EPRI

Historically Black Colleges and Universities (HBCUs) as a Model for Fostering Long-Term Career Success

GridEd
The Center for Grid Engineering Education

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EPRI PREPARED THIS REPORT

NOTE

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Acknowledgments

EPRI prepared this report

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Key contributors include faculty at the six GridEd affiliate HBCUs of focus in this report: Alabama A&M University (AAMU), North Carolina Agricultural and Technical State University (NCAT), Prairie View A&M University (PVAM), South Carolina State University (SCSU), Tennessee State University (TSU), and Tuskegee University (TU). Additionally, this work was made possible by the HBCU graduates that EPRI had the privilege to engage with to hear authentic experiences to provide context to how HBCUs support their alumni as a foundation for this work.

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Abstract

The utility sector is currently facing a workforce shortage, along with a growing demand for engineers equipped with the knowledge and skills necessary to guide our energy systems through the energy transition. Historically Black Colleges and Universities (HBCUs) are renowned for their engineering programs and their success in addressing underrepresentation in STEM fields. This report highlights the power and energy systems curricula and capabilities offered by HBCUs that participated in EPRI's GridEd program. HBCUs are well-positioned to cultivate the skills needed to design and operate systems with higher levels of distributed energy resources, which is essential for achieving decarbonization goals while ensuring affordability, reliability, and resilience. Further, HBCUs' organizational culture and approach to professional development could serve as a model for employers to enhance job satisfaction, retention, and equity among utility workers.

Keywords
Workforce development, training, workforce pipeline, power and energy education, community engagement, diversity, equity, & inclusivity (DEI)

Executive Summary

WHY THIS MATTERS

The utility sector is currently facing a workforce shortage, along with a growing demand for engineers equipped with the knowledge and skills necessary to guide our energy systems through the energy transition. Historically Black Colleges and Universities (HBCUs) are renowned for their engineering programs and their success in addressing underrepresentation in STEM fields.

This report highlights the power and energy systems curricula and capabilities offered by HBCUs that participated in EPRI's GridEd program from 2014 to 2024. HBCUs are well-positioned to cultivate the skills needed to design and operate systems with higher levels of distributed energy resources, which is essential for achieving decarbonization goals while ensuring affordability, reliability, and resilience. Further, HBCUs' organizational culture and approach to professional development could serve as a model for employers to enhance job satisfaction, retention, and equity among utility workers.

HOW TO APPLY RESULTS

This work highlights how utilities and energy employers can partner with Historically Black Colleges and Universities (HBCUs) to build a skilled and diverse energy workforce. By incorporating insights from HBCU curricula and the lived experiences of students, we can enhance long-term career pathways for college graduates entering the energy sector, especially for currently underrepresented groups.

Implementing strategic actions—such as setting recruiting quotas, improving access, fostering diversity, and enhancing job satisfaction—can create a workplace culture that promotes community and career fulfillment for all employees. This approach is essential for attracting and retaining talent while advancing equity in power and energy systems.

LEARNING AND ENGAGEMENT OPPORTUNITIES

- EPRI's DOE-funded GridEd program leverages industry research and university engagement to educate a future electric grid workforce of competent and well-informed engineers.
- EPRI's Training and Development offerings are designed using science of learning experience, informed by broad collaboration, and backed by EPRI's 50 years of RD&D.

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PROGRAM: 174 DER Integration

Introduction

Introduction

Why This Matters

Awareness is needed to recruit and retain the workforce required to decarbonize U.S. electric supply by 2035. There is an opportunity to build and expand the workforce pipeline connecting utilities to populations currently underrepresented in their workforce. This report proposes that Historically Black Colleges and Universities (HBCUs), a vital source of clean energy workforce supply, may be a model for reaching and supporting potential workforce entrants early and through the end of their careers.

A curriculum review of the universities like University Gaps Assessment in Digital Power Systems Education (EPRI, 2020) is included. Instead of "Digital Power" this report refers to "Power and Energy" Systems Education which are assumed to include significant digital technologies (e.g., information and communications technologies, inverter-connected generation) to enable electrification, high penetrations of distributed energy resources (DER).

All of this lends to the need for power and energy systems engineers that have the technical and critical thinking skills to not only manage these changes, but to move to a state where interoperation of DER within power supply and delivery are the norm.

IN THIS REPORT

EPRI'S UNIQUE ROLE

EPRI's Training and Development area works to deepen the knowledge and skills of today's energy workforce and the workforce behind the clean energy transition. Designed using EPRI's technical and science of learning experience, informed by knowledge sharing through collaboration, and backed by EPRI's 50 years of R&D. (EPRI, 2024c)

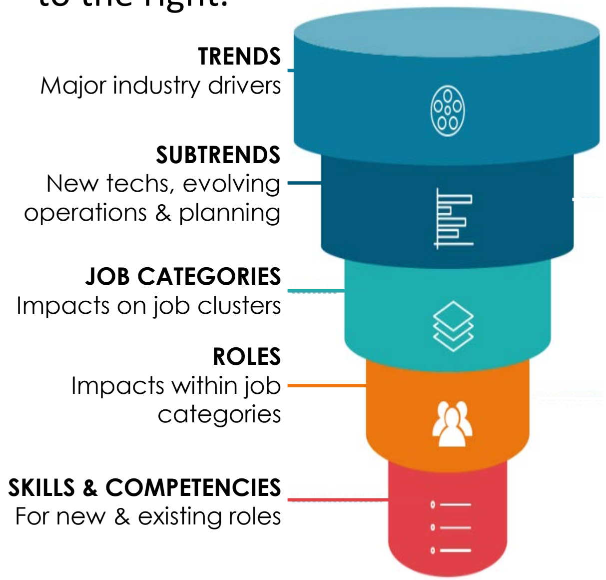
EPRI's DOE-funded GridEd program leverages industry research through utility and university engagement to empower new and continuing students to become competent and well-informed engineers. GridEd work is done in collaboration with several EPRI programs and initiatives.

- EPRI|U for T&D as the training developer and provider for T&D areas
- H2EDGE is a hydrogen workforce development initiative modeled after GridED; Details are on the website for Hydrogen @ EPRI activities. (EPRI, 2024a)
- EVs2Scale2030™ workforce development activities, including government-funded projects to enable widespread U.S. transport electrification by 2030. (EPRI, 2024b)

Developing the Next Generation of Power and Energy Systems Engineers

OBJECTIVES AND OUTCOMES OF DOE FUNDING 2014 – 2024

The U.S. DOE EERE funded GridEd to establish a university and utility consortium as a center for grid engineering workforce development. The work aimed to addressed the challenges of 1) retirements and competition for talent, 2) increasing electrification and DER integration, and 3) information and operational technology (IT/OT) convergence. The mission was to train the next generation of power and energy systems engineers to design and develop the needed grid architecture and infrastructure. The three streams of GridEd activities are described to the right.



GridEd Methodological Framework for Skills Transformation
Based on: (EPRI, 2022b)

Strategic GridEd activities assessed changing utility roles and required skills to manage increasing levels of DERs in power and energy systems. Training gaps were prioritized to be addressed at universities or in the current utility workforce. (EPRI, 2022b) The strategic work also looked at opportunities to fill gaps in and build the workforce pipeline to increase the volume of supply over time.

GridEd'S THREE ACTIVITY STREAMS

Strategic Workforce Development Activities:
Gaps assessments working with utility partners to update skills mappings and role descriptions of a handful of utility jobs related to integration of. Utility representatives included human resources (HR) and staff from technical areas.

University partners advised on current power and energy systems curriculum in ABET-accredited Electrical and Computer Engineering Degrees to inform where and how gaps may be filled at the university level. Utility HR and technical staff shared practices to strengthen the connection between university students and electric utilities as a potential employer.

University Curriculum Development: Development of curriculum and course materials working with partner universities based on gaps identified and prioritized in strategic activities. Outcomes of this activity include new and revised undergraduate and graduate courses, partner university co-development of two Digital Power Systems courses, and training of professors across the university network to deploy the courses.

Professional Training Short Courses: Developed and designed to fill current on-the-job gaps identified in strategic activities to keep utility workforce in pace with university curriculum supported by EPRI R&D. This includes live online courses, computer-based training courses, in-person, and classroom courses taught primarily by EPRI subject matter experts.

APPROACH

Overview of the Research Approach

To better understand HBCUs as part of the clean energy workforce pipeline, EPRI carried out both desk research (e.g., online curriculum, course catalogs) and in-person engagements with faculty, students, and utility representatives. The curriculum review surveyed topics that address information and communications technologies (ICT), cyber security, and data science skills relevant to operating and planning modern energy systems. (EPRI, 2020)

The six GridEd affiliate HBCUs in this assessment are: Alabama A&M University (AAMU), North Carolina Agricultural and Technical State University (NCAT), Prairie View A&M University (PVAM), South Carolina State University (SCSU), Tennessee State University (TSU), and Tuskegee University (TU).

Degrees and Departments Surveyed: Graduate-level and ABET-accredited bachelor Computer Science, and Electrical, Electronic, Computer, and Mechanical Engineering programs
Topics Surveyed: Power and energy systems, data sciences, information and ICT and cyber security, and DER integration

CONNECTING WITH THE HBCUs

- Regular meetings and workshops with the six HBCUs and local utilities.
- Campus visits to Alabama A&M, Tuskegee, and Tennessee State Universities for feedback on student success and industry integration.
- Facilitated open discussions with a handful of HBCU graduates outside of the GridEd network about their transition to corporate jobs.

CAMPUS VISITS

- Introductions from universities, utilities, and industry.
- Overview of the university's power and energy courses and programs.
- Discussions on skills needed by utility employers.
- Gathering student perspectives on career transitions.

HBCU GRADUATE LIVED EXPERIENCES

Participants included a range from early career recent graduates to those 30 years into their career.

- Insights into challenges faced in transitions and support needed.
- What could improve access of HBCU graduates to utility careers.
- What could employers learn from HBCUs about fostering long-term career paths for high-potential and high-performing individuals.

Curriculum Review Approach

Degree and Course Surveying

A summary of the scope of the curriculum and course survey is provided here. Note that this work focused on a small sample of HBCUs, the findings may not represent all HBCUs.

TOPICS COVERED AND DESCRIPTIONS

The competency frameworks from the 2020 *University Gaps Assessment in Digital Power Systems Education* were used in this report, based on subject matter expertise, feedback from electric utility hiring managers, and university network input. Currently addressed competencies and opportunities to augment curriculum were assessed across the following four areas. (EPRI, 2020)

1. Power and Energy Systems from traditional foundational power systems courses to broader energy systems studies
2. Data Analytics to deal with large amounts of digital equipment (e.g., sensors, controls) data and methods of drawing insights from large data sets (e.g., artificial intelligence)
3. ICT and Cyber Security to support wide-scale distributed digital sensing and controls of energized DER
4. DER Integration including Internet of Things (IoT) as a holistic framing, and courses that cover renewable generation (e.g., wind)

SUMMARY OF HBCU COURSE SURVEY

A total of 119 courses were reviewed at the six HBCUs across computer science, and electrical, computer, and mechanical engineering departments. The number of undergraduate (U) and graduate (G) level courses in these four areas is summarized in the following table for each of the HBCUs.

Each course surveyed addresses one or more of the four topical areas of interest, the number of topics covered by the total courses at each university is included as well. This provides an idea of how multi-faceted the included courses cover.

	Power & Energy		Data Sciences		ICT & Cyber		DER Integration		Total Courses	Topics Covered
	U	G	U	G	U	G	U	G		
AAMU	4	4	1	4	3	2	3	4	19	26
NCAT	7	1	5	4	1	2	2	0	20	22
PVAM	4	12	6	3	8	2	3	4	31	42
SCSU	6	1	1	1	2	0	4	0	12	15
TSU	5	4	5	3	1	3	2	1	19	24
TU	2	7	1	4	4	2	1	3	18	24

Lived Experiences

Beyond Desk Research & GridEd Engagement

In addition to campus visits and desk research on the subset of HBCUs affiliated with GridEd, EPRI looked to "lived experiences" of HBCU students. This allowed authors to hear authentic accounts of personal experiences in a more intimate setting to get thoughtful input on meaningful opportunities to better engage, recruit, and retain HBCU graduates. This input augmented and provided context for desk research to shape insights that better capture the student voice.

SUCCESSFUL TRANSITIONS FROM HBCU TO CORPORATE SETTINGS

Overall there is value in establishing a more robust relationship with HBCU professors as ongoing transitional mentors/sponsors of graduates. Considerations include:

- The unique ways HBCUs support students, including post-graduation
- Challenges entering the workforce as an underrepresented individual
- Connect with graduates working in HR on addressing recruiting gaps
- Opportunities to better connect the dots between industry and sources of diverse grads
- Universities as a pathway to local communities that may be underserved, underrepresented
- Recruiting with retention as a priority

DISCUSSION PROMPTS

- Why HBCUs? What drew you? What do they uniquely provide?
- What was your experience like as a student, in terms of connecting to the industry, charting a path to/through a career in energy (or wherever folks headed/landed)?
- Are there challenges for students that go through HBCUs in terms of access to jobs, career growth resources, or access to other resources in the industry?
- Any lived experiences you'd care to share, confidentially, to illustrate any of the points or provide more context?
- What could be done to improve HBCUs as a critical part of the diverse clean energy workforce pipeline?
- Any resources you're aware of, at the school, or as a graduate?
- Anything you do to "reach back" and support next generations?

Putting it All Together

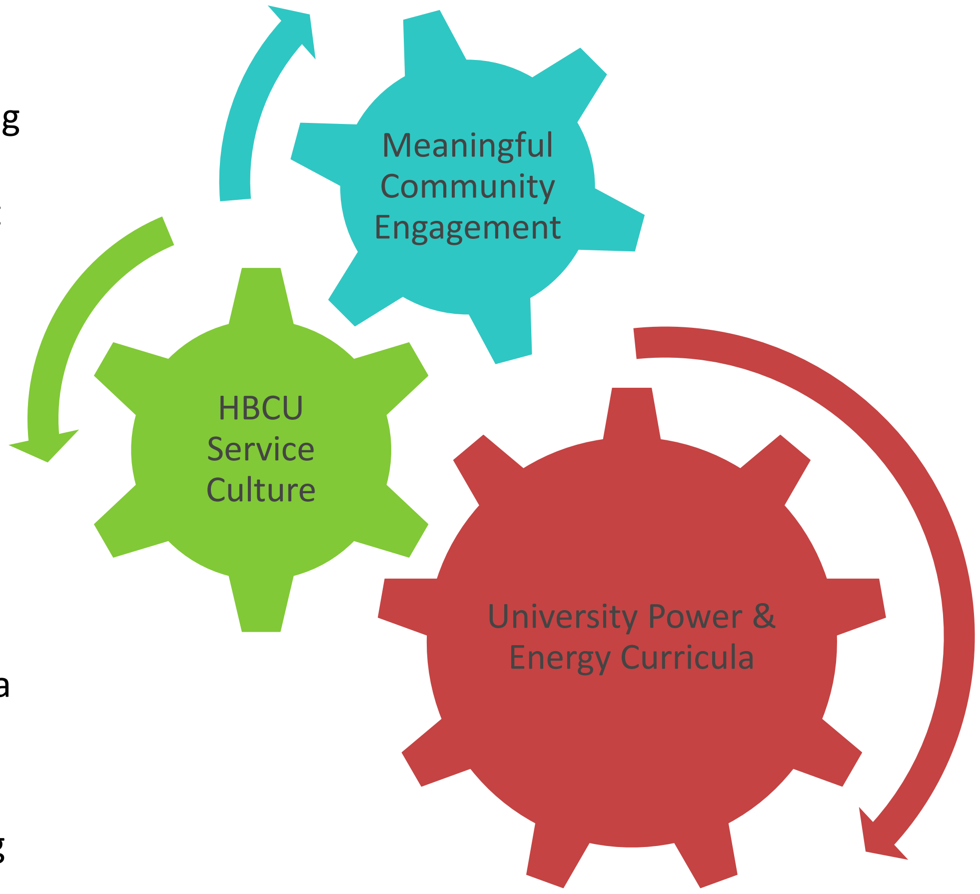
Opportunities to Improve Recruiting and Retention

Gaps and opportunities naturally exist in curricula, courses, engagement, and workplace culture. Meaningful impact comes in understanding how to holistically approach designing actions for improvements in meeting recruiting quotas, improving access and diversity, and retaining talent. In other words, cultivating a culture of belonging and mutual benefit for employees, utilities as employers, and the communities they support.

To this end, two complementary EPRI reports are used in synthesizing and summarizing the findings in this work.

- EPRI's *Reaching Disadvantaged Communities with Training* report provides framing for the information and insights gathered through this research and engagement, and framing for setting goals for workforce development activities. (See illustration below.) (EPRI, 2023a)
- EPRI's *Landscape Review of Community Engagement Leading Practices: Key Takeaways* provides the research foundation for meaningful community engagement practices as a necessary and integral component of action plans to broaden reach and as a result improve access and diversity. (EPRI, 2024e)

Addressing opportunities will involve meaningful community engagement, understanding student preparation coming out of university power and energy system programs, and adapting a culture of service similar to that described of HBCUs in carrying out this work.



HBCU Summaries

Alabama A&M University

Huntsville, Alabama

Alabama A&M (AAMU) is a public university, founded in 1875 by Dr. Daniel K. Wims in Huntsville, Alabama, and designated as a land grant university in 1890. The university has a student population of about 6000 students.

POWER AND ENERGY SYSTEMS COURSES AND CURRICULUM

Surveyed 19 courses across the Computer Science (CS), Electrical Engineering (EE), and Mechanical Engineering (ME) departments.

HIGHLIGHT OF STUDENT SUPPORT OPPORTUNITIES

- Apple New Silicon Initiative (NSI) at AAMU in the College of Engineering, Technology and Physical Sciences, established with an Apple Innovation Grant to support development of silicon and hardware technology curriculum in partnership with Apple
- NSF Research Experience for Undergraduates (REU)
- The Freshman Academy providing freshman and transfer students with support services for academic success in post-secondary studies

Subject	Undergrad	Graduate	Total
Power & Energy	4	4	**8**
Data Sciences	1	5	**6**
ICT & Cyber Security	3	2	**5**
DER Integration	3	4	**7**
Degree Level Total	**11**	**15**	**26**

NOTABLE ENERGY SYSTEMS OFFERINGS

EE 422/522 Smart Grid Cyber Security

Smart metering infrastructure, and smart metering communication/ sensor network security and privacy for utilities and subscribers.

EE 306 Survey of Energy Systems

Electric power source (fossil and renewable) fundamentals, including storage, transmission, and distribution of energy and impacts. Includes coverage of generation costs, distribution, etc., and technical characteristics of the technologies.

EE 426/526 Next Generation Mobile Networks

Architecture, application, and service aspects of 5G mobile networks, including coverage of Internet of Things (IoT) and smart grid networks concepts.

ME 541 Renewable Energy

Renewable energy physical principles, existing and emerging technologies, and interaction with the environment. Technologies covered include biofuel, hydroelectric, wind, geothermal sources, as and wave tidal generation.

North Carolina A&T University

Greensboro, North Carolina

North Carolina A&T University (NCAT) is a public, land grant institution, established in 1891 with John Oliver Crosby elected as the first president of the university. Located in Greensboro, North Carolina, NCAT has about 14,000 active students, and a alumni population of over 70,000.

POWER AND ENERGY SYSTEMS COURSES AND CURRICULUM

Surveyed 20 courses across the Advanced Engineering Technology (AET), Computer Science (COMP), Electrical and Computer Engineering (ECEN), and Mechanical Engineering (MEEN) departments.

HIGHLIGHT OF STUDENT SUPPORT OPPORTUNITIES

- STEPs4GROWTH (S4G), a North Carolina clean energy workforce development project funded by the U.S. Department of Commerce and led by NC A&T
- College of Engineering Ambassadors Program
- The NCAT & University of Minnesota (UMN) Research Partnership
- Aggies for Engineering and Community Enrichment (AECE)

Subject	Undergrad	Graduate	Total
Power & Energy	7	1	**8**
Data Sciences	5	4	**9**
ICT & Cyber Security	1	2	**3**
DER Integration	2	0	**2**
Degree Level Total	**15**	**7**	**22**

NOTABLE ENERGY SYSTEMS OFFERINGS

AET 293 Power Technology
Basic energy and power technology concepts including mechanical, hydraulics, pneumatics and electrical methods of transmitting and controlling power sources

AET 425 Wind and Wave Energy Technologies
The reliability, economics and environmental implications of wind and wave technologies, various aspects of turbine technologies and their development, and research on selected turbines, energy applications and operating principles

AET 427 Hybrid Energy System Technology
The underlying fundamentals of all major energy storage methods, and economics and sustainability when combining multiple power systems to meet load

ECEN 430 Power Systems, Energy Conversion and Electric Machinery
Study the electric power system as an interconnection of energy conversion and transmission devices, including electric machinery, energy and power, and the operations of such

Prairie View A&M University

Prairie View, Texas

Prairie View A&M University (PVAM) is the second-oldest public higher education institution in the state of Texas. Founded in 1879 as a public land-grant institution in Prairie View, Texas, PVAM has a population of about 9000 students.

POWER AND ENERGY SYSTEMS COURSES AND CURRICULUM

Surveyed 31 courses across the Civil Engineering (CVEG), Computer Science (COMP), Electrical Engineering (ELEG), General Engineering (GNEG), and Mechanical Engineering (MCEG) departments.

HIGHLIGHT OF STUDENT SUPPORT OPPORTUNITIES

- Students Participating in Transcendent (S.P.I.T.) Knowledge a premier student speakers' series
- Emerging Leaders Academy to provide students with the opportunity to develop and or increase their leadership knowledge and skills
- Engineering Career Development Office specializing in supporting engineering and computer science students to develop career skills

Subject	Undergrad	Graduate	Total
Power & Energy	4	12	**16**
Data Sciences	6	3	**9**
ICT & Cyber Security	8	2	**10**
DER Integration	3	4	**7**
Degree Level Total	**21**	**21**	**42**

NOTABLE ENERGY SYSTEMS OFFERINGS

COMP 3343 Internet of Things

Introduction and fundamentals of the Internet of Things(IoT), to build up solid technical knowledge and skills, focusing on creative thinking, with a hands-on project.

ELEG 4371 Foundation and Application of Internet of Things

A systematic introduction to IoT technology, including devices, system design, embedded sensing and processing, low-power IoT networking and communication, and computing and data analytics.

ELEG 4378 Mobile Edge Computing

An introduction to mobile edge computing covering architecture, from the edge devices via middle layers up to the cloud. It will consider the performance of mobile edge computing technologies, their storage, efficiency, etc., and security and privacy issues.

ELEG 6387 Smart Grid: Fundamentals of Design and Analysis

Evolution of the power grid including integration of variable energy resources, DER impacts, macro and micro grids, and grid communications standards.

MCEG 3312 Renewable Energy and Energy Sustainability

Energy conversion, utilization and storage technologies, such as wind, solar, biomass, fuel cells and hybrid systems, and the physical and technological principles, and economics and environmental impacts.

South Carolina State University
Orangeburg, South Carolina

South Carolina State University (SCSU) is a land-grant institution and South Carolina's only public HBCU, established in 1896 in Orangeburg, South Carolina. Currently nearly 3000 students enrolled with more than 30,000 active alumni.

POWER AND ENERGY SYSTEMS COURSES AND CURRICULUM
Surveyed 12 courses across the Mechanical Engineering Technology (MET), Electrical Engineering Technology (EET), Computer Science (CS), Transportation (TRP), Industrial Engineering (IE), and Cyber Security (CSY) departments.

HIGHLIGHT OF STUDENT SUPPORT OPPORTUNITIES

- Call Me MiSTER: To address a need for more Black males at the head of classrooms, opportunity to be role models for children of color
- 1890 Ag Innovation Scholars: For high-achieving students interested in working in South Carolina's biggest industry, agriculture

Subject	Undergrad	Graduate	Total
Power & Energy	6	1	**7**
Data Sciences	2	0	**2**
ICT & Cyber Security	2	0	**2**
DER Integration	4	0	**4**
Degree Level Total	**14**	**1**	**15**

NOTABLE ENERGY SYSTEMS OFFERINGS

COMP 3343 Internet of Things
Introduction and fundamentals of the Internet of Things(IoT), to build up solid technical knowledge and skills, focusing on creative thinking, with a hands-on project.

393 Solar Energy and Conservation
Study of solar energy systems, empahsizing heating and cooling of buildings. Methods of energy conservation, system design variations and relative advantages and practical limitations covered.

396 Energy Applications of Microcomputers
Two applications of microcomputers for energy conservation explored, an energy audit that uses field data to estimate building heat loss, and an example of load shedding implemented as a game to minimize inconvenience. from a structure. Students apply this to their own residence.

CSY 345 CPS and IOT Security

Overview of IoT and cyber-physical systems (CPS) and applications, architectures, standards, protocols, communications, technologies, and security. Enabling technologies such as cloud computing, edge computing, and data analytics are covered along with various platforms and tools for designing and building IoT applications.

Tennessee State University

Nashville, Tennessee

Tennessee State University is a public, land-grant institution in Nashville, Tennessee, founded in 1912. Total enrollment is in the range of about 7000 students, across two Nashville campuses, the 500-acre main campus set in a residential neighborhood along the Cumberland River, and the downtown Avon Williams campus near Nashville's business and government district.

POWER AND ENERGY SYSTEMS COURSES AND CURRICULUM

Surveyed 19 courses across the Electrical and Computer Engineering (EECE), Computer Science (COMP), Computer and Information Systems Engineering (CISE), and Engineering and Computational Sciences (ENCS) departments and graduate programs.

HIGHLIGHT OF STUDENT SUPPORT OPPORTUNITIES

- B.L.A.C.K., Inc., Brothers for Love, Achievement, Culture, & Knowledge to bring about positive change in participants' communities, change how young black males were viewed, and eliminate barriers that hold black men back in society.

Subject	Undergrad	Graduate	Total
Power & Energy	5	4	**9**
Data Sciences	5	3	**8**
ICT & Cyber Security	1	3	**4**
DER Integration	2	1	**3**
Degree Level Total	**13**	**11**	**24**

NOTABLE ENERGY SYSTEMS OFFERINGS

COMP 4760 Distributed Algorithm Design

Introduction to computing models and algorithms of distribution systems, exposing students to an array of big data analysis theories, techniques and practices. The project-based course provided hands-on distributed computing experience on distributed computing with different data types.

ENCS 6030 Modeling and Simulation of Cyber Physical Systems

Focus on cyber-physical systems consisting of devices communicating with one another and interacting with the physical world via sensors and actuators. Coverage of modeling, simulation, establishment of specifications, and conducting analysis. Also touches on some aspects of modeling and simulation of dynamics systems and hybrid systems.

ENCS 6530 Analysis of Modern Energy Conversion and Conservation Systems

Covers energy needs and sources relevant for smart power grid design and analysis. This includes fossil-fuel based energy, nuclear, renewable energy sources (e.g., hydrogen, solar, wind, geothermal, biomass, and ethanol), and a variety of energy conversion systems (e.g., photovoltaic power conversion, fuel cells, battery storage systems).

Tuskegee University

Tuskegee, Alabama

Tuskegee University was founded by Dr. Charlotte P. Morris in 1881, in Tuskegee, Alabama. Total enrollment in is the range of about 3,000 students, about 85% of which is undergraduate.

POWER AND ENERGY SYSTEMS COURSES AND CURRICULUM

Surveyed 18 courses across the Computer Engineering (COEG), Computer Science (CSCI), Electrical Engineering (EENG), Mechanical Engineering (MENG), and Information Systems and Computer Security (ISCS) departments.

HIGHLIGHT OF STUDENT SUPPORT OPPORTUNITIES

- Boyz II Gentlemen: For males, under the leadership of Mister Tuskegee University; Topics are related to chivalry, etiquette, male representation on an HBCU campus, team-building exercises, and skills
- Future STEM Professionals Club: Develops networking and professional skills, a STEM identify, career orientation, etc.

Subject	Undergrad	Graduate	Total
Power & Energy	2	7	**9**
Data Sciences	1	4	**5**
ICT & Cyber Security	4	2	**6**
DER Integration	1	3	**4**
Degree Level Total	**8**	**16**	**24**

NOTABLE ENERGY SYSTEMS OFFERINGS

EENG/MENG 542 Renewable Energy

Coverage of renewable energy resources and technologies such as solar, wind, biomass, geothermal, hydroelectric, and fuel cells, to enable participants to recognize, understand and evaluate the different renewable energy supply options. Energy storage technologies will also be covered (e.g., batteries, ultracapacitor, flywheel, along with interconnection issues with DER.

EENG 644 DIRECT. ENERGY CONVERSION II

Covers a variety of courses to address student's needs, which may include electrogasdynamic, magnetohydrodynamic, thermoelectric, thermoelectronic and thermionic converts, utilization of solar proton influx, or ground level and terrestrial energies.

ISCS 560 Internet of Things

Introduction to the IoT paradigm, and the required IoT architecture, networking, and cyber security. Threats and solutions to IoT challenges will be surveyed, and programming of IoT devices will be introduced.

Power and Energy Systems Engineering Curriculum Review

Summary of Curriculum Review

A total of 119 courses were reviewed at the six HBCUs across computer science, and electrical, computer, and mechanical engineering departments. Currently addressed competencies and opportunities to augment curriculum were addressed across the following four areas.

1. Power and Energy System from traditional foundational power systems courses to broader energy systems studies
2. Data Analytics to deal with large amounts of data created by digital power equipment (e.g., sensors, controls) and advanced methods of drawing insights from large data sets (e.g., artificial intelligence)
3. Information and Communications Technology (ICT) and Cyber Security to support wide-scale distributed digital sensing and controls
4. DER Integration ranging from energizing individual DER (e.g., PV, storage) in traditional systems to Internet of Things (IoT) as a more holistic framing, also captures courses that cover renewable generation (e.g., wind)

The number of undergraduate (U) and graduate (G) level courses in these four areas is summarized in the following table for each of the HBCUs.

	Power & Energy		Data Analytics		ICT & Cyber		DER Integration		Total Courses	Topics Covered
	U	G	U	G	U	G	U	G		
AAMU	4	4	1	4	3	2	3	4	19	26
NCAT	7	1	5	4	1	2	2	0	20	22
PVAM	4	12	6	3	8	2	3	4	31	42
SCSU	6	1	1	0	3	0	4	0	12	15
TSU	5	4	5	3	1	3	2	1	19	24
TU	2	7	1	4	4	2	1	3	18	24

COMPETENCY FRAMEWORKS

In the 2020 report, EPRI summarized the courses and curriculum surveyed across universities in terms of associated competencies. The HBCU research used the same approach to understand the ranges and coverage of course offerings.

This work covers a small number of universities, and the assessment is not meant to be representative of the curriculum and/or courses available across HBCUs. The work provides a starting point for further study and conversations on where there are opportunities for the GridEd project to do additional work.

Find qualified candidates with both data science skills and background knowledge in or the desire to learn modern power systems. The remainder of this chapter focuses on the competency frameworks for the areas of Data Analytics, ICT and Cyber Security, and DER Integration.

Surveyed courses in each area are categorized as either “bridging” courses that link the power system domain knowledge to the desired competencies, shown on the right for Data Analytics and ICT & Cyber Security. While the boxes on the left are courses that offer deeper coverage of the topic, typically in non-electrical engineering departments. For instance, courses in computer science or mechanical engineering departments. These courses may not include direct links to application in power and energy systems, but tend to provide better rounded coverage of a topic, which may then be tailored to apply to power and energy.

Data Analytics for Power and Energy Systems with Digital Technologies
Desired College Graduate Competencies

Competencies required for employees who will be working in data analytics within the utility industry and more generally the energy industry is outlined here. This applies to both a power and energy systems engineer who is moving into data science-focused role, and a data scientist who is focusing their work on power and energy engineering applications. This area covers data analysis of large datasets as well as the artificial intelligence knowledge and skills that allow assessment of large datasets to identify patterns, and technologies like machine learning and neural networks for advanced learning and controls in large complex systems.

DATA SCIENCES COMPETENCY FRAMEWORK

Design Analysis

- Identify data analytics needs for key applications in modern power and energy systems that employ digital sensing, communications, and control technologies
- Design data analysis plans appropriate for key analytical applications in the power and energy system domain
- Determine the best way to evaluate analytical results in the context of power and energy system planning and operations
- The ability to anticipate and/or decipher competing outcomes using data science vs. traditional power systems engineering

Conduct Analysis

- The ability to explore data appropriately, and from that clearly summarize results and document findings
- Build or apply appropriate algorithms within the power and energy engineering domain

Incorporate Analyses into Power System Planning and Operation

- Identify and integrate data analytics work into power system planning and operating processes where valuable (e.g., efficiency gain, improved precision or performance)
- Where not directly integrable, implement abilities to read and write data to/from native power system planning and operational systems
- Package data analytics work for visualization and reporting in utility operations

Data Analytics for Power and Energy Systems

HBCU Course Competency Framework

The following is a competency framework for someone who will be performing data analytics work in electric utilities. This applies to both a power engineer who is moving into data science area and a data analytics who is now performing analysis in the power engineering area. Artificial intelligence (AI) is a set of technologies that enable computers to perform a variety of advanced functions, including the ability to see, understand and translate spoken and written language, analyze data, make recommendations, and more. Internet of things (IoT) courses cover both data sciences as well as likely some AI as an enabling technology. Cyber-physical systems (CPS) also cut across data sciences with potential AI for support as well.

	Bridging Courses	Data Science		Artificial Intelligence
UNDERGRAD	Data Analytics in Python Engineering Applications of AI Foundation and Application of IoT Introduction to Artificial Neural Networks Mathematics for Data Science	Data Mining and Analytics	IoT: Systems and Applications CPS and IoT Security	Artificial Intelligence Genetic Algorithms Machine Learning Distributed Algorithm Design Mobile Edge Computing
GRADUATE	Introduction to Science Introduction to Data Analytics Introduction to AI Machine Learning (ML) for Engineering Applications	Big Data Analytics Management of Information Systems Data Analytics Techniques	Data Mining and ML Internet of Things (IoT)	Artificial Intelligence Genetic Algorithms Neural Networks Machine Learning Multi-agent Systems Modern/Advanced AI Generative AI & Foundations Models

ICT and Cyber Security for Power and Energy Systems with Digital Technologies
Desired College Graduate Competencies

Employees responsible for design, implementation of, and management of information and communications technologies (ICT) require unique competencies compared to a standard power systems engineer, including cyber security as a key consideration in ICT. These also apply to employees whose primary background is in IT/OT that transitions to working with power systems' applications of ICT and cyber security.

ICT AND CYBER-SECURITY COMPETENCY FRAMEWORK

Data Acquisition

- Understand power system data analytics needs, and be able to plan data analysis in the power systems domain
- Identify the best approach to evaluate data analytics results in the context of power systems, including the ability to anticipate and/or decipher competing outcomes using data science vs. traditional power systems engineering
- Familiarity with the operation and management of internet/proprietary networking in electricity markets and power system operations
- Communication protocols and standards for power grids, including those for system operation, control, substation and distribution automation, and Advanced Meeting Infrastructure (AMI)
- Ability to identify and apply advanced computing approaches in power systems settings, e.g., use of graphics processing unit (GPU) and other accelerators, cloud computing, edge computing

Cyber security and vulnerabilities

- Familiarity with cyber security concepts and technologies for power and energy systems
- Understand cyber security vulnerabilities, e.g., attacks and intrusions in power grid components and systems
- Understanding of Critical Infrastructure Protection (CIP) standards and their application

Power System Asset Cyber Security

- Cyber security for connected inverters, Supervisory Control and Data Acquisition (SCADA) networks, renewables, AMI, distribution automation, substation automation, and microgrids
- Understand interdependencies of cyber and power systems, and cyber-physical system security of an integrated cyber-power system

ICT and Cyber Security for Power and Energy Systems with Digital Technologies

HBCU Course Competency Framework

Traditional power systems programs provide a strong background in the physical power systems, as deployment of new ICT technologies cyber security becomes an increasing challenge in the power industry. The following is a competency framework for someone who will be performing data analytics work in electric utilities. Courses that aim to bridge the gap between physical systems and digital systems regarding ICT/cyber security are shown in the box on the left.

	Bridging Courses	Cyber Physical	Cyber Security	Comp. Networking
UNDERGRAD				Next Gen. Mobile Networks
				IoT: Systems & Applications
	Smart Grid Cyber Security		Principles of Information Security	Distributed Algorithm Design
	Fundamentals of Cyber Security Eng.		Introduction to Cybersecurity	Fund. of Info. Assurance
	Internet Security for Electrical Engineers		Introduction to Info. Security	Internet of Things (IoT)
	Foundation and Application of IoT	CPS and IoT Security	Computer and Network Security	Mobile Edge Computing
	Cybersecurity and Public Policy	Cyber Physical Systems	Advanced Fund. of Cybersecurity	
GRADUATE	Cybersecurity Fundamentals and Principles	Principles of CPS	Introduction to Cybersecurity	Internet of Things (IoT)
	Smart Grid: Fund. of Design & Analysis	CPS Modeling & Sim.	Information, Privacy & Security	Mgmt of Info. Systems
				Network Security

DER Integration for Power and Energy Systems with Digital Technologies
Desired College Graduate Competencies

The nation's power grid faces major ongoing challenges through the rapid integration of large penetrations of distributed energy supply resources, that may be connected through inverters, have variable energy output, and may be operated by customers. The variability and uncertainty of these resources pose challenges for traditional power system resource planning, economics, and reliable operation. Digital technologies may be used to manage the fast-changing phenomenon that the modern grid is subjected to by allowing for faster control response to maintain grid stability. There is an increasing for students to have background in assessing, planning, and operating systems with high levels of interconnection of these new technologies at both the distribution and bulk system levels.

DER INTEGRATION COMPETENCY FRAMEWORK

Alternative Energy Resources

- Energy conversion principles, and alternative energy resources and power conversion technology (e.g., thermal solar generation, wind)
- Modeling and analysis of power systems with energy supply that has variable output, is inverter-connected, and with that more complex physical dynamics and economics
- Modeling and analysis of interconnected DER at the grid edge, including flexible loads
- Impacts assessment of higher penetrations of inverter-connected energy supply (e.g., power quality, voltage stability, protection issues)

Power Electronics Interface with Grid integration of DERs

- Power electronics-based controls in inverter technologies (e.g., grid-forming, grid-following, synthetic inertia)
- Modeling and simulation tools for microgrids with DERs
- Familiarity with DER interconnection standards, and the ability to follow the evolution of these at the distribution and bulk system levels

Active Power Distribution Systems with Digital Technologies to Efficiently Manage Grid Resources

- Simulation tools and modeling for devices and management systems that provide decentralized active control at the distribution level, (e.g., advanced distribution management systems, distributed energy resources management systems, microgrid energy management systems)
- Familiarity with the concepts of flexible and transactive demand, (e.g., real-time pricing, home area networks, smart loads and appliances), including electricity market mechanisms for customers operating DERs in a distribution system (e.g., transactive energy, DER-provided ancillary services)

DER Integration for Power and Energy Systems with Digital Technologies

HBCU Course Competency Framework

DER integration competencies are framed slightly differently that the data analytics, and ICT and cyber security areas are. The courses surveyed are mapped into three categories, courses that deal with energy supply technologies and systems, courses that deal with grid integration of DERs, and courses that introduce active distribution systems concepts. The three areas are closely related and somewhat interconnected.

	Energy Resources & Systems	Grid Integration of DERs	Active Distribution Systems
UNDERGRAD	Energy Production Systems Design of Renewable Energy Systems for Remote Community Wind and Wave Energy Technologies Hybrid Energy System Technology Solar Energy & Conservation Renewable Energy & Energy Sustainability	Power Systems II IoT: Systems and Applications CPS and IoT Security	Next Generation Mobile Networks IoT: Systems and Applications Distributed Algorithm Design Energy Applications of Microcomputers
GRADUATE	Renewable Energy Sources Solar Thermal Engineering Direct. Energy Conversion II Energy & Environmental Sustainability Analysis of Modern Energy Conversion & Conservation Systems	Internet of Things (IoT) Power Electronics in Power System Smart Grid: Fundamentals of Design and Analysis	Internet of Things (IoT) Power Electronics in Power System Smart Grid: Fundamentals of Design and Analysis

EPRI

Competency Gaps

High-level gaps in university curriculum, based on the 2020 EPRI study and the survey of 6 HBCUs carried out here, are noted below for the data analytics, ICT and cyber security, and DER integration.

There is an opportunity to step back from where typically start at systems dominated by rotating mass, where different types of dynamics can be studied independently. For instance, when studying rotational dynamics and frequency swings in a network as the load on rotating-mass-based generation fluctuates, could assume that voltage dynamics are much faster and essentially can be treated in de-coupled manner. Assume that the voltage remains constant. However, with increasing integration of DER that are inverter-connected and distributed across levels of the power system, traditional approaches to power systems studies leave gaps, or simply need to evolve. Right now, interconnection systems studies as a practice for graduating electrical engineers is rapidly evolving, with a need for university curriculum to evolve with it.

DATA ANALYTICS

- Lack of course offerings specific to power and energy systems use cases, or that integrate with traditional power system analysis courses.

ICT AND CYBER SECURITY

- Introduction to modeling of information and communications systems, cyber-physical systems, and the security of cyber-physical systems.
- An understanding of cyber system models and their integration with, or co-simulation of such with the large number of existing and future power system software tools to better understand the dynamics of integrated systems.
- Principles of integration of technologies that are new in power systems and their potential security impacts, e.g., AI, decentralized operation and control, 5G, internet of things (IoT), data centers, cloud computing, edge computing.

DER INTEGRATION

- There is growth in IoT-focused courses (e.g., IoT techs, smart grid, mobile networks) leaning towards architecture, and cyber and physical systems, however very little on demand-side resources and systems (e.g., flexible loads, vehicle-to-grid) as part of the DER influx.
- Opportunities to study the economics and potential market mechanisms for transacting energy at the grid edge, i.e., how energy storage and flexible loads can be used to mitigate intermittency impacts of renewable generation.

HBCUs as a Model for Supporting Long-Term Career Success

Lived Perspectives on Transitioning from an HBCU to Industry

The authors worked with HBCU graduates that went into corporate settings to get lived perspectives, focusing on opportunities for employers to better support new graduates. These insights may be similar to others' from underrepresented populations, graduates of smaller universities, etc. The progression of a student entering college to the point of retention in a job/industry or career are illustrated below as framing.

WHAT WE HEARD ABOUT THE HBCU EXPERIENCE

What is unique about HBCUs?

They tend to have a community feel, with a sense of comfort, security, and trust, described as feeling like "home." For people of color, you are the majority, you "see yourself" everywhere, and with that a feeling of shared background and experiences.

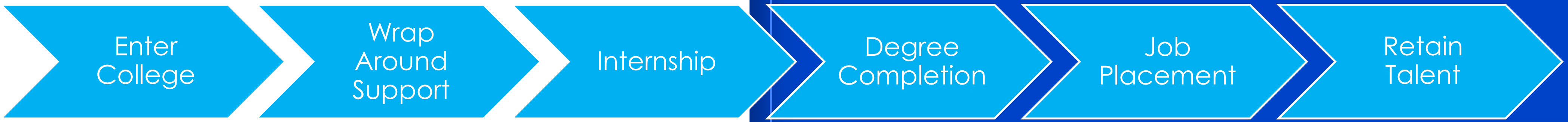
There is an expectation of black excellence and graduates as representatives of the HBCU name and program. Tokenism mentalities are not tolerated. In some cases, HBCUs outperforms non-HBCU counterparts.

What was your experience like as a student?

Mentoring from professors was pro forma, to encourage and empower high-potential individuals that attend HBCUs, and continues beyond graduation. Graduates hear from their former professors throughout their career, the support doesn't stop at graduation.

WHAT WE HEARD ABOUT TRANSITIONING TO INDUSTRY

- Corporate settings, particularly larger companies, can differ significantly in terms of the culture of community and service to one another found on HBCU campuses.
- From an HR representative perspective, the need to access diverse populations (i.e., challenges connecting with underrepresented populations) comes down to looking in new/different places and providing a positive experience for new graduates.
- There is an opportunity to be targeted about reaching specific populations and adjusting how employers are canvassing potential workforce supply.
- Having a workplace culture that provides a sense of community for potentially anyone, not just those who already work there, is key. Having a culture that "feels like family" to incumbent employees may not translate to employees that don't feel like a part of that family.
- There is an opportunity to tailor onboarding activities to cultivate a positive cultural transition for any new graduate coming into a company for the first time. Some diversity may be apparent, but when you're working to draw significant numbers there may be more to creating a culture that provides a sense of belonging for myriad diverse populations.



Putting it All Together

Opportunities to Improve Recruiting and Retention

The chevron illustration of a worker's journey below provides framing for setting goals for workforce development activities. (EPRI, 2023a) Opportunities for employers include:

- Reach future graduates and workforce before they enter college, with early awareness of clean energy transitions and what that means for them, their community, and society.
- Improve engagement by being present as an industry and future "home" for graduates early on in academic careers, e.g., sixth through twelfth grades.
- Connect with college students as a part of the wrap around support built into college student services through career centers, mentoring programs, speaking opportunities, etc. to encourage consideration of energy careers.
- Improve coverage at career fairs and as a presence hiring new graduates. Whenever possible, make sure the presence at these events is diverse and relatable in terms of cultural speak and authenticity. Outreach it may not be exhaustive, but it can be targeted.
- Consider where workforce naturally draws from (i.e., where is the pump already "primed"), and where to begin building presence in new communities to fill gaps in diversity and/or access to.

MEANINGFUL ENGAGEMENT

EPRI's Landscape Review of Community Engagement Leading Practices: Key Takeaways provides the research foundation for meaningful community engagement practices as a necessary and integral component of action plans to broaden reach and as a result improve access and diversity. (EPRI, 2024e) Key insights relevant to improving support and long-term success of utility workforce follow.

Outcome-Driven Engagement

Connecting with communities to raise awareness of energy transitions and the potential community benefits should start with engagement methods should **consider the wants and needs of communities** along with the drivers (e.g., budget, timeline) desired outcomes.

Key Attributes of Meaningful Engagement

- Structured as ***collaborative*** engagement with two-way feedback between the employer and the potential future workforce
- With a focus on ***equity*** in determining where to grow awareness and workforce in terms of potential value and benefits
- Identify communities based on ***inclusivity***, targeting historically disadvantaged, underserved, or underrepresented populations
- Empower the public by ensuring broad awareness of what clean energy transitions mean to them, how they can have a voice, and inviting them to be a part of the necessary workforce.

Key Takeaways and Opportunities

Key Takeaways and Opportunities

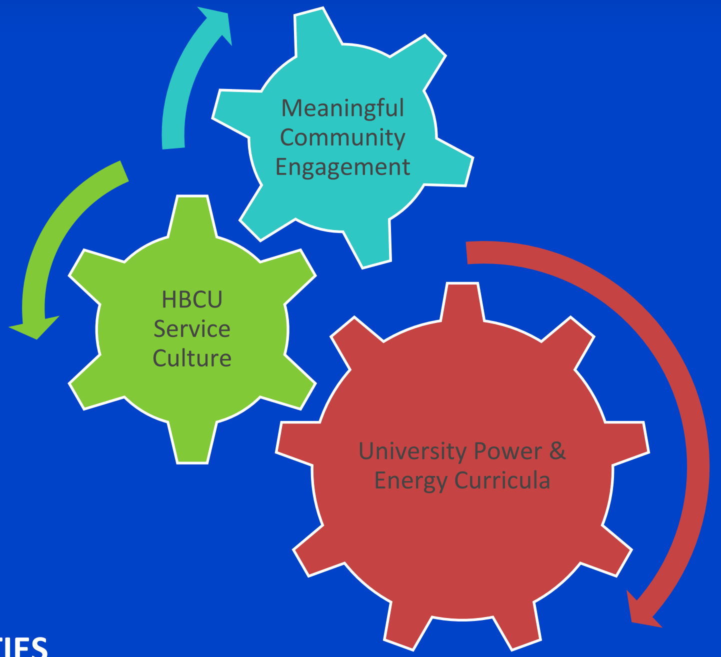
There is an opportunity for the next evolution of EPRI's GridEd consortium to have more structured HBCU engagement and increase their potential to contribute to the clean energy workforce, both in terms of high-value student experiences and volume of graduates entering the industry.

There are opportunities for employer presence in underrepresented areas via community outreach starting in preschool through college, creating a supportive pathway for students into successful careers.

- **Entering College**: Engaging students early about clean energy careers.
- **Internship**: Providing practical experiences during studies.
- **Degree Completion**: Supporting students through graduation.
- **Job Placement**: Helping graduates find jobs in the industry.
- **Retaining Talent**: Ensuring ongoing support and career development after hiring.

Employer considerations may include: Where best to reach students early? How to prepare and empower students in underrepresented populations for successful transitions into corporate settings? How to prepare your company and culture to provide a culture where diversity is embraced, and anyone may find a sense of belonging?

While training is not a focus in this work, the theme of putting people first is central when considering how to design learning. The reader is referred to EPRI's *Modernizing Energy Workforce Training: An Introduction to Active, Learner-Centric Learning Environments* for additional information and resources on learner-centric training. (EPRI, 2024d)



OPPORTUNITIES

- Consider the entire worker journey, which starts very early in life, positioning the opportunity for a life-long, high-quality career to make positive impact in your community and globally
- More holistic approach to how students are brought into power and energy systems curriculum and programs in engineering degrees to broaden career opportunities (e.g., strategy or innovation roles)
- Establish a more robust relationship with HBCU professors as ongoing transitional mentors/sponsors after placement within utilities.
- Leverage HBCU graduates in your company in recruitment activities (e.g., on-campus career fairs, alumni events, sorority/fraternity activities)
- Similar or in addition to a relocation package, compile a package (i.e., reference materials) to support integration into the local community, e.g., cultural events, churches, LGBTQIA+ organizations

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