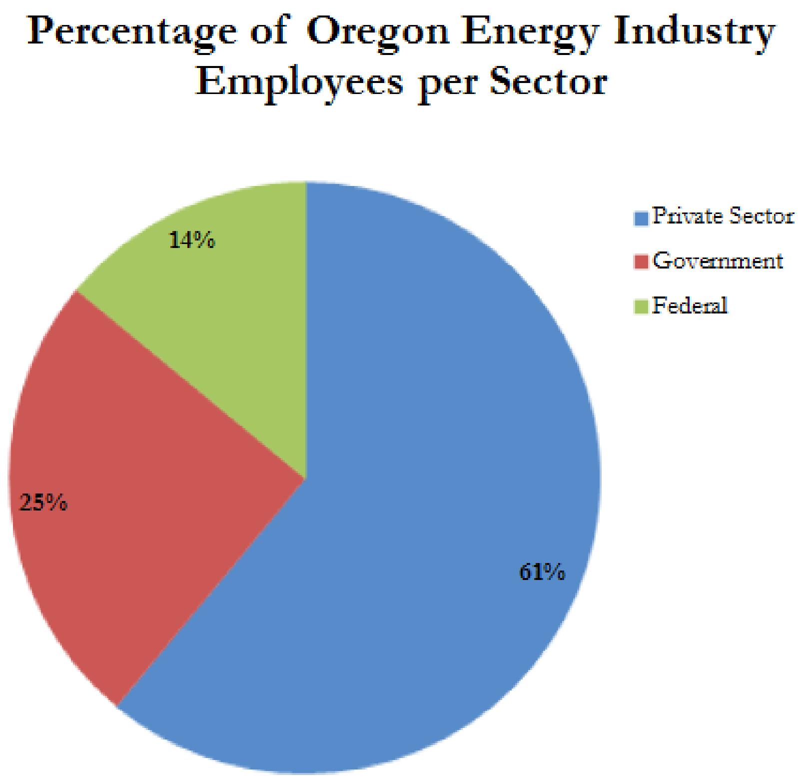


Figure 4: Percentage of Oregon energy industry employees per sector as of 2009.[15] Note that the vast majority work for private agencies, meaning that workforce predictions based solely on Utility statistics neglect the majority of the actual workforce.

The Oregon Employment department predicts a 20% growth in the Oregon high tech sector between 2010-2020.[53] There were 9,975 employees in the Oregon energy sector as of Q4 2009; of which 61% were private sector, 25% were government employees, and 14% worked for federal agencies (Table 4).[15] An estimated 8%-12% of these employees were power engineers.[16] This gives a projected growth in the number of power engineering jobs in Oregon of up to 240 new positions between 2010-2020. This figure does not account for job creation resulting from carbon restrictions or the renewable energy market. The actual number of new power engineering jobs in Oregon by 2020 is likely much larger. If we account maximum growth numbers for carbon limitations, this figure jumps to 1,366 new positions in Oregon by 2020.

The large number of new engineering positions is not a huge stretch of the imagination, considering that the solar industry is reporting yearly growth rates of 26% for 2011 and 17% for 2012.[54] The wind industry has also recently began rebounding after a brief slowdown.[55] The 2012 Global Wind Energy Outlook, published by Greenpeace, predicted a base conservative growth rate for wind energy in the U.S. of 130%-194% over the 2011-2020 time frame.[17] There were a reported 3,000 existing jobs in the Oregon solar and wind industries in 2011.[56] Applying these growth rates to Oregon's wind and solar energy workforce, as a function of respective industry size, there will be between 322-723 combined wind and solar energy engineering positions created within this span; providing 62% of the heightened carbon limit scenario positions.[57, 17, 54] Low and high estimates for retirement, graduation, and job creation are shown in Figure 5.

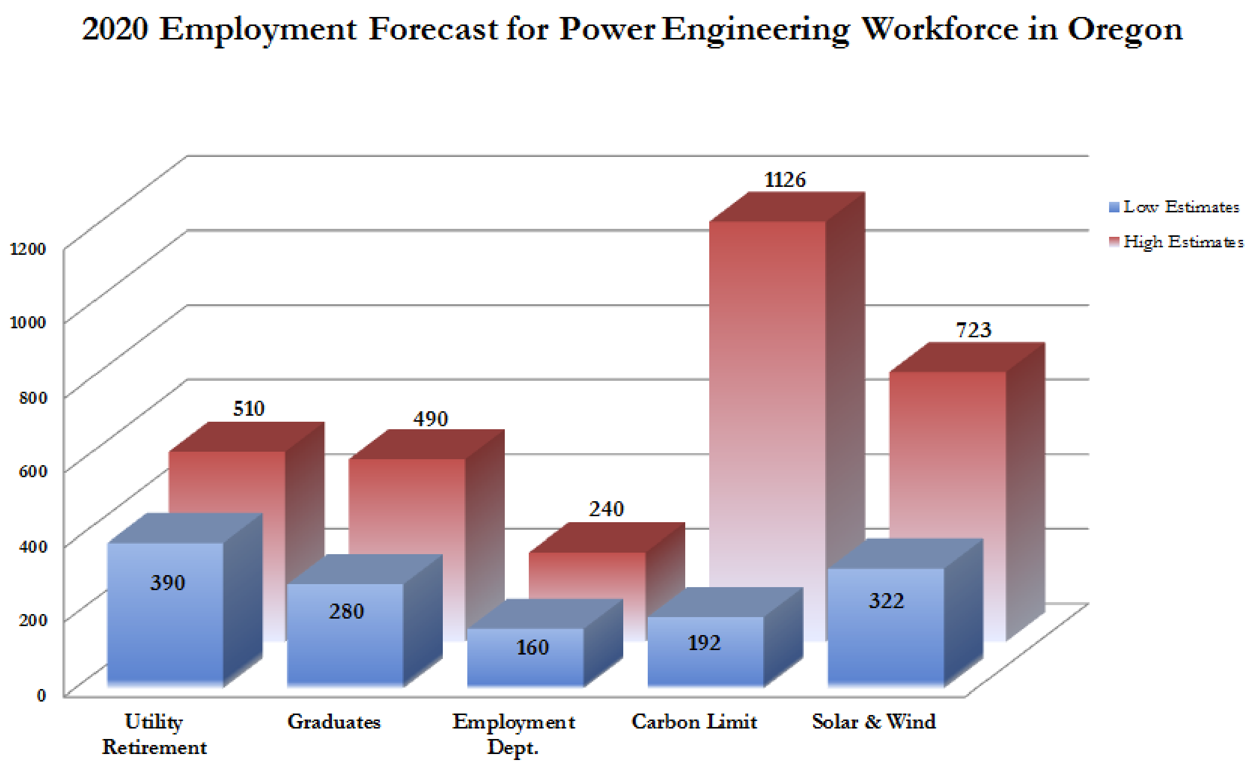


Figure 5: 2020 Low and high estimates for Oregon power engineering retirement, graduation, and job creation per forecast mechanism and industry. Employment deficit analysis shows that the 2020 power engineering workforce will fall short by a minimum of 60 or maximum of 1,596 employees. These metric extremes are formulated in cases including and excluding the carbon limit additions; as well as pairing maximum graduates with minimum industry needs, and vice-versa.

The outlook is dismal for Oregon's ability to triple predicted Power Engineering graduates by 2020. Assume the national STEM metrics of 14% entrance with a 50% attrition rate for Oregon.[22, 44] For a base reference, suppose Oregon were to attain the world average STEM target of 23%, and the weight of power-engineering-specific degree declarations from total STEM degrees to remain the same. It would require a corresponding 82% retention rate to change the total graduate prediction of 490 to the target 1,366 on the 2013-2020 range. However, if the ratio of power engineers to the total number of STEM students in Oregon were to increase, the retention rate could be reduced as a factor of this growth. These targets will be very difficult to achieve. This growth paradox carries with it two essential needs in education development. First, students who would not necessarily pursue engineering degrees must be targeted for recruitment into power engineering. Second, educational offerings must be formatted to, not only attract, but also retain students.

If nothing is done to reform power engineering education in Oregon, the State will experience a compounding workforce shortage. This would result in the loss of institutional knowledge, putting Oregon's power industry and high-tech manufacturing economy at a significant competitive disadvantage. Even if educational advancements were unable to produce the maximum predicted workforce demands of 2020, they would greatly enhance the quality of entry-level engineers and initiate the process of workforce supply parity. An increased supply of entry-level power engineers is meaningless without effective education and industry exposure at the university level. In other words, Oregon cannot maintain a competitive power industry and support a robust manufacturing economy without dedicated investments in power engineering education.

4 Filling the Workforce Gap: Oregon Power Engineering Education Project

It is abundantly clear that Oregon would benefit greatly from innovation in power engineering education. This comes at a time of projected power engineer shortages, along with dismal university retention rates and delayed professional development of entry-level power engineers. To achieve tangible results, this curriculum advancement must tie together power engineering programs across Oregon, provide experiential learning environments, and promote internship opportunities through innovative industry-university partnerships. We believe that this will eliminate educational and funding redundancies, as well as help professionalize power engineering graduates. We intend to promote investment in human capital by creating an industry-focused learning environment, the Oregon Power Engineering Education Project.

The collaborative nature of this project will foster a network of power engineers that is well-versed in communicating and working together. The internships, the project-centric course curriculum and the Portland Power Engineering Project Center, discussed in section 4.1.2, will help graduates develop interpersonal skills while simultaneously building lasting professional networks. In order to foster these professional skills and networks, we will not offer any fully-online courses. Online education detracts from developing these interpersonal skills and networks. Furthermore, active communication, collaboration and experiential learning are imperative for the long-term progression of our graduates' careers. In this era of Massive Open Online Courses (MOOCs) and online degree programs, we feel the best approach is to move in the opposite direction by focusing locally to develop professional relationships. We will, however, offer hybrid online/in-class courses, when appropriate, in order to accommodate alternative methods of course scheduling and modern modes of learning.

Our proposed education framework is a general archetype for engineering education that can be applied to any field where a localized concentration of industry and university resources exist. Our purpose is to instigate change in the overall educational paradigm beyond this initial application to power engineering. Oregon is ripe with other industries that could benefit from this approach, including the high tech cluster, the green building industry, software and agribusiness.

Our approach is based on diversifying possibilities for learning and reaching goals. Great minds are discovered by opening multiple venues for discovery, rather than forcing very diverse intellects to compete for a single learning stylistic goal. Modes of fostering this advancement are planned in accordance with evaluated essential learning needs: fundamental skills, innovative projects, industry experience and creative research.

4.1 Framework for the Future: Pillars

The following sections delineate a plan to combine power engineering programs offered at Oregon Institute of Technology, Portland State University and Oregon State University. This consolidation is accompanied by the addition of two shared project and innovation centers, located at Portland State University and Oregon State University. In combining efforts, the three institutions can each refine their unique strengths; thus creating a more comprehensive Oregon power engineering educational framework and garnering a stronger reputation. Our approach focuses on four main pillars applicable to all universities, with measurable outcomes.

4.1.1 Pillar 1: Internship Program

We intend to develop an internship program that will partner with industry to provide all power-related engineering students at OIT, PSU and OSU with an internship. Participation in an internship will be mandatory for all bachelor-level power engineering students. We plan to seek internship opportunities through partnerships with companies of the Portland Power Pool (Appendix A). Many of these companies have already expressed cooperative positions because they understand the risk involved with employee shortages and under skilled entry-level engineers. Three avenues for internships are available to students: PPP, MECOP, or independently arranged.

Participating companies will provide a crucial role in the students' education, helping to "professionalize" the students through work experience, a task that universities are not well suited to do. Students will begin internships during the Summer after their junior year, working full time during the Summer and then continue the internship at reduced hours during their senior year. Employers within the PPP will be subject to a dual intern clause, whereby they are asked to accept pairs of interns. This clause is set to for 1:1 exceptional and ordinary students, based on GPA. The purpose for a dual intern clause is the full realization of investing in people: C-level students can be made great through finding purpose and being professionalized early. Furthermore, internship programs must accept more students in order to produce heightened numbers of industry-ready power engineers.

The benefits of a focused and versatile internship program are apparent to all parties. Students whom would otherwise maintain low-wage and odd-hour jobs will be afforded higher pay and reasonable schedules during their schooling. This would likely carry a positive impact on educational achievement and retention rates. Universities will be relieved of the ongoing burden and shortcomings they face over professionalizing students. Companies can recruit from a known talent pool, and develop needed skills within their future staff. This is a particularly profound shift because many electrical engineering students that currently hold internships within the power industry are not power students and do not aim for employment in the power industry. Therefore, companies are spending wasted effort on educating staff that will not be retained after the internship ends. This gives companies less incentive to invest in the quality of the internship and ends up harming the progress of the student. The benefits of a focused and practical approach to internships are self-sustaining because all parties are incentivized to invest in the quality of their contribution.

4.1.2 Pillar 2: Portland Power Engineering Project Center & OSU Teaching Labs

We intend to develop two centers to promote power engineering education and projects: a 5000 square-foot project center located at PSU to serve PSU and OIT students, the Portland Power Engineering Project Center; and a 2500 square-foot teaching and research project laboratory at Oregon State University.

The Portland Power Engineering Project Center will serve as a dedicated space for capstone/senior and graduate student projects. It is meant to promote an entrepreneurial environment, as well as spur collaborative innovation. We intend it to host industry-sponsored projects, student-initiated projects as well as student-run start-up companies. This facility will be the hub tying universities and industry together by establishing inter-sector partnerships. The Portland location is essential for proximity to companies within the Portland Power Pool, which will be closely aligned with senior capstone projects. This location also allows ease in commuting for the majority of students in the Portland Metro area. Required funding for the Center will be minimized by the available space at PSU for a lower cost than other real estate. Many supplemental labs and project facilities at PSU will also be available to students, greatly expanding flexibility for project design and fabrication. These aligned PSU project assets are listed in Appendix C.

OSU will also expand operations to include an additional teaching and projects laboratory center. Much like the Portland Power Engineering Project Center, this facility will align with existing expertise and research facilities at OSU. Funding for this endeavor will enhance teaching labs at OSU and meet the needs of students living in Corvallis. It is imperative to maintain the new facility as a predominantly undergraduate creative research mechanism; like the Portland Power Engineering Project Center, it is meant to foster ingenuity in problem solving and forward thinking abilities.

The pedagogical purpose for these two facilities is to restructure the undergraduate engineering education experience. These centers are proposed under the documented needs for curriculum upgrades in STEM education.[21, 22, 11] Our intention is to expose students to open-ended engineering problems, foster teamwork and innovation; all to generate student excitement in power engineering. The facilities will host multiple higher education levels (undergraduate through PhD). Students are encouraged to take ownership over their education through opportunities afforded at these facilities. Experience- and research-oriented learning is proven to increase undergraduate retention levels in STEM.[21] As a curriculum upgrade development, these facilities can also be used for term-long projects, required in all upper-division power engineering courses.

An important note for both proposed facilities is the need for autonomy in operations. Revolution in research and education thrives on freedom of action. Success based on this philosophy can be seen through the astonishing accomplishments of *Lockheed Martin's* ®SkunkWorks program; where scientists and engineers, left to their own devices, produced several revolutionary and legendary aircraft designs.[58] If the Oregon power engineering innovation centers are to succeed, they must have independent governance/management/administration and autonomous control over the use of their funding.

4.1.3 Pillar 3: Engineering Pedagogy

As the consortium between OIT, OSU and PSU evolves, so will diversification of course offerings (see Appendix B). We intend to align, as much as possible, the course offerings of the two Portland-area schools, OIT and PSU. Initial focus will be given to 400- and 500-level courses, focusing on eliminating course redundancies and leveraging the wider array of faculty expertise. It is essential for each university to allow rapid development and approval of new courses that are created by consensus of the inter-university faculty representatives. This will likely require restructuring or fast-tracking of the course approval process, depending on the university. Efforts for course consolidation and diversification will leverage the fact that each institution already specializes in a particular domain of power, which can be given more focus. A brief listing by university follows:

- OIT - Renewable energy generation; Energy storage
- OSU - Power electronics, Smart grid; Electrical machines & drives, Excellence in funded research, particularly wave energy generation
- PSU - Power systems protection, operations & planning

With an eye toward promoting long-term investment in power engineering pedagogy, we intend to fund three graduate student positions, one at each university, that will promote innovative research on engineering pedagogy. The graduate students funded through these positions will receive multi-year funding to conduct studies on teaching methods, assessment, retention and other engineering education topics. We expect these students to have a significant role in the teaching laboratories and capstone projects. Results will be documented via journal publications, thesis and dissertations; and implemented where appropriate by the students as a research requisite. These positions will not only promote innovation within our power engineering programs, but also produce the future expert teaching and advising faculty which are currently in short supply.

4.1.4 Pillar 4: Collaborative Undergraduate Projects

Power-related capstone/senior projects for all bachelor-level power students will be required as a fundamental curriculum advancement, with the intent of promoting inter-institutional advising and project teams. We intend to create a funding mechanism for these power-related capstone/senior projects so as to provide the teams with some funding that they can apply to their projects.

Often, capstone projects originate as proposals from an industry partner, and senior projects are closely aligned with faculty research. We also intend to create a second funding structure, one that encourages independent and innovative student projects. We envision an Innovation Investment program with two phases of funding. The program will hand out 18 $1k Phase I grants and 6 $5k Phase II grants per year, with the Phase II grants given to a subset of the previous years' cohort of Phase I grantees. The purpose of this program is to provide students with a means by which they can pursue project ideas outside of the more structured capstone/senior project mechanisms, and to instill in students the idea that innovation is rewarded and has a meaningful place within the power industry.

We believe that the prospect of funding capstone/senior projects and the phased funding for innovative projects will attract a large and passionate student base to the power engineering programs at OIT, PSU and OSU.

4.1.5 Measured Outcomes

Pedagogical research students at each school will be responsible for yearly data collection and reporting of success and progression metrics. Pre-defined metrics for reporting are listed in Table 3.

Table 3: Success Metrics Categories and Reported Sums

Category	Reported Metrics
Intern Program	Employer reviews of interns
	Intern reports on internships
	Number of intern placements per year
Engineering Pedagogy	Enrollment numbers in collaborative 400/500 level courses
	Graduate student pedagogy
	Pedagogy-related papers
	Pedagogy-related presentations
	MS thesis and PhD dissertations
Collaborative Undergraduate Projects	Number of power-related projects per year
	Number of inter-institutional projects per year
	Amount of Phase I investment
	Amount of Phase II investment
	Progress of Phase I projects
	Progress of Phase II projects
Employment	Number of graduates finding employment within the Portland Power Pool
	Number of graduates finding employment within the national power industry
Retention	Enrollments in power-related engineering courses
	Comparison of enrollments in 1st power course to last power course (BS & MS)
	Number of BS and MS power graduates per year
	Ratio of power cohort sizes to overall ECE/REE student cohort sizes

4.2 Four-Party Plan: Strengths & Contributions

As mentioned, our educational needs evaluation has shown necessary access for each student to four main types of education: fundamental skills, innovative projects, industry experience and creative research. These foci encompass the broad spectrum of active and experiential learning, which foster student investment in subject matter. Each participating university has unique abilities in fulfilling these specific needs. Pre-existing strengths of the three universities are evaluated for leveraging and further development within a combined educational platform. The objective strengths and beneficial contributions per university are discussed here.

4.2.1 Oregon Institute of Technology

Strengths
Power Teaching Hub for Renewables and Energy Storage
Contributions

The Oregon Institute of Technology boasts the largest power-related engineering teaching faculty and the most diverse catalogue of course offerings relating to the field. This is invaluable to providing students with solid fundamental skills and knowledge base. OIT will serve as a strong teaching resource for the Power Engineering Project, where students can find coursework relating to renewables and energy storage, and attain the knowledge base necessary for developing projects and research. Because OIT has a special focus in renewable energy, they will also provide a venue for students to gain understanding of the requirements for integration of renewable and stochastic energy into the bulk electric power grid.

OIT will benefit from this partnership through attracting conventional power students, which would otherwise not attend a program specifically focused on renewables. They will also have the advantage of using state-of-the-art research and project facilities located at PSU and OSU, outfitting their students with a wider range of learning, development, and entrepreneurial opportunities.

4.2.2 Portland State University

Strengths
Project Advising and Industry Partnerships for Intern Program
Contributions

Portland State University will contribute to the education consortium by providing a gateway for professionalizing students. PSU carries the advantage of a location in the heart of downtown Portland; as well as many existing supplemental resources owned by the institution. The locational advantage puts students attending PSU in close proximity to internship opportunities with companies of the Portland Power Pool. This advantage is augmented through the PPP industry ties, already established at PSU. Advisers at PSU will be responsible for aiding internship coordination on the account of students from all three universities. Additionally, project advising and access to supplemental labs (Appendix C) will be provided by Portland Power Engineering Project Center employees, both faculty and GTAs.

In collaboration with outside universities, PSU can expand potential project content through gaining diversification in course and research offerings. Students with expanded skill sets, earned at OIT and OSU, will produce thoughtful and innovative work at the Portland Power Engineering Project Center. PSU will also benefit from gaining a reputation as a school for professionalization, attracting a focused and dedicated student base.

4.2.3 Oregon State University

Strengths

Research Excellence in Energy Systems, Smart Grid and Renewable Energy

Contributions

Oregon State University is the top-tier power engineering research institution in Oregon, particularly with high regard for the Wallace Energy Systems & Renewable Facility. Leveraging this research expertise though the Power Engineering Project would promote Oregon's reputation to one of international acclaim. Top students with research potential from OIT, PSU and OSU will be identified and directed to OSU for research-based graduate and undergraduate projects. OSU will gain additional advantage through expansion of its power-related undergraduate teaching labs. Collaboration with PSU and OIT could lead to expanded course options for OSU students. OSU will broaden its research base through fostering new creative research, and also allowing students the option to build on the work of former research guests to create evolving, multi-tiered projects with a wide range of contributors.

OSU students will participate in power-related internships, and will have the opportunity to collaborate with PSU and OIT students through capstone/senior projects and innovation projects. OSU faculty can focus more clearly on research, knowing structures are in place to help undergraduate students find internships, project funding and careers. OSU faculty can also leverage the diversity of power engineering faculty at OIT and PSU when seeking collaborators for research projects.

4.2.4 Portland Power Engineering Project Center

Objective
Center for Projects, Industry Collaboration and Student-Run Start-up Companies
Outcome

Though the Portland Power Engineering Project Center will be located on the PSU campus, it will contribute to the consortium through providing a location where students from the three universities can interact and collaborate on projects. This will foster relationships that will be carried into industry and create a networked power engineering community across Oregon. Students will be required to work closely with companies of the PPP, and encouraged to partner with each other in entrepreneurial ventures. The Center will exist as a means to foster innovative minds, as well as to professionalized students.

4.3 Implementation Strategy

Implementation of the four-party plan will begin with an initial collaborative meeting between OIT, PSU and OSU; to build a working model for consolidation efforts between geographically close universities. Shortly after, the institutions will work together to develop the internship program. This will be conducted through contracted partnerships with existing and new industry affiliates. The second phase of implementation will include creation of the Portland Power Engineering Project Center and teaching lab expansion at OSU. The primary phase focuses on foundational elements and establishment of best practices, while the second phase creates an atmosphere for innovative learning and fosters educational renaissance. Appendix D lists all goals, with accompanying descriptions, timeline, annual funding requirements, and matched funding sources and amounts.

4.3.1 Near-Term Requirements

Immediate needs for the year-one developments include university cooperation, outside funding of $598,070 and university/industry matched dollars in the amount of $428,800 (Appendix D). These funds will be spent on a pilot intern program, facility construction at PSU and OSU, faculty hires, and administrative support. Outside funding will be a product of donations and grants. Parallel to the funding effort will be a series of meetings between university faculty representatives and industry. These meetings will establish course offerings per institution; degree schedules, options and advising strategies; internship affiliates; and industry input on education needs.

4.3.2 Long-Term Planning & Goals

Annual operations past year-one will require $411,020 in outside funding and $1,383,000 in matched university/industry dollars (Appendix D). This will support interns, maintain labs, create three GTA allotments, fund student projects, and provide administrative staff. Success metrics will be reported by GTAs, beginning in year-two. Initial start-up grants are needed to provide three years of outside support; during which time the consortium will arrange firm annual funding for independent operations beginning in year-four.

4.3.3 Sustained Funding

Two main venues exist for sustained funding to promote the four educational pillars: continuous sustained funding, and involvement from private industry. A potential source for sustained funding is a public purpose charge, mandated by the PUC and set aside specifically for power engineering education. This investment is in the interest of the PUC due to the risk associated with relying on an undereducated and understaffed workforce to implement PUC objectives. Public purpose charges raise $170 million annually for conservation and Renewable Portfolio Standards. There is a palpable risk that the targets of the public purpose charges cannot be reached without an expanded number of power engineers. A small public purpose charge dedicated to educating regional talent would help ensure the implementation of PUC objectives.

Private industry funding could come in several forms, including in-kind donations, grants and gifts, or sponsored applied research. For instance, industry partners may be interested in sponsoring graduate students to study grid function, economics and workforce trends, which in turn could lead to further funding and/or grants based on the findings of such studies. Economic growth in Oregon will not happen without a steady supply of affordable, reliable power. Holding this as a top priority will attract outside funding from manufacturers looking for low operating costs.

Potential sources of funding include:

- Foundation grants and gifts
- Private Sector umbrella grants
- PUC Mandated and OBDD
- Applied research projects scholarships

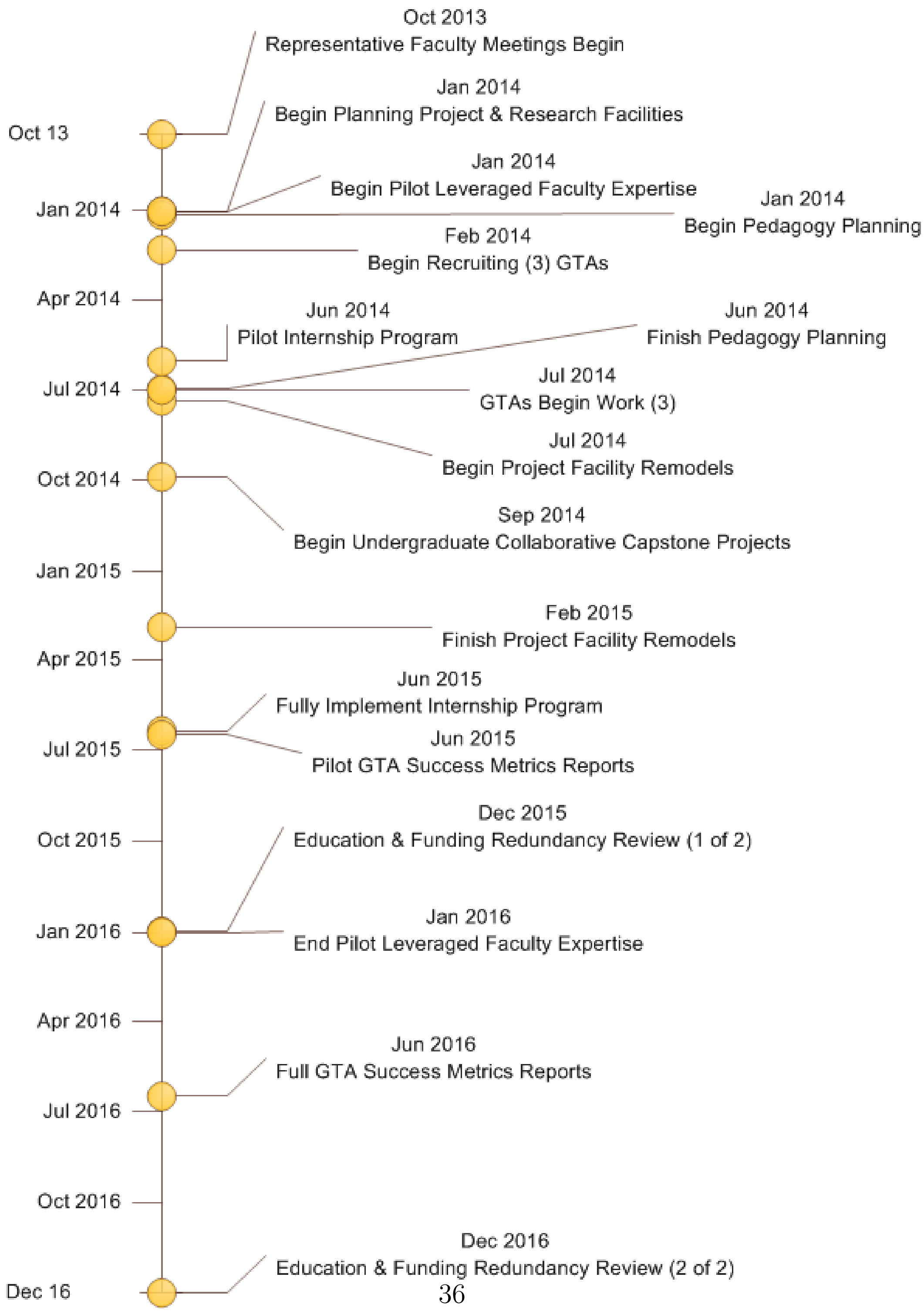
Regarding Applied Research, topics that may be of interest to industry partners may include:

- Energy conservation
- Distributed and renewables generation
- Utility workforce pipelines
- Energy efficiency
- Implementation of smart grid technologies
- Organizational development projects

4.3.4 Timeline for Implementation

Efforts for consortium alignment, curriculum development and facility construction will span the course of two years, beginning in Quarter 1 of 2014 (Appendix D). A planning reference timeline is shown below, Figure 6. This includes basic elements of building the consortium, and will be enhanced as further tasks are identified during planning phases of 2014.

Figure 6: Timeline for Implementation



5 Future Work Recommendations

The proposed Oregon power engineering education consortium can be realized through three initial action steps, which we detailed herein. The first two steps consist of coinciding efforts to define structures for 1) strategic sustained funding, and 2) independent governance. The first step will serve to allow long-term establishment and maintenance of the proposed consortium. The second step will assure effective and efficient spending targets and outcomes. We assert a third recommendation to ourselves, to seek initial grant funding to get this project started.

5.1 Develop Sources of Strategic Funding

We recommend OESTRA conduct research on two aspects of long-term strategic funding. First, a survey of current spending by power industry stake-holders on education and workforce development; and second, an identification of long-term funding sources and respective investment targets. Initial funding for the Oregon Power Engineering Project is not permanent; it is purposed as an establishment and proof of concept mechanism. Continued success of the education consortium will depend on procurements of sustained funding.

5.1.1 Sector Funding Allocation Study

The state of Oregon currently allocates several hundred million dollars annually to energy-related departments and programs. A detailed analysis of this funding should be undertaken to assess state expenditures on energy policy, conservation, renewable generation, etc. This information should reflect the purpose and targeted outcomes of state spending, and create a foundation for measured outcome analysis. Quantification of existing resources will strengthen the impact of current expenditures. This study should identify funding sources, funding amounts, goals and outcomes of recipient programs, program overlaps and redundancies. Data provided by the study will enable the reader to:

- Identify funding line item objectives

- Evaluate ability to measure outcomes (economic, social, environmental)
- Identify duplication of spending
- Contemplate strategies designed to increase spending impact
- Cross reference policies and spending with Oregon Energy Plan
- View similar investments by other public jurisdictions for collaborative purposes

5.1.2 Investment Targets by Entity & Method

Strategic development of long-term funding should begin with a full assessment of targeted goals per potential funding source. The consortium should create agreements with industry aimed at producing an engineering workforce with skills tuned for stake-holder needs. Industry should take part in identifying workforce needs and assist with funding the education effort. Ideally, a portion of the funding would be committed for 15 years or more in order to give the universities the ability to attract top academic talent and give investors assurance that measured outcomes will be achieved. Below is a list of potential funding sources and stakeholder constituencies.

- Organizations that set state and regional energy policy objectives, such as following:
  - PUC mandates
  - Oregon RPS goals
  - Northwest Power Planning and Conservation Council goals
  - Governors 10 Year Energy Plan
- Federal agencies including the US Department of Energy and BPA to address:
  - Workforce attrition
  - Smart Grid innovation

- Oregon Business Development Department/Oregon InC including:
  - Invest in talent associated with target clusters and business recruiting efforts
- Industry/private sector including:
  - Educating engineers in the area of energy conservation techniques in the manufacturing environment
  - Innovation among the thriving power engineering sector
- Private donations
  - Private foundations and individuals interested in supporting the combination of economic prosperity and sustainability

5.2 Governance

To meet the requirement for autonomous operations of the education consortium, we recommend exploring the creation of an entity for independent governance that would set goals and measure outcomes. This would involve establishment of a new "Oregon Energy Council" or like-entity charged with setting goals, distributing funding and establishing standards for accountability. Preliminary models could be drafted in conjunction with the Hatfield School of Government at PSU.

Important constituencies should include but not be limited to:

- Investor owned and public utilities
- Bonneville Power Administration (BPA)
- Oregon Public Utility Commission (PUC)
- Energy Trust of Oregon (ETO)
- Smart Grid Oregon (SGO)

- Oregon Business Development Department (OBDD)
- Oregon Innovation Council (OR Inc)
- Engineering & Technology Industry Council (ETIC)
- Industrial Customers of Northwest Utilities (ICNU)
- Manufacturing 21
- Companies of the Portland Power Pool (Appendix A)

Accountability could encompass ability to redirect/cancel every five years based on:

- Achievement of enrollment and graduation objectives
- Meeting of project milestones
- Change of direction for business reasons

5.3 Interim Planning & Steps Forward

The Oregon Engineering & Technology Industry Council (ETIC) recently revised its strategy for funding engineering education, creating a new "Renewable Fund" that relies on Industry-University teams to identify innovative engineering education projects and assess the success of those projects. We find it highly fortuitous that ETIC had the foresight to entreat an engineering education renaissance concurrently with OESTRAs funding of this study. Beyond the dual advantage of these closely aligned undertakings is a clear affirmation of purpose. In response to the ETIC challenge, and in collaboration with industry stakeholders, OESTRA, and other engineering programs in Oregon, we are proposing to significantly expand the number of engineering graduates as well as improve their education and relevancy to industry workforce needs, as outlined in section 4 of this report. We will apply for funding through ETIC in November of 2013 in order to initiate the development of our power engineering education vision. Appendix D outlines the project timeline, as well as a proposed budget specifying ETIC grant funding and industry/university matching funds.

6 Conclusion

Oregon's electric power industry currently faces a challenge and an opportunity, the outcomes of which both depend critically on the availability of engineering talent. First, the long-anticipated large-scale retirement of power engineers is now underway, resulting in significant turn-over and threatening the loss of critical institutional knowledge at BPA and the regional utilities. Second, a strong regional power engineering industry has been growing in significance; as the talent pools within utilities nationwide dry up due to retirements, many in-house utility engineering positions are being filled by out-of-house talent from consultancies and developers. Across the nation, investments in energy infrastructure, expansion of regulatory compliance, and mandates for smart grid development are all driving demand for engineering talent. Many of the companies that provide these power engineering services have chosen to locate in Portland, Oregon.

The 100-plus companies of the Portland Power Pool represent a significant strategic economic asset for the state of Oregon. The expertise within its consultancies, utilities, manufacturers and innovators provide world-class engineering products and services, not just to Oregon customers, but to clients worldwide. This formidable economic cluster depends on a vast institutional knowledge built up over generations by a well-educated engineering workforce. Our objective in formulating this plan for the Oregon Power Engineering Project is to provide a reliable workforce pipeline of well-prepared engineering graduates. The next generation of power engineers will not only maintain this institutional knowledge and ensure the success of the Portland Power Pool, they will also further expand the industry's significance to Oregon's economy.

The framework proposed in this document is a collaborative unification of the three power engineering programs in the state of Oregon; offered at Oregon Institute of Technology, Portland State University and Oregon State University. The Oregon Power Engineering Education Project will leverage existing university resources, eliminate redundant educational investments, and evolve the educational paradigm for power engineering education in Oregon. The proposed educational platform will incorporate innovative teaching methods and experiential learning; develop close collaboration between universities and industry; and employ measurable outcomes to justify investment. These efforts will provide a power engineering workforce pipeline that will benefit the graduates of the state's engineering schools, the companies of the Portland Power Pool and the overall economy of Oregon. Addressing the engineering education needs of the power industry is vital for meeting Oregon's 10-year energy goals, its ambitious RPS target, and the forward-thinking mandates of the Oregon PUC.

A Appendix: Companies of the Portland Power Pool

Engineering Consultancies

1. Black & Veatch (Lake Oswego, OR)
2. Brown & Kyser (Battleground, WA)
3. Clear Edge (Hillsboro, OR)
4. The CADMUS Group (Portland)
5. Cascade Energy (Portland)
6. CH2M Hill (Portland)
7. Christenson Electric (Portland)
8. David Evans & Associates (Portland)
9. Ecofys (Corvalis, OR)
10. Elcon (Beaverton, OR)
11. Evergreen Engineering (Hillsboro, OR)
12. FirstPoint (Portland)
13. GE Energy (Portland)
14. GL Garrad Hassan (Portland)
15. Glumac (Portland)
16. Harris Group (Portland)
17. HDR (Portland)
18. IEC Corp (Lake Oswego, OR)
19. Interface Engineering (Portland)
20. Inspec, Inc. (Portland)
21. Jacobs Engineering Group (Lake Oswego, OR)
22. Johnson Controls (Milwaukie, OR)
23. NAES (Hillsboro, OR)
24. Oregon Electric Group (Portland)
25. PAE Consulting Engineers (Portland)
26. PECI (Portland)
27. Pike Energy Solutions (Portland)
28. Portland Engineers (Portland)
29. POWER Engineers (Portland; Vancouver, WA)
30. Stantec (Beaverton, OR)
31. Taurus Power and Controls (Tualatin, OR)

Regional Utilities: Investor-Owned, Public, Municipal and Co-op

32. PacifiCorp (Portland, IOU)
33. Portland General Electric (Portland, IOU)
34. Eugene Water and Electric Board
35. Clark, Skamania, Cowlitz WA PUDs
36. Columbia River, Tillamook OR PUDs
37. Western Oregon, Hood River, Wasco regional OR electric cooperatives
38. Cascade Locks, Canby, McMinnville, Forrest Grove OR municipalities

High Tech

39. Air Advice (Portland)
40. BPL Global (Beaverton, OR)
41. DECK Monitoring (Portland)
42. Elster Solutions (Portland)

43. Energy Connect (Portland)
44. EnerSol (Portland)
45. ESA (Clackamas, OR)
46. EV4 Oregon (Portland)
47. EVRAS (Portland)
48. Leviton (Tualatin, OR)
49. Lucid Energy (Portland)
50. Mohr Solutions Power (Hillsboro, OR)
51. NorthWrite (Portland)
52. Obvius (Hillsboro, OR)
53. Peregrine Power (Wilsonville, OR)
54. PowerMand (Portland)
55. Powin Energy (Tualatin, OR)
56. Rinehart Motion Systems (Wilsonville, OR)

Power Equipment Manufacturers

57. Advanced Energy (Bend, OR)
58. Cooper Bussman (Tualatin, OR)
59. Eaton (Wilsonville, OR)
60. Okanite (Tigard, OR)
61. Revolt Technology (Portland)
62. Sanyo (Salem, OR)
63. Schneider Electric (Portland; Salem, OR)
64. Solar World (Hillsboro, OR)
65. United Street Car (Clackamas, OR)
66. Veris Industries (Portland)
67. Xzeres Wind (Wilsonville, OR)
68. Western Integrated Technologies (Portland)

Large Industrial Power Consumers

69. Intel (Hillsboro, OR)
70. Daimler Trucks (Portland)
71. Longview Fiber (Longview, WA)
72. Precision Castparts (Portland)
73. Port of Portland (Portland)

Federal & Non-profit Entities

74. Army Corp of Engineers, Portland District
75. BPA (Portland; Vancouver, WA)
76. Bonneville Environmental Foundation (Portland)
77. ColumbiaGrid (Portland)
78. EnergySec (Clackamas, OR)
79. Energy Trust of Oregon (Portland)
80. Northwest Power and Conservation Council (Portland)
81. Northwest Power Pool (Portland)
82. Pacific Northwest National Labs (Portland; Richland, WA)
83. Smart Grid Oregon (Portland)
84. Western Electric Coordinating Council (Vancouver, WA)

Developers & Operators

85. enXco (Portland)
86. Horizon Wind (Portland)
87. Iberdrola Renewables (Portland)
88. REpower (Portland)
89. RES Americas (Portland)
90. Suzlon Wind Energy (Portland)
91. Vestas Americas (Portland)

Solar Designers & Installers

92. Advanced Energy Systems (Eugene, OR)
93. Elemental Energy (Portland)
94. Imagine Energy (Portland)
95. Lite Solar (Clackamas, OR)
96. REC Solar (Portland)
97. Solar City (Portland)
98. Sunlight Solar Energy (Bend, OR)
99. SynchroSolar (Portland)

Others

100. Gore Electric (Portland)
101. McLaren Inc. (Tualatin, OR)
102. Underwriters Laboratories (Camas, WA)

B Appendix: Oregon University Consortium Power-Related Upper Division Courses

Oregon Institute of Technology

1	REE 331	Fuel Cells
2	REE 333	Batteries
3	REE 335	Hydrogen
4	REE 345	Wind Power
5	REE 347	Hydroelectric Power
6	REE 412	Photovoltaic Systems
7	REE 413	Electric Power Conversion Systems
8	REE 453/529	Power System Analysis
9	REE 454	Power System Protection & Control
10	REE 469	Grid Integration of Renewables
11	REE 515	Energy Engineering I
12	REE 516	Energy Engineering II
13	REE 517	Energy Engineering III
14	REE 527	Wind Power Generators
15	REE 545	Applied Photovoltaics

Oregon State University

1	ECE 4/531	Power Electronics
2	ECE 4/532	Dynamics of Electromechanical Energy Conversion
3	ECE 4/533	Power Systems Analysis
4	ECE 4/537	Smart Grids
5	ECE 4/538	Electric & Hybrid Vehicles
6	ECE 530	Contemporaty Energy Applications
7	ECE 534	Advanced Electrical Machines
8	ECE 535	Adjustable Speed Drives and Motion Control
9	ECE 536	Power Systems Protection

Portland State University

1	ECE 347	Power Systems I
2	ECE 348	Power Systems II
3	ECE 4/520	Analytical Methods for Power Systems
4	ECE 4/548	Power Systems Protection
5	ECE 4/549	Power System Design
6	ECE 510	Generations Systems Analysis & Design
7	ECE 510	Transmission Planning
8	ECE 510	Distribution Planning
9	ECE 541	Power Operations Fundamentals I
10	ECE 542	Power Operations Fundamentals II
11	ECE 547	Energy Economics
12	ECE 550	Power System Stability
13	ECE 580	Advanced Power System Protection

C Appendix: Supplemental Project Facility Assets Available at PSU

Facility Name	Available Equipment
Power Engineering Education Lab	(4) LabVolt power stations
	Three-phase power systems components
	Power supplies
	Prime movers
	Dynamometers
	Synchronizing modules
	Transformers
	Adjustable electrical loads
	Synchronous & asynchronous motors/generators
	Split-phase motors
	DC machines
	Protection lab
	SEL digital relays
	Synchrophasors (SEL- 311L, 351, 551)
	Adaptive multi-channel sources (SEL-AMS)
	Automation controllers (SEL- 2411, 3530)
	Various electromechanical relays
	Time overcurrent
	Directional overcurrent
	Auxiliary voltage & current
	Fuse & CT testing stations
	Tektronix oscilloscopes
	Industry-relevant software
	ETAP
	PowerWorld
	ATP
	ASPEN
PNNA Clean Room	Mask Aligner OAI Model 204, 500W DUV/NUV
	Wet Bench
	Spin Coater
	Fume Hood
	Profilometer Dektek 3030

Facility Name	**Available Equipment**
Mechanical Engineering Machine Shop	Conventional Lathes & Milling Machines 2 & 3 axis Milling Machines Brake & Shear (Sheet Metal capability) Welding (Mig, Tig & Acetylene torch) Plastic Injection Molding Precision Surface Grinding Rapid Prototyping Machine Laser Cutter CNC Programming (Master Cam X5)

Electronics Prototyping Lab	Full Spectrum 80w Laser Cutter
	Stratisys Mojo 3D printer (FDM)
	LPKF S63 Printed Circuit Board Router
	Soldering Equipment
	    Hakko Soldering stations: various tips, vaccum & hot air
	    Beijing Torch Co. T200N Desk Reflow Oven
	Misc Hand tools

Intel Lab	(43) 2.8GHz Dell Precision T1500 machines Windows 7 & 10 Linux operating platforms Programming & IC design tools open 7 days a week, 24 hours a day

Tektronix Lab	(30) fully-equipped test stations
	    4-channel oscilloscopes
	    DVMs
	    Programmable function generators
	    Spectrum analyzers
	    Programmable power supplies
	    Pentium 4 PCs

Capstone & Digital Design Lab	Standard measuring equipment Dedicated fabrication & test equipment Presentation/demonstration area Secure storage Digital signal processing equipment Soldering stations

Facility Name	**Available Equipment**

SRTC Outdoor Solar Testing	Living Laboratory
	  Green roof technology
	  PV at a 4.9 kW peak output
	  Monitoring equipment

PV Test Facility	Five different types of solar arrays
	  Varied panel & inverter technologies
	  5kW peak output

Center for Electron Microscopy & Nanofabrication	Surface Analysis
	  Quantachrome Nova 2200e Suface Analyser
	  XPS, UPS, AES
	TEM
	  FEI Tecnai F-20 TEM
	  JEOL 2000FX TEM
	SEM
	  FEI Sirion SEM
	  Zeiss Sigma VP FEG SEM
	FIB
	  FEI Strata 237 Dual Beam FIB
	Sample Preparation
	  Lesker Thin Film Deposition System
	  Cryo-Ultramicrotome
	  FEI MarkIV Vitrobot
	  Gatan PIPs Ion Miller
	  Other Specimen Preparation Facilities

Chemistry & Physics Supply	Glassware Chemicals Chemical testing & analysis tools
Atmospheric Chemistry Lab	Air quality testing tools Environmental quality analysis software

VLSI Lab	(24) Sun Microsystems Sun Ray 2 thin-client systems
	  Access UNIX on remote Sun servers
	  Industry-strength IC design tools
	    Mentor Graphics
	    Cadence
	    Synopsys

D Appendix: Timeline & Budget

Pillar	Description	Timeline
Comprehensive Intern Program	Mandatory internships for all power students Partner with companies of the Portland Power Pool All power students required to participate or find internship through MECOP or on their own	Pilot in Summer 2014 Fully implement Summer 2015
Power Engineering Project Center and OSU Power Teaching Lab	Power Engineering Project Center Located within PSU Engineering Building Close to the companies of the Portland Power Pool Close to the students in the Portland Metro area OSU Power Teaching Lab Located at the OSU Campus Align with the research facilities of OSU Enhance existing teaching lab strengths at OSU Meet needs of students living in Corvallis	Begin planning in Q1-14 Remodels Q3-14 through Q1-15
Promote Engineering Pedagogy	Course Alignments 400- and 500-level courses Principally focused on OIT-Wilsonville & PSU Expand course offerings to wider student body Leverage greater diversity of faculty expertise Avoid redundancies Promote Future Engineering Educators Fund grad students interested in engineering pedagogy Multi-year funding (NOT bridge funding) Research teaching methods, assessment, retention, etc.	Planning in Q1/Q2-14 Pilot AY 2014/15 Fully implement AY 2015/16 Hire 1st GTAs in Summer 2014
Collaborative Undergraduate Projects	Capstone/senior Projects Require power-related capstone projects for all BS power students Create a capstone/senior project investment program Promote inter-institutional advising and project teams Innovation Investment Create an Innovation Investment program Multi-phase investment process	Planning in Q2/Q3-14 Fully implement AY 2014/15

Pillar	Funding Yr 1	Yr n+1	
Comprehensive Intern Program	($268,800)		Match - Yr 1, Internship pay from companies, $20/hr, 840 hrs/yr, 16 students
		($1,008,000)	Match - Yr n+1, Internship pay from companies, $20/hr, 840 hrs/yr, 60 students
Power Engineering Project Center and OSU Power Teaching Lab	$32,500		Power Center Renovations, $6.5/$ft^2$, 5000 ft^2
	$16,250		OSU Teaching Lab Renovations, $6.5/$ft^2$, 2500 ft^2
	$288,000		Power Center lab bays, 24 bays (PCs, benches, test equip, etc.), $12k/bay
	$144,000		OSU Teaching Lab bays, 12 bays (PCs, benches, test equip, etc.), $12k/bay
		$18,000	Lab upkeep, $500/bay•year, 36 bays (PDX &
		($90,000)	Power Center rental value, $18/$ft^2$•year
		($45,000)	OSU Teaching Lab rental value, $18/$ft^2$•year
	($50,000)	($100,000)	In-kind equipment donations and discounts from industry
	($50,000)	($50,000)	Cash donations from industry
Promote Engineering Pedagogy	($60,000)	($90,000)	Match - Faculty release time, $10k/faculty•term, 3 terms/yr, 3 faculty
	$54,720	$54,720	Summer faculty support, 3 faculty, 1 mo ea, w/
	$36,000		GTA stipend. Summer, Yr 1, One GTA per institution, $12k/summer
		$90,000	GTA stipend. One GTA per institution, $30k/year
		$45,900	GTA tuition remission and OPE
Collaborative Undergraduate Projects		$32,000	Capstone grants, 16 capstone groups per year, $2000/group
		$18,000	Phase I innovation funds, 18 grants per year, $1000/grant
		$30,000	Phase II innovation grants, 6 grants per year, $5000/grant
		$16,000	Lab consumables, 20% of grant funds
		$106,400	Administrative Support, $70k salary, 52% OPE
	$26,600		Admin Support, Summer 2014
	$598,070	**$411,020**	**Grand Total, ETIC**
	($428,800)	**($1,383,000)**	**Grand Total, University & Industry Match**

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