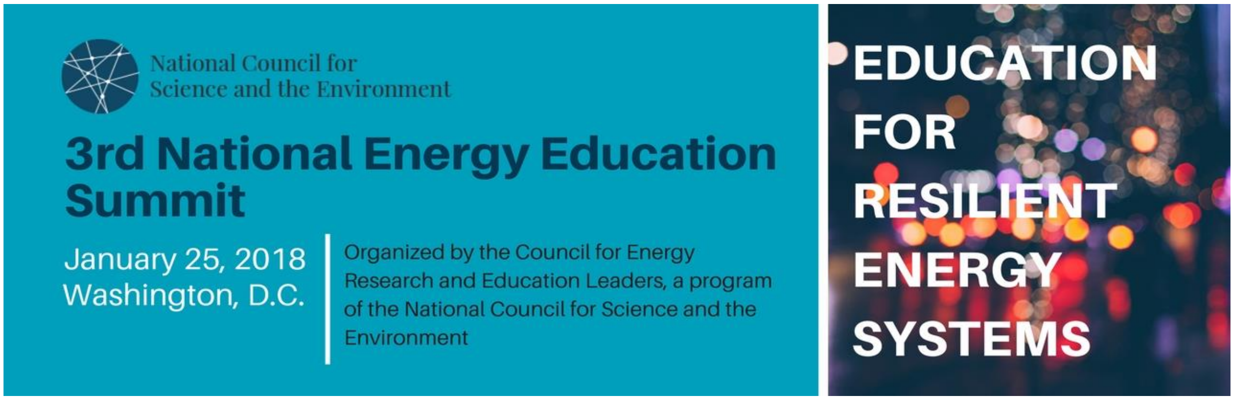

Report from the 3rd National Energy Education Summit:

Education for Resilient Energy Systems

January 25, 2018

Hyatt Regency Crystal City

Near Washington, D.C.

www.EnergyEducationSummit.org

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January 25, 2018

Dear Colleague:

Welcome to the 3rd National Energy Education Summit! Our theme this year is “Education for Resilient Energy Systems”. Building on the resilience focus at the National Council on Science and the Environment (NCSE)’s National Conference and Global Forum earlier this week, today we will be taking a deep dive into what resilience means for energy systems, and how we can educate the next generation of energy professionals to achieve energy security, reliability, and sustainability.

The past year has made the importance of resilient energy systems more visible than ever. From the hundreds of thousands of citizens still without reliable power in Puerto Rico and the Virgin Islands, to Florida, Texas, Maine, California and New York, we have seen massive power outages associated with intense hurricanes, extreme heat, and bitter cold and ice. The realities of climate change, coupled with disruptive transformations in energy supply, distribution, storage and interconnectivity, have challenged everyone from federal regulators to corporate leaders to reevaluate the paradigms of the past. How can we as educators accelerate the acquisition of the skills and expertise so our students can find and implement meaningful and lasting solutions to these challenges… across this nation and around the world? Today we have assembled leading experts to engage that conversation, to share our insights, and to learn together.

If your institution is not already a member of NCSE, I also want to take this opportunity to encourage you to join. In addition to complementary and/or discounted registrations at NCSE events like this, you will also benefit from our programs supporting energy and environmental research, education, and policy. For nearly three decades NCSE had provided the benchmarks and best practices that interdisciplinary programs need for success and created the networks and mentoring programs that help everyone from high school students to senior administrators become effective leaders for change.

We look forward to working with you today and in the future, advancing the frontiers of Education for Resilient Energy Systems!

Tom Richard, Ph.D.
President, NCSE Council of Energy Research and Education Leaders
Professor and Director, Institutes of Energy and the Environment, Penn State University

The National Council for Science and the Environment

The National Council for Science and the Environment (NCSE) is a not-for-profit organization that works to improve the scientific basis for environmental decisionmaking.

NCSE specializes in programs that foster collaboration between the diverse institutions and individuals creating and using environmental and sustainability knowledge; including research, education, environmental, and business organizations, as well as all levels of government. NCSE works collectively with its community to strengthen the role and use of science and higher education in policy.

NCSE brings together individuals, institutions, and communities to advance environmental and sustainability science and education, working across three strategic areas:

- Research and Education
- Leadership and Community
- Policy and Decisionmaking

For more information, go to www.ncseglobal.org

The Council of Energy Research and Education Leaders

The Council of Energy Research and Education Leaders (CEREL) is a multi-disciplinary membership program of NCSE made up of leaders of academic energy research and education centers, institutes, and programs. It provides the means for leaders in energy research, education, and communication to collaboratively use knowledge about energy to improve education, decision-making, and, more generally, the well-being of society.

The main areas of activity for CEREL are:

Education – developing an interdisciplinary field of energy education and sharing approaches to preparing the future workforce;

Research – advocating for support of university-based energy research as well as generally advancing, informing, and elevating the national debate about energy;

Collaboration – helping energy leaders achieve success through engagement, education, outreach and communication.

Summit Agenda

8:45 AM **Morning Plenary - Introductions and Framing of the Summit**

9:15 AM **Plenary Discussion: The Future of Energy**

10:15 AM **Plenary Discussion: Education for Resilient Energy Systems: Preparing the Workforce for Today and Tomorrow**

11:15 AM **Break**

11:30 AM **Table Top Discussions: An Opportunity for Individual and Small Group Conversations with Speakers**

12:30 PM **Networking Lunch and Poster Session**

2:00 PM **Session 2: Symposia and Skill-Building Workshops**
Concurrent Sessions

- Session 2.1 - Energy and Choices
- Session 2.2. Exploring the Power Grid: Developing Materials for K-12 Students (workshop)
- Session 2.3 - Energy Degree Programs, Minors and Concentrations
- Session 2.4 - Connections between Energy Education and Energy Practices on Campus and in Local Communities
- Session 2.5 - Introductory Energy Education: Energy 101 and General Education

3:45 PM **Session 3: Topics in Energy Education**
Concurrent Sessions

- Session 3.1 - World Energy Simulation - Facilitator Training
- Session 3.2 - Defining Resilience and Sustainability in an Energy Context
- Session 3.3 - K-12 Energy Education
- Session 3.4 - Diversity: Advancing Diversity in the Sustainable Energy Field

5:15 PM **Adjourn**

Morning Plenary: Introductions and Framing of the Summit

Hundreds of new energy education courses, certificates and degrees have been developed over the last 10 years. It is the focus of this Summit to extract lessons learned, challenges to be addressed and new tools for solutions. Because many educators are isolated from each other, the Summit is an opportunity to share practices and build community.

Tom Richard, President, Council of Energy Research and Education Leaders; Director, Institute for Energy and Environment, Penn State University.

Plenary Discussion: The Future of Energy: Projections and Perspectives on Energy Supply and Demand, Implications for Education and the Workforce

April M. Salas, Executive Director, Revers Center for Energy, Tuck School of Business, Dartmouth College (moderator)

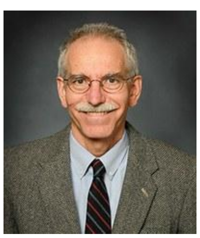
Sam Baldwin, Ph.D., Chief Scientist, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy.

John E. Monken, Senior Director, System Resiliency and Strategic Coordination in the ITS Division of PJM Interconnection.

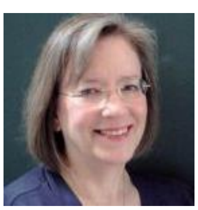
Janet Peace, Senior Vice President, Policy and Business Strategy, Center for Climate and Energy Solutions.

Plenary Discussion: Education for Resilient Energy Systems: Preparing the Workforce for Today and Tomorrow

A discussion involving employers from different industry types and sectors and analysts. What are employers looking for with respect to skill sets and abilities? How do interdisciplinary skills connect with technical skills? What innovative approaches are universities and colleges using to educate their students? How can academia and business work together to advance diversity and inclusiveness?



Tom Richard, Director, Institute for Energy and Environment, Penn State University (moderator)



Ann Randazzo, Executive Director, Center for Energy Workforce Development - a non-profit consortium of electric natural gas and nuclear utilities and their associations.

Scott Sklar, President, The Stella Group and Adjunct Professor, The George Washington University and Leader of GWU's Environment and Energy Management Institute.

Table Top Discussions: An Opportunity for Individual and Small Group Conversations with Speakers

Discussants:

- **Sam Baldwin**, Ph.D., Chief Scientist, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy
- **John E. Monken**, Senior Director, System Resiliency and Strategic Coordination in the ITS Division of PJM Interconnection
- **Janet Peace,** Senior Vice President, Policy and Business Strategy, Center for Climate and Energy Solutions
- **April M. Salas**, Executive Director, Revers Center for Energy, Tuck School of Business, Dartmouth College
- **Scott Sklar**, President, The Stella Group.
- **Ann Randazzo**, Executive Director, Center for Energy Workforce Development.
- **Sudeep Vyapari,** Executive Vice-President, Association of Controls Professionals
- **Brian Lovell,** Association of Controls Professionals

Networking Lunch and Poster Session – Regency Ballroom

Featured Posters:

- Energy Outreach: K through Gray, **Larissa Johnson**, Montgomery County, Maryland Department of Environmental Protection.

The Montgomery County Maryland Department of Environmental Protection is committed to engaging 100,000 residents with energy education programming over the next 5 years. To achieve this goal, the Residential Energy Program has developed a series of workshops targeted to specific age groups that teach similar energy concepts. We have developed energy education and outreach programs for elementary age students, adults and families, and our senior population, all while staying on message. Each workshop is interactive and engaging, and empowers participants to learn through technology, literacy and the arts.

The three main programs we created are:

Energy Express: The target audience for this program is elementary-aged students. In summer 2017, the County partnered with the public libraries to support their Summer Reading Program theme, “Build a Better World.” As a direct result, we provided more than fifteen workshops where kids (and their guardians) learned about different energy sources and how their choices impact the environment. They also had the opportunity to build either a solar-powered car or a wind turbine that powered a mini light bulb. The workshop combines arts and crafts, with engineering and technology. We inspired the kids to start thinking of themselves as scientists and engineers who could “build a better world” and save energy.

Energy Exploration: Energy Exploration is an interactive experience for all ages. Participants, often families, play with arcade-like games to discover how to save energy and money in their homes. The “games” include Whac-a-Pollutant and Energy Racers, and they provide interactive and fun learning experiences for participants. Energy Exploration events are open-houses, where families explore the games at their own leisure, often while attending other non-environmental facilities or events. For example, over the past year, we partnered with libraries to host Energy Exploration events, and focused on literacy to encourage families to read more about energy topics together.

Energy Essentials: By 2020, in Montgomery County, 20% of our residents will be over the age of 65 years old and most will be on fixed incomes. It is vital that County energy programs connect with this population and provide the tools and resources to help them reduce their energy bills. Our Energy Essentials programs are tailored to give Seniors a fun way to think about their energy choices. These workshops incorporate hands-on reusable art projects and conversations about energy conservation, efficiency and renewable energy. The participants leave with their own handmade wind chime or solar sun catcher.

- Energy Education that Makes K-12 Energy Wise, **Vicki Foust**, Ph.D., MBA, North Carolina A&T.

Education of our youngest generation about energy and sustainability is more important than ever. We need as many people focused on energy efficiency, energy sustainability, and carbon reduction as possible if we are to meet the reduction goals set at The Paris Accords, and provide a sustainable energy future. This session will introduce a successful approach to a university energy education outreach program targeting the local K-12 school district.

The Center for Energy Research and Technology (CERT) at North Carolina Agricultural and Technical State University (NCATSU) has a mission to educate K-12 students within surrounding counties about energy. CERT has five programs that support its mission: Energy Day, Energy Educator Workshop, CERT Energy Education Series, School Energy Wise Clubs, and support for student NEED (National Energy Education Development) Project Competition.

Energy Day is an annual event attended by approximately 2,000 students from our local school districts. Students engage with over sixty age-appropriate energy exhibits that are facilitated by STEM professors, graduate students, and energy industry-sector professionals. Energy Educator Workshop is a two-day summer event for K-12 educators to learn more about energy and how to engage students with energy concepts in the curriculum through the use of CERT’s Energy Education Modules. The workshop also provides instruction and support for Energy Wise and National Energy Education Development Project (NEED) competition. Along with energy education, workshop attendees also receive continuing education credit.

CERT’s Energy Education Series provide teachers with a plug-and play interactive lesson which teaches specific energy concepts in a fun and engaging way. Teachers check a “kit” out from CERT, and then use resources available on CERT’s website to lead them through the activity. The entire module includes a video which leads the class through the activity, teacher instructions for setting up the activity, student activity sheets, a quiz question bank, and components for eight classroom stations. These modules allow teachers to provide an engaging activity to teach crucial energy concepts with very little planning or effort. Energy Wise is a county wide K-12 energy efficiency initiative to achieve energy reduction and teach students energy efficiency. NEED's mission is to "promote an energy conscious and educated society" with its targeted K-12 energy education curriculum.

K-12 energy education results include: Energy Educator Workshop completion by almost half of the school system's science teachers; yearly growth of Energy Day attendance; and yearly growth of Energy WISE and NEED participation. These programs have resulted in a significant reduction in energy usage for the school system. To build upon CERT's energy education mission success, and to scale up the program, CERT has new K-12 energy education opportunities in development in collaboration with the school system science curriculum team. CERT's K-12 energy education program has the goal of inspiring sustainability centers at other institutions to provide educational outreach in their local communities. Activities include Energy Day demonstrations, the Energy Educator Workshop agenda, Energy Wise and NEED program activities, and CERT's Energy Education Series.

- Advancing Interdisciplinary Systems Learning through an Undergraduate Energy Science and Policy Course, **Gina L. Keel**, Ph.D., SUNY Oneonta

Students from undergraduate majors including physics, political science, and environmental sustainability develop an understanding of energy issues from diverse disciplinary perspectives and collaborate on problem solving, with a focus on policies for sustainable use and production. Physics concepts of work, energy and power are connected to real-world energy production and distribution initiatives. Social science dimensions include examination of institutions, actors, and decision processes in energy policy and the politics surrounding energy production and consumption, including economic and social trade-offs along policy options. Energy system development and innovations are critically examined, with particular attention to the New York State REV initiative promoting distributed energy resources, integration of renewables into grids, and enhanced reliability and resiliency. Students tackle energy policy questions by integrating physics with analysis of social, economic, and environmental systems, thereby strengthening student's numeracy and analytical skills and fostering civic engagement.

- National Science Foundation INCLUDES program at Delaware State University: Establishing a Baccalaureate Program on Renewable Energy Engineering, **Aristides Marcano**, Ph.D., Research Professor, Department of Physics and Engineering, Delaware State University

Renewable energy is the new America's enterprise of the 21st century. The effort requires the education of a new kind of engineers and scientists with deep knowledge of the latest advances in the generation of green energy with a high commitment for the preservation of the environment in a more sustainable world. The educational offer on Renewable Energy is limited in the country. At Delaware State University in Dover, Delaware, we are making our contribution to reduce this gap. We are building a new baccalaureate program in Renewable Energy Engineering taking advantage of the new National Science Foundation INCLUDES program. This program promotes the creation of networks around one common idea. In our case, the idea is the education of new generation of scientists and engineers in the area of new green energy technologies and their applications. Our goal is to involve a significant representation of underprivileged, underserved, and underrepresented in STEM minority students in the effort. The character of our university as a historically black college with more than 125 years of service to the nation will provide an excellent background for the success of the initiative. The program is expected to be approved by the University by the end of 2018.

- *Helping students build robust conceptual models of energy storage and transfer*, **Colleen Megowan-Romanowicz,** Ph.D., Senior Fellow, American Modeling Teachers Association

Modeling Instruction helps students develop and use coherent conceptual models of energy storage and transfer across science disciplines. Collaborative problem solving and sense-making, powerful representational tools, and a learning environment that emphasizes evidence-based scientific reasoning combine to equip students with effective tools for identifying and analyzing energy transfer and storage in any context. Teachers beginning in middle school and continuing through high school physics, chemistry, biology, earth and space sciences employ the same interactive engagement methods and use the same representational strategies and linguistic practices and choices, enabling students to transfer what they know to novel contexts by recognizing evidence energy storage and transfer. The Modeling Instruction approach to energy includes multiple disciplines, energy is used as a crosscutting concept through every science course that provides pre-post concept inventory gains for students and teachers who learn to use conceptual models as tools for thinking and problem solving.

SESSION 2: Symposia and Skill-Building Workshops
Concurrent Sessions

2.1 Energy and Choices

- Organized by **John H. Perkins**, Ph.D., The Evergreen State College
- Choices at an Institutional Level, **Cathy Middlecamp**, Ph.D., University of Wisconsin - Madison (moderator)
- Choices and Nuclear Technologies, **Sharlissa Moore**, Ph.D., Michigan State University
- Choices at the Policy Level**, Adam L. Reed**, Esq. University of Colorado – Boulder

This session explored energy education in terms of choices in different contexts and about different issues.

First, we looked at the institutional scale of a university and learn how an instructor can utilize a campus as a “living laboratory” in which to teach energy and related issues of sustainability. Institutions that purchase energy on a larger scale may have faced even more complicated choices, and if so they probably employed engineers to identify the best options. A college campus is likely to have a wealth of projects, master plans, and data sets that underlie choices made at the institutional level. Important as these choices are, however, individuals, institutions, and industries making them probably had one or a few criteria guiding their actions, and the decision-makers operated in a specific policy context that originated at the governmental level.

Second, we looked at choices made around contentious technologies, specifically new designs of nuclear power plants. Students may be unaware of the multiple, complex factors and values that affect the design of the technology. Each choice made results in trade-offs; for example, Taebi & Kloosterman argue that molten salt reactors are designed with the goal of sustainability and cannot result in a meltdown, but the trade-off is that radioactive molten salt could be released into the environment. Multiple stakeholders are involved in these choices, including the engineers designing the technology, new start-up companies funded by wealthy individuals such as Bill Gates, government R&D programs and nuclear waste policies, and citizen groups and environmental nonprofit organizations. It is important for stakeholders to communicate across disciplinary divides and worldviews to make choices about contentious technologies.

Third, students in energy courses are often exposed to techno-economic measures of energy systems performance such as LCOE or carbon intensity, but rarely have the opportunity to grasp the broader context of energy as part of the fundamental scaffolding for civilization, culture, values, and personal and group identity. Likewise, while many students are fascinated with the concept of broad energy system transition, few courses offer an in-depth understanding of major historical energy transitions and their political, social, and economic contours. The benefits of such study to students are not merely academic; by learning about the history of energy transition and the ways in which our values inform our framing of desirable means and policy outcomes, students become more critical and insightful about potential technologies, strategies, policies, and goals that are regularly proffered as "silver-bullet" solutions to energy and climate challenges, and develop more nuanced and complex worldviews regarding the challenge of energy transition.

Finally, we examined the choices that only governments can make: whether to favor any specific primary energy source and, if so, by what policies and to satisfy which criteria and its associated standards. Governments have the capacity to make choices favoring or disfavoring specific primary energy sources through formulation and enforcement of policies. Some governments may elect to set no priorities and leave choices entirely to market conditions, but others may set priorities to, for example, protect a specific industry, mitigate an environmental problem, or maximize energy independence.

A way of summarizing these differences is to say that choices and scale matter. Individuals, institutions, industries, and governments make choices at different scales and with different responsibilities. Students and citizens need to learn about choices and decision-making in these different contexts. They also need to learn about the criteria and standards that have historically guided choices and decisions, and they must learn about the analytic techniques and new criteria and standards that may be needed in the future.

2.2 Exploring the Power Grid: Developing Materials for K-12 Students

- **Michael Arquin**, KidWind Project, Principle, REcharge Labs

Over the last 15 years we have been focused on helping teachers and students explore and understand energy concepts in general with particular interest in wind and solar. Through this work it became clear to our team that students have a very limited understanding of where their electricity comes from and what the power grid is and how it functions. As we searched for materials, curricula and programming that would support a better understanding of the power grid we came up short and we started to develop our own materials that meet our stringent educational standards.

While utilities have done a great job educating customers about electrical safety, we find little evidence that they are interested in helping educators understand the system. At this moment there is a fantastic opportunity to develop high quality materials around this complex system that can provide students a robust learning experience and help the public understand the challenges that the power grid faces at this critical juncture with the rise of distributed generation, climate change and carbon taxes.

REcharge Labs has developed a prototype platform to help students explore the power grid. We have initiated significant partnerships with the GRIDED, the TCPIG program at University of Illinois, Bonneville Environmental Foundation and other organizations as we refine physical representations, develop activities, training and programming.
https://vimeo.com/232705330

We have some ambitious goals for the Power Grid Kit and see it as important starting point for students to understand where their power comes from and the consequences of our energy choices. Our main goals for this platform are:

- To motivate students and educators to creatively explore the complexities and challenges of the current power grid infrastructure.
- To improve energy literacy amongst students and educators by providing opportunities to work with physical and digital energy system models and hands-on activities, so they can become more informed decision makers and active citizens.

By increasing engagement and understanding around issues related to the power grid we hope to address the following:

- improve understanding amongst students and educators about how electricity is generated, the impact of the electricity generation and how the "system" works
- showcase future workforce opportunities around the power grid
- highlight the challenges and opportunities presented by making the grid greener
- improve students STEAM skills by providing a robust system based educational spaces around the power grid
- foster more informed decision makers and active citizens, who can communicate about energy and understand impacts and consequences as outlined in the DOE's Energy Literacy Framework.

Our focus in the 2017-18 academic year will be on the myriad of ways this platform could be use in short duration experiences (museum walk up) to
longer classroom projects (3-5-7 days). Over the next academic year we plan to work with educators to develop a library of uses for the unique platform. Some specific goals for the Power Grid Kit platform in 2017-18 are below:

● Develop refined and innovative versions of curricula & videos for elementary, middle and high school classrooms. Develop guides for more informal spaces such as museums and utilities.
● Hold 4 workshops for educators -- IL, MN (planned) seeking 2 other target locations
● Hold a 3-day summer workshop focused around the physical and digital versions of the power grid kit. (Summer 2018)
● Find 10 educators in a variety of environments to test, provide in depth feedback and to become a core master trainer group.

This workshop will introduce participants to this project, allow them to explore the Power Grid Platform and engage in a discussion about potential partnerships and outreach opportunities.

2.3 Energy Degree Programs, Minors and Concentrations

- Moderator: **Scott Williams**, Wisconsin Energy Institute, U. of Wisconsin, Madison
- Energy Education Programs at US Colleges and Universities, **David Blockstein**, Ph.D., National Council for Science and the Environment and **Shirley Vincent,** Ph.D.**,** Principal and Owner, Vincent Evaluation Consulting, LLC

The National Council for Science and the Environment (NCSE) conducted a census in 2016 of 1638 U.S colleges and universities to identify interdisciplinary or non-traditional broad energy (NTBE) degree programs, energy specializations within disciplinary degree programs and energy-oriented minors and certificate programs.

Interdisciplinary energy education is still a nascent field but the number of programs increased over the last few years from 39 in 2012 to 59 currently. Only 133 (8%) of the 1638 institutions included in the census offer non-traditional energy academic programs. Although all Carnegie classification types of four-year colleges and universities offer non-traditional energy academic programs, most programs are found at publicly-funded doctoral research (R-1) universities.

There are only 58 interdisciplinary or general non-traditional energy degree programs (in contrast to 1859 interdisciplinary environmental and sustainability degree programs) offered at a total of 45 universities (39 are doctoral degree-granting universities). These degree programs cover a wide diversity of topics, predominately energy science and technology, alternative energy, and energy policy, but also include environmental sciences, management, sustainability, systems and other topics. These programs are also split relatively evenly between undergraduate (54%) and graduate programs (41% masters, 14% doctoral).

The census identified 208 additional degree programs in disciplinary or professional fields with formal energy specializations (concentrations, tracks, focus areas) within their degree programs, including a variety of engineering and technology disciplines, business administration, interdisciplinary environmental fields (environmental science, studies, management, policy), policy studies, public affairs; law, sustainability, geosciences, agriculture and a few other academic areas. More than one-third (37%) are in engineering and technology disciplines, including 18% of the degrees at the doctoral level degrees and 38% of the degrees at the master’s level. Public policy and public administration programs comprise 14% of the total; business administration and energy economics programs comprise 15% of the total; each of the other disciplines and professional fields comprise 8% or less.

These programs are also relatively evenly split between undergraduate (48%) and graduate programs (41% masters, 11% doctoral); but include more undergraduate programs.

A total of 193 non-traditional minors and certificate programs were also identified. Most (56%) are designed for undergraduates and cover topics in a number of areas, especially sustainability, environment, and climate and engineering, technology and science. Other non-traditional energy minors and certificates cover topics including alternative and renewable energy, management and economics, general energy studies, resources and water, energy policy, systems, wind, solar, and nuclear energy, the built environment, systems, and energy law.

Non-traditional energy programs are located in varied administrative locations. Overall, most programs are offered by departments (40%), with smaller proportions offered by schools or divisions within a college (8%) or by primary level schools, divisions or colleges (17%). Substantial proportions of academic programs span academic units (23%) are in centers and institutes (10%). In this regard they are similar to interdisciplinary environmental and sustainability academic programs. Interdisciplinary and general degree programs and minors and certificate programs are more likely to be located in centers and institutes than are disciplinary and professional degree programs with specializations. Programs spanning academic units are prevalent locations for all three types of programs.

- Bachelor of Science in Energy Engineering (BSEEN), **Ali Razban**, Ph.D., Indiana University Purdue University Indianapolis (IUPUI)

Energy engineers are at the forefront of key challenges facing our planet and nation: production of clean energy and water, protection of the environment and sustainable economic development. As traditional energy resources are depleted, greenhouse gas concentrations rise and energy costs spiral, energy engineers will help society transition to a sustainable energy future. They will invent alternatives to today's fossil-fueled power plants and cars, using renewable energy sources and bio-fuels. The BS Energy Engineering degree was created in response to the need that businesses expressed for graduates with special know-how. Energy Engineering courses accelerate students' learning and professional development by introducing real-life projects and providing active mentoring in classroom, lab and field settings. The required courses are based on Mechanical Engineering and Electrical Engineering disciplines plus courses solely focused on Energy Engineering such as, Electromechanical Materials, Sustainable Energy, Solar Energy system design and Compressible Flow and Renewable Kinetic Energy Design. Advanced and elective courses in Energy Efficiency and Management, Fuel Cell & Battery Engineering, Materials for Energy Conversion, and Power Plant Engineering are among the offerings of this unique engineering program. Faculty members of the Energy Engineering program come from several engineering and science disciplines. They are industry professionals and engineering scientists with advanced degrees and specialized training. Their research seeks to develop the next generation of hybrid cars, power plants, airplanes, smart materials, manufacturing processes, energy efficient buildings and nanoscale technologies.

- Sustaining Graduate Education Programs for Energy Business Professionals, **Timothy Coburn**, Ph.D., University of Tulsa

This presentation discussed the evolving genre of graduate energy business degrees for working professionals and presented best practices for attracting students, and retaining them postgraduation, in the face of continuing change, downward economic pressures, and uncertainty that characterizes today's global energy industry.

2.4 Connections between Energy Education and Energy Practices on Campus and in Local Communities

- Moderator: **Sudeep Vyapari**, Ph.D., Executive Vice-President, Association of Controls Professionals
- Leveraging Onsite Solar to Boost Student Achievement in and Outside of the Classroom at the University of Richmond, **Rob Andrejewski,** Ph.D., Director of Sustainability, University of Richmond and **Anthony Smith**, Ph.D., President and CEO, Secure Futures

Onsite solar energy at the University of Richmond (UR) provides diverse education opportunities for students, faculty, staff and UR community members both in and outside the classroom. The presentation addressed the following questions: What tangible and intangible value does onsite solar provide to a university? How is solar energy preparing university students to lead in a global context? What are the differences between onsite and offsite solar? What kinds of colleges are good candidates to leverage onsite solar?

In spring 2016 Secure Futures installed a 204.8 kW solar array on the campus of UR, making it the first application of SolarWorld USA bifacial solar technology in North America. The array is also the first solar installation in Virginia to utilize a Power Purchase Agreement (PPA) under a Dominion Virginia Power pilot program in 2013. Under the PPA, UR purchases energy from the array that is owned and maintained by Secure Futures, at no capital expenditure.

The solar array at UR represents the university's ongoing commitment to sustainability, while serving as a research lab for its students and faculty. With over 64 different classes incorporating sustainability across campus, the solar array provides a tangible resource for UR course curriculum.

Lending itself to a variety of learning opportunities for students in multiple disciplines and departments, the array has several test conditions, including two surface types (gravel and white membrane), two solar panel types (monofacial and bifacial), and two inverter technologies (micro inverters and string inverters). Combined, these six variables allow student and faculty researchers to analyze which combination of technology is most efficient, providing an in-situ testbed for the economic value and energy production of new solar technology.

- "Power Dialog" As an Annual Student-Lead Public Event in an Undergrad "Energy, Culture, Society" Course, **Kathryn A. Milun**, Ph.D., University of Minnesota, Duluth

To promote public education and discussion of the EPA's Clean Power Plan in 2016, the Center for Environmental Policy at Bard College organized a nation-wide effort for students to engage in face-to-face dialog with state-level regulators in all fifty states. Bard provided curriculum and other organizing tools to help faculty teach students how to research and create an evidence-based public dialog around the US's effort to meet the global warming pollution targets set by the EPA. At the University of Minnesota Duluth, an undergraduate course, Anth3300: Energy, Culture, Society, participated in 2016 Power Dialog and has made that event into a key curricular component of this annually taught course. This presentation by the course's creator outlines how the Power Dialog was integrated into the social science course, into the community's public reflection on local energy policy, and into a yearly student-lead public event with city and state government officials on local energy policy.

- Participatory Learning Through the Race to Zero Competition, **Chris Hazel**, Energy Efficient Housing Research Group, Penn State University

For the past four years, members of the Pennsylvania Housing Research Center (PHRC) and the Energy Efficient Housing Research Group (EEHR) at Penn State have collaborated to support student design teams for the Department of Energy (DOE) Race to Zero competition. The annual competition requires students to design a market-rate net zero-energy ready home that responds to local context, climate, and builder knowledge/material availability. PHRC and EEHR have used the Race to Zero as a tool to educate the next generation of high-performance residential design professionals as well as a mechanism for engaging with partners in the local community. Each year, undergraduate and graduate students across multiple disciplines -- including architecture, architectural engineering, civil engineering, and energy engineering -- assemble a team to design a Zero Energy Ready Home (ZERH) to meet the needs of a local affordable housing organization. The general project process has remained consistent from year to year; however, the educational approach of the project has changed annually. Educational approaches have spanned across formal university classes, extracurricular organizations, and collaboration with industry professionals, the variations of which are based upon the specific needs of each project, the capabilities of the students involved, and available university resources. This presentation will examine the concepts, strategies, and design processes for developing and delivering the educational approach for the past four Race to Zero design competitions and the proposed educational outline for Penn State's 2017-2018 entry that partners with a new community partner, a local production builder.

- Integrated, Immersive Energy Education - A directed collaborative**, Brian Lovell,** President, Association of Controls Professionals

The mission of the Association of Controls Professionals (ACP) is to develop and provide educational resources, certifications, and industry guidelines for professionals and aspiring professionals in the sale, design, installation, maintenance, and optimization of energy management and building automation control systems. ACP provides a nationally-recognized certification program for building automation technicians. The certification process will be designed for compliance with standards ANSI/ISO/IEC 17024-03, ANSI/ASTM E2659-09, and ANSI/IACET 1-07.

2.5 Introductory Energy Education: Energy 101 and General Education

- The Comparative Energy Project: A Visual and Interactive Educational Tool for Comparing Energy Sources, **Bhawani Venkataraman**, Ph.D., and **Sean Hughes**, student, Eugene Lang College, The New School

The Comparative Energy Product is an interactive and visual educational tool, that conducts a comparative analysis of electrical energy sources (non-renewable and renewable) used to power a city. The tool compares the health, environmental, and social costs associated with the most dominant energy sources used for electrical energy and the fastest growing renewable energy sources: coal, natural gas, nuclear, solar and wind. In developing this tool, data from the research literature has been synthesized, including emission factors of greenhouse gases and air pollutants, energy and power densities, energy return on investments, capacity factors, and social costs and benefits. This data is then visualized through the tool, to allow the user to assess the benefits and risks of different energy portfolios. The intent of the tool is to educate individuals on the complexities about energy sources used for electrical energy and to provide objective comparisons of the pros and cons of these energy sources.

The tool takes a narrative approach to engage the user in learning and exploring the many issues around energy sources and why society needs to pay attention to decisions being made about energy. The narrative culminates in an interactive data visualization that the user is prompted to manipulate in order to create and compare their own energy portfolio through the resulting emission levels based off of the amount of electrical energy they typically use in a month. An objective of this tool is to move away from the political discussion around energy and instead draw from science and data to provide an objective comparison. In this way, the goal is for the user to recognize that there are benefits and risks associated with all energy sources, and to recognize that while there are no "perfect" solutions, and that there may be many ways forward, protecting health and the environment for all must be a key factor. The hope is that this understanding will also promote the development of informed opinions and actions by the user - from personal to political, such as understanding the role of government in supporting a transition towards less polluting energy sources and why this is necessary.

The paper presents the framework and goals of the tool and discusses the research and data sources used in the comparative analysis of the energy sources. The paper also presents a learning activity that has been developed for an introductory course at the undergraduate level titled Energy and Sustainability. The activity consists of several parts: students will begin by listing pros and cons of each energy source drawing from their prior understanding, identify what they believe is an "ideal" energy portfolio for New York City and will be asked to justify their choices. Next, students will use this tool to explore the pros and cons of each energy source and the different "costs" associated with each energy source. Having now compared these energy sources, students will be asked to reflect on their previously identified energy portfolio, how they might modify this portfolio now, and again justify changes. Additional follow up questions will also ask students to reflect on their own personal actions as well as the role of elected officials in moving a city like New York to "clean" energy and why this might be important for the city. Students' responses will be used to assess the effectiveness of this tool in assisting students develop an objective understanding of the benefits and risks of different electrical energy sources, as well as the ability of students to use the tool to make informed decisions around personal and political actions.

- Introducing Energy and Environmental Concepts in their Mutual Context and the Context of Place: Energy Literacy in College, **Christopher Coughenour**, Ph.D., University of Pittsburgh – Johnstown

Energy literacy is essential to informed public decision making, affecting a host of sectors from economics to land use planning to public and private investment in new energy technologies. Despite this, most colleges and universities offer few course options to a wide undergraduate audience. Environmental science and environmental geology are perhaps the most common/available choices, and represent, for many students, their only formal exposure to energy and sustainability issues.

An inspection of several leading textbooks reveals that only one to two chapters are devoted to energy concepts per se. In these texts, emphasis is placed on the workings of Earth systems and anthropogenic environmental change. The chapters on energy concepts, particularly as related to fossil fuel production, tend to emphasize historical production rates, present consumption, and a dichotomy between energy production and environmental issues. Most students who have exposure to energy concepts are, thus, often taught portions of the subject and largely from the perspective of environmental science. This is problematic in terms of energy literacy for two primary reasons. First, most students would not be 'energy literate' as defined by the U.S. Department of Energy (DOE) in learning their seven essential principles of energy. Second, some students may feel that some energy discussions are unbalanced or overly-politicized. The result of these barriers is that most undergraduate students are not prepared via their formal studies to make informed assessments of energy policies.

One approach to this problem is to incorporate more and entirely separate discussions of energy production, consumption trends, and economics. Familiarizing students with more details of the energy industry facilitates meaningful engagement with several essential principles of energy literacy. At the University of Pittsburgh-Johnstown, this is also an opportunity to use place-based learning, as the campus itself is built over underground coal mine workings. The student body is largely derived from Pennsylvania and surrounding states, and there is personal awareness of the extensive historical, cultural, economic, and environmental significance of energy production in the region. By providing more detailed discussions of energy resources in their own right and then discussing environmental issues, students are better equipped to independently think through the seven essential principles of energy literacy and begin a journey of continued learning thereafter.

- Inspiring Future Leaders in Energy Education and Research: Regional to Global Scale, **Pankaj Sharma**, Ph.D., MBA, Purdue and National Cheng Kung University, Tainan, Taiwan.

I have been involved in developing three energy education and research programs to inspire future leaders. These future leaders have been students from U.S. High Schools, mostly from Midwestern states, Graduate, undergraduate and post-doctoral students from Purdue, Cadets and Midshipman from the U.S. Military Academy and the U.S. Naval Academy and finally undergraduate and master students from Taiwan. I present my personal experience in conceptualizing these programs, key challenges, and results of assessments. A brief description of these programs is given below.

Energy Academy: The Duke Energy Academy at Purdue (DEAP), targets middle and high school U.S. teachers and students, with the goals of (1) inspiring teachers to communicate the importance of STEM and energy scholarship in their classrooms and providing them with resources and incentives, and (2) inspiring students to enter the STEM pipeline and to consider energy-related fields in their educational and professional career goals. The Energy Academy is structured to stimulate thinking and problem-solving learning, as well as to facilitate open discussion through tours, lectures, demonstrations, and hands-on activities. These culminate in policy discussion, light entertainment activities, and project presentations made by student groups and teachers based on their lab experiences and web-based research. During the weeklong immersive experience, teachers were encouraged to develop energy lesson plans and incorporate the knowledge gained into their classroom curricula to promote understanding of energy-related STEM topics.

Navy Enterprise Partnership Teaming with University for National Excellence (NEPTUNE) and Navy STEM programs: U.S. Navy operates around the globe to provide national security. One of the main challenges is maintaining technical superiority. In addition, U.S. Navy workforce is aging. Navy has also set a very ambitious goal to meet its future energy needs using 50% alternative sources. A next generation of STEM workforce is required to support above challenges especially considering that we are living in an interconnected world and so the global threats are also increasing. We have been funded by the Office of Naval Research to develop research and education programs for training Navy personnel, US undergraduate, graduate and post-doctoral students. We aim to deliver new domain experts with: (1) deep knowledge base in an energy-related discipline; (2) ability to work in an interdisciplinary “team science” environment; (3) mirroring societal diversity; (4) prior exposure to Navy culture. Navy personnel, ROTC students and veterans are engaged in energy-related research projects working with Purdue faculty and students.

The ‘NEPTUNE Center for Power and Energy Research at Purdue’ comprises technology development of batteries, thermal management, electronics, hydrogen, aviation fuel, and cyber security.

The ‘Navy STEM course: Power and Energy, onshore and afloat’ educates a pipeline of leaders in Navy-related STEM who can operate in an interdisciplinary science environment to accelerate discovery, have deep knowledge in an energy-related discipline, form a diverse cohort, and have knowledge and interest in pursuing technical career paths within the Navy. The course includes group projects, a field trip and guest lectures from Purdue faculty and technical leaders from Naval Surface Warfare Center, Crane, Indiana. Our plan is to transition to a web-based platform to extend the reach of this course nationally.

Energy Strategy and Policy: Nexus of Energy, Water, Food, Climate and Environment. The current world population is 7.6 billion people and it is expected to reach an estimated 9 billion people by 2050. The energy and food production need to double under the constraints of clean environment and water and global warming. This course is a part of an International Bachelor’s and Master’s Degree programs at the National Cheng Kung University, Tainan, Taiwan. The course brings together opportunities for both interdisciplinary and team learning. Students are engaged in an interdisciplinary discussion that focused on complex topics at the intersection of energy strategy, society, and policy including several other skills critical to thinking holistically and as a future leader. Various components of course deliveries include: (1) icebreaker and team formation, (2) base lectures, (3) guest lectures, (4) games, (5) case studies, (6) field trip, (7) group reading assignment, presentation and discussion, and (8) final team report and presentation.

- Teaching Energy Engineering Content to Non-Engineering Undergraduates**, Joel N. Swisher**, Ph.D. PE, Western Washington University (session moderator)

Understanding energy systems requires an interdisciplinary approach that blends science, technology, economics, business and policy content. The highly technical content in the energy field has made engineering colleges a convenient home for many academic energy programs. However, there is also growing need for education and research in the business and policy aspects of the energy system, which would also entail significant technical content, and for the education and training of technically astute professionals whose skillsets are not as specialized as most engineering graduates. All of these students would benefit from learning some amount of technical content, covering various topics commonly offered in engineering colleges.

Such topic areas include energy conversion processes, energy efficiency, building science, renewable energy, electricity systems and utility planning.   Filling this need is not a simple as enrolling these non-engineering students in the relevant undergraduate engineering courses. In many cases, they find that there are long chains of prerequisite courses in math and engineering, and that engineering course enrollment is limited and entry competitive. Even if resources are available to overcome the enrollment barriers, the problem remains that many engineering topics are taught with a level of specialization and mathematical depth that precludes most non-engineering students from even attempting these courses, despite the topics’ relevance to their intended careers.

Engineering curricula are carefully designed, and there is no motivation for diluting the technical content of existing courses. Nevertheless, there is a need to teach some of this content, specifically in the energy field, to non-engineers and to engineering and science students who are less specialized or may be specialized in other fields. Filling this need would better prepare such students to join the energy profession, and it would also enable them to bring adequate technical knowledge to experiential learning opportunities such as capstone courses, enabling engineering and non-engineering students to better learn from one another. Such experiences could also apply design thinking, entrepreneurship and innovation skills, etc.

Teaching energy engineering content to non-engineering undergraduates usually requires some simplification of the mathematical treatment, compared to comparable engineering courses. For example, in teaching heat transfer principles related to energy efficiency in buildings, one can replace multivariate calculus and differential equations with basic calculus or even pre-calculus, by assuming heat transfer is one-dimensional and steady-state. While this treatment is not as theoretically complete, it still allows the student to address key analytic problems and design tradeoffs. The payoff from this type of simplification is both an enlarged audience and a greater emphasis on design method, system-level thinking, and communication of results.

A wide range of technical topics could be taught to a diverse non-engineering audience using this approach. Building energy performance and the design of energy efficiency measures and programs would find myriad practical applications. Electric power systems and utility resource planning and policy opens a field that is ripe for innovation and disruption. Energy and carbon mitigation and management is a growing need in organizations nation- and worldwide. In each of these examples, there is a knowledge gap that could usefully be filled, between the highly specialized engineering treatment and the typical non-technical business and policy approach.

- Energy as an organizing principle for science learning across the disciplines, **Colleen Megowan-Romanowicz,** Ph.D., Senior Fellow, American Modeling Teachers Association

A robust energy concept is central to an understanding of all science. Although treated as if it is a straightforward and easily defined quantity, energy is notoriously difficult for people to understand, and is often confused or confounded with the concepts of force and power and even speed. K-12 teachers are not immune to this confusion, and the result for their students is often a fragmented, incoherent energy concept that is of little use in considering (let alone solving) problems beyond those that appear in their textbook.

The Modeling Method of Instruction, a research-validated, highly effective pedagogy in use for 30 years across the country and around the world, helps teachers reorganize their science instruction in middle and high school around the handful of conceptual models that form the content core of science and utilizes energy as a unifying theme through courses and across disciplines. In discipline-focused Modeling Workshops teachers learn to use a pedagogy that mirrors the NGSS Science and Engineering Practices and develop a set of powerful representational tools and practices that support student thinking and learning. Macroscopic and microscopic views of energy storage, transfer and conservation, and attention to defining systems enables students in Modeling classrooms to adopt an energy perspective when analyzing problems from many contexts.

It is time to rethink both the way science instruction is organized and the way teachers are prepared to enact this instruction to optimize students' ability to apply fundamental concepts and tools to addressing real world problems, not just in the classroom but wherever they encounter them.

SESSION 3: Topics in Energy Education
Concurrent Sessions

3.1 World Energy Simulation – Facilitator Training

- **Michele Putko**, Ph.D., University of Massachusetts – Lowell

Workshop participants learn to tailor and lead an engaging exercise to enable students, colleagues, or the general population to explore what is needed to address our global climate and energy challenges. The World Energy Simulation created by Climate Interactive combines an engaging role-play exercise with current science through a computer model, En-ROADS (Energy Rapid Overview and Decision-Support) simulator. Simulation participants take on the roles of leaders of key energy and societal sectors, responsible for charting an emissions pathway that limits global temperature rise to < 2°C above preindustrial levels, the agreed upon goal of the international climate agreement. Participants form groups, negotiate and enter their proposals into the En-ROADS model, which provides real-time feedback on the impacts of their decisions, including global temperature rise, greenhouse gas emissions and concentrations, energy use and source, and more. The simulation enables participants to learn for themselves and come to their own conclusions about the challenges and opportunities for creating a low-carbon economy. Participants learn to lead and tailor the simulation for unique audiences. See World Energy Simulation: https://www.climateinteractive.org/programs/world-energy and Climate Interactive, creator of simulation: https://www.climateinteractive.org

3.2 Defining Resilience and Sustainability in an Energy Context

- Moderator: **Adam L. Reed**, Esq. University of Colorado – Boulder
- Empowering Energy-Water Nexus Resilience: Experiential Learning to Address Urban Hydroelectric Micro-turbine Barriers, **Jennifer Sklarew**, Ph.D., George Mason University

Energy and water systems face numerous challenges to resilience. These include technological and infrastructure vulnerabilities, institutional struggles, and supply-demand balance uncertainties. The interdependence of these systems can compound these challenges, particularly in communities facing severe energy and water insecurity. It also can offer opportunities to jointly improve both systems' resilience and sustainability. Absorption capacity barriers and high costs challenge the large-scale use of resiliency-enhancing technologies at the energy-water nexus. Newer technologies with reduced maintenance requirements and smaller scale applications offer solutions to concurrently improve clean water and electricity access. Hydropower micro-turbines provide one such solution. These turbines typically use the natural flow of water to produce 5 to 100 kW of electricity; pico-hydro systems produce less. Micro- and pico-turbines do not require large dams or other significant infrastructure that can increase greenhouse gas emissions, cost, and maintenance requirements. They do not consume or pollute water. This technology thus can sustainably overcome some of the challenges associated with trade-offs between water and energy system resilience. Successful application of hydropower micro-turbines requires understanding of the technical, ecological, geological, socio-economic, and institutional barriers to their use. Examining existing projects reveals some of these barriers and potential solutions. Several U.S. pilots explore micro-turbine use in drinking water and storm water pipes. Some university projects use existing dams and weirs on rivers to produce power. However, none of these U.S. projects combine campus storm water management with green power generation and experiential learning. A number of international examples also offer lessons, including projects in Japan and Sri Lanka. Collectively, these cases suggest several common barriers; the projects' designs also indicate some solutions.   Building on these collective lessons, a multidisciplinary project conducted by faculty from George Mason University's College of Science (COS) and Volgenau School of Engineering (VSE) incorporates experiential learning to develop a holistic assessment of barriers and potential solutions for hydropower micro-turbine use. Through two pilots – one in the U.S. and one in a developing nation --, the project aims to identify the necessary technological, geographical, ecological, institutional, and socio-economic features needed for deployment of hydroelectric micro-turbines in urban areas facing severe energy and water insecurity. This approach integrates energy and environmental policy with science, geography, mechanical engineering, water resources and environmental engineering, and international development.

The project tests three hypotheses. First, challenges to hydropower micro-turbine deployment vary by location. Second, institutional relationships can create, worsen or mitigate these challenges, hindering or enabling turbine deployment. Third, addressing relationships and identifying solutions to challenges can enable hydropower micro-turbine features that foster energy and water system resilience. This project's pilots that test these hypotheses and support micro-turbines' joint contributions to energy and water system resilience also serve as an experiential learning tool. Hands-on learning, environmental stewardship research, and related educational activities for Mason's Fairfax campus and nearby communities involve academic programs in engineering, environmental science and policy, energy and sustainability, sustainability studies, physics, and international development. Our faculty-student project team is building and deploying two micro-turbines in storm water runoff pipes on George Mason University's Fairfax campus. The pilot will enable us to identify any technical, geographical, ecological, institutional and socioeconomic challenges and assess potential solutions. While designing and constructing the turbines on campus, our multidisciplinary faculty-student team will study the challenges associated with turbine construction, including turbine replication potential to facilitate maintenance, repairs, and possible expanded use. We will use the pilot's energy output to test and assess small-scale applications, such as emergency lighting and cell phone charging stations. The experience of designing, building and maintaining the turbine will enable effective analysis of challenges and solutions, and it also will develop skills transferable to communities deploying hydropower micro-turbines in the future. Through educational programs and signage, the project will promote institutional and community support by providing local lessons on micro-turbines' potential to address storm water runoff and produce electricity. We expect to find that institutional support plays a pivotal role in resolving technological, geographical, ecological and socio-economic challenges. Key institutional factors involve contributors to absorption capacity for the technology. The faculty-student team will apply findings from the U.S. pilot in a developing nation pilot to assess challenges and identify solutions for communities with limited resources. From these analyses, the project will generate best practices that will facilitate successful applications of micro-turbine technology even in these areas with the greatest electricity and water needs. We selected Ghana and India as potential candidates for the international pilot, based on these nations' solid progress in both electricity and drinking water access from 1990-2012. This advancement suggests that they may possess the institutional support for combined resilience-building across both systems.   As nations across the globe strive to build energy and water system resilience, hydropower micro-turbines can offer a sustainable joint solution in certain contexts. National governments and local communities can benefit from a holistic perspective on lessons learned from existing projects. By applying experiential learning to identify and address challenges in a developed nation pilot and a developing nation pilot, Mason's project will inform policies in both developed and developing nations. These pilots' deployment in a well-endowed community and a resource-constrained community also will enlighten a variety of local communities' efforts. The analyses of existing projects and the two pilots will generate lessons that can enable deployment even in communities experiencing the most severe water and electricity access, as well as limited resources and inadequate institutional capacity.

- Removing the Barriers to Energy Education and Implementation: Essential Actions, **Debra Rowe**, Ph.D., Oakland Community College, President, US Partnership for Education for Sustainable Development

This presentation identified the essential roles and components for quality energy education in our country and the barriers we must overcome to fulfill these roles at a crucial time in human civilization. Energy education is needed at multiple levels. All high school students and undergraduates need core information about key concepts to be able to participate as educated voters, consumers, investors and community members. Key concepts include: the connections between our energy choices and climate instability, the economic and technical viability of meeting our most of our energy needs with efficiency and renewable energies, the basics of energy policy today and potentials for the future, and the connections between our energy choices and human health and well-being. (Connecting energy concepts to the sustainable development goals is also very useful for students in their adult roles.) All academic areas could potentially contribute to this basic energy literacy from their discipline's perspective, but energy literacy often falls through the cracks with very few academic areas taking on the responsibility to include it and the typical undergraduate is not learning these core concepts, unless they are in a specific energy or sustainability related program.

For engineering, architecture, urban planning, and business majors, the core concepts of sustainable design, the circular economy, ecological economics and community wealth building need to be integrated into curricula. For technical programs at community colleges and similar institutions, programs in construction, design, heating and cooling and business should include key concepts and skills related to each area and its connections to sustainable design, green building, renewable energies and energy efficiency, the circular and sustainable economy, policy impacts and economic analysis. All students need to learn how to help be the change agents required to shift our societal organizations to a more sustainable future. There is a growing number of such curricular integrations at the level of these majors and technical programs, but still not close to what is needed to meet our energy, economic and environmental and health needs in this country. Accreditation agencies need to make this the new norm. Professional development, textbooks, labs and certifications need to include the above to institutionalize these changes. We have some good successes and precedents but the momentum for change needs to continue. We can support each other in building this momentum. Informational and networking resources are available to help.

- Adapting Authentic Sustainability Research into Projects Appropriate for K-12 Classrooms, **Matthew Johnson**, Ph.D., Penn State University

Environmental education in K-12 settings is important both for preparing a well-trained workforce capable of researching, designing, constructing, and maintaining resilient and sustainable infrastructure systems and for producing citizens prepared to make difficult decisions related to these systems. The purpose of this session will be to discuss the use of existing research projects about environmental issues in K-12 STEM contexts.

Recent reforms call for science educators to engage students in the practices of researchers to learn content (NRC, 2012; NGSS Lead States, 2013). They also recommend students learn about engineering in addition to science, argue against a focus on discrete STEM disciplines and promote concepts that bridge disciplinary boundaries, known as crosscutting concepts (NRC, 2012). Two of the practices promoted in NGSS, using mathematical/ computational thinking and modeling, make clear the connections and interdisciplinary work required in STEM. Thus, using authentic research projects about resilient and sustainable infrastructure as contexts for environmental education provide opportunities for teachers to engage their students in the practices of researchers to teach important crosscutting concepts and disciplinary ideas.

Many environmental education outreach programs suspect that the distrust of climate change science is due to lack of exposure and/or knowledge. However, the “over-reliance on hype and alarmism” that characterizes much of the communication related to climate change will do little to change either the minds of skeptics (Whitmarsh, 2011, pg. 699) or those teachers motivated to attend professional development related to climate change issues. Rather than focusing on a lack of knowledge, we propose to highlight the “messiness” of research to better engage teachers and students in the multidisciplinary work that relies on systems thinking, cause/effect relationships, and the concept of stability versus change (crosscutting concepts). We feel that participation in the practices of research will be more effective in preparing generations of citizens that better understand how scientific knowledge is derived.

This session describes the ways in which the Center for Science and the Schools has used the research project, NorthEast Woody, warm-season Biomass consortium (NEWBio) as the basis for a week-long teacher professional development workshop on using biomass for liquid fuels, as facilitated by the Center for Science and the Schools (CSATS), a group located in Penn State’s College of Education that works with faculty from the STEM colleges to develop, propose, plan and implement professional development programs for K-12 teachers that are both related to authentic research projects and aligned with current state and national science and technology standards. Two interventions we find to be particularly useful in developing curriculum based on research projects are to use the MASTER Model (Ward, 2016) to develop CLassroom Research Projects (CLRP) (Hill et al, 2017).

The Modeling Authentic STEM Research (MASTER) Model (Ward, 2016) is used as both a framework and a process to consider research as a system of interconnected and interdependent components. In the context of NEWBio workshops, the MASTER Model has been particularly helpful for teachers to understand the connections in the complicated work to develop the cellulosic biofuels system, and the need for specialists in agronomy, mathematical modeling, sociology and other fields to work together to make progress toward social, economic, and environmental sustainability.

The CLRP is a unit of study that focuses on explaining a particular phenomenon or addresses a particular problem. It involves several steps, and specifically pushes back against the linear, step-wise model of the “scientific method” that misrepresents the work of scientists. Using the MASTER model and concept mapping approach to authentic research, teachers are able to develop CLRPs for their class that are aligned with their current curriculum, but also with current research-based best practices in education.

One CLRP that came from the NEWBio workshop is to plant a garden of bioenergy crops capable of generating cellulosic ethanol in marginal land (e.g., a strip mine). The evaluation of the students’ work is based on multiple criteria, including cost. Therefore, the garden must take into account the species of bioenergy plant, the treatment and soil amendments, harvest, and pre-processing, similar to the focus of NEWBio.

Prior to planting, students use the CYCLES model (Saha, et al, 2016) to model growth of various bioenergy crops in conditions with and without irrigation and fertilizer. Then, students grow potential species and/or varieties in small scale plots to answer questions like “which plant grows best in these conditions?” A number of measurements can be taken to answer this question, but each has its own drawbacks. For example, harvesting the whole plot gives the most accurate measure of raw biomass, but eliminates the opportunity to take multiple data points. Also, the moisture content prevents a simple comparison between the masses of raw biomass and the model relies on mathematical conversions. After the gardens grow, students choose their method of pretreatment and convert the cellulose in their crops to glucose. The amount of glucose from the conversion is first extrapolated to the entire plot and then is used as a proxy for the amount of ethanol that could be fermented.

At several points during this long-term project, timely and relevant concepts of biology, agriculture, and earth systems can be taught. For example, one biology teacher uses this project to teach about: 1) macromolecules, particularly glucose, cellulose, and enzyme function; 2) photosynthesis, especially how the chemical conversion of carbon dioxide to glucose (and ultimately cellulose); 3) genetics, such as genotype/phenotypes, synthetic biology, and hybrids; and 4) natural selection related to the fitness of different species/varieties of bioenergy crops under various conditions.

We have had growing success introducing teachers to the concepts of MASTER Models and CLRPs based on authentic research taking place in the NEWBio Consortium. We feel that other research projects across multiple disciplines could be adapted similarly and our hope is that this session sparks a productive conversation surrounding teaching important STEM concepts through participation in the practices of researchers.

3.3 K-12 Energy Education

- Energy Efficiency and Energy Literacy: The First National Energy Literacy Survey, **Elissa Richards** (moderator) and **Gary Swan**, National Energy Foundation

The National Energy Foundation (NEF) has recently completed the first ever National Survey on Energy Literacy in the U.S. The survey has been administered to 2,005 randomly selected high school seniors, with the objective of finding out what students know (knowledge), feel (attitudes) and are doing (behaviors) about energy and energy efficiency as they complete their K-12 journey. High school seniors have been selected as the target for this survey because of this critical juncture in a student’s life where they become voters, possible utility bill payers, college students, and/or members of the full-time workforce.

The results are fascinating, particularly as we examine the correlation between knowledge, attitudes and behaviors. For example, if a student scores high on the knowledge portion of the test, how well does that translate to their actions? Additionally, the national sample is stratified for various demographic factors, including family income level, ethnicity, gender, high school GPA, and region of the country. Exploring the differences in energy literacy among these subgroups provides some powerful insights that can help drive new energy efficiency program design for both utilities and government. Another area for insight is the development from the data of energy-related “personas,” much like psychographics that are used in product marketing.

Specific knowledge categories in the survey include: Basic Energy Concepts, Energy Use, Energy Efficiency & Conservation, Sources & Types of Energy, and Energy Tradeoffs & Implications. Students’ responses lead to an overall Energy Literacy Score, scaled on a 1-to-100 point scale. Data show a score distribution that follows a typical bell curve, suggesting a well-designed set of questions. A pilot survey to approximately 350 participants was administered in February and March to help refine the final questionnaire.

NEF’s survey research partner is Cicero Social Impact, a reputable research group that has worked in partnership with the Clinton Foundation, the Gates Foundation, the George W. Bush Presidential Center, and many other national organizations. NEF believes this is an unprecedented project and has produced an unprecedented data set that will help inform education, utility and government stakeholders as they create critical energy related curriculum and policies for the future.

- Plasma in Energy Education in Florida Science Standards, **David Devraj Kumar**, Ph.D., Florida Atlantic University

In order to address growing calls for sustainable clean energy, the importance of education on plasma, the fourth state of matter, and its role in energy production cannot be overlooked in science curriculum. Plasma is mentioned as a state of matter in the Florida Science Standards. For example, section SC. 912.P.8.1 states, “differentiate among the four states of matter (solid, liquid, gas and plasma) in terms of energy, particle motion, and phase transitions” (CPALMS, n.d.). However, the fourth state of matter is not adequately addressed in depth nor is connected to other suitable topics, including energy.

In terms of energy production, the Florida Science Standards deal with renewable energy and alternative energy under section CTE_ENGY. 68.GNRATN.03.02, and address fusion as part of nuclear reaction under section SC. 912.P.10.11. Although other energies, such as mechanical, electromagnetism, and heat are addressed within the Florida Science Standards, the role of plasma in fusion energy is completely missing.

It is necessary that students be provided with grade level specific enriched information and learning opportunities to develop transferable knowledge of plasma in energy production. In this context, the following changes are needed in science education. The Florida Science Standards regarding the states of matter should provide meaningful learning opportunities for increasing student understanding of plasma. Energy standards should be augmented to include the role of plasma in energy production. Pedagogically appropriate instructional modules, suitable for addressing plasma and plasma in clean energy, should be designed for elementary, middle and secondary grades. Plasma and plasma-based energy education should be addressed in science teacher preparation curricula. This presentation also discusses implications for policy and evaluation.

- Wind Energy Education for K-College, **Michael Arquin**, Ph.D., Founder and Director, KidWind Project

Over the last 16 years we have been involved with a variety for projects and organizations around materials development, curricular tools and student programming related to wind power. We present information about the following programs:

The Wind for Schools Program (WfS) was created in 2006 by the Department of Energy (DOE) and the National Renewable Energy Laboratory's Wind Powering America Program. The intent was to create a program that would teach the next generation of wind energy workers to support the rapid growth of the wind industry Today, the WfS program is operating in 12 states and is expanding its successful program into additional states. Currently, universities across the country host classroom studies, as well as field assessments, and installations of small wind turbines at K-12 schools and universities. The fundamental goals of WfS are to: Engage, educate, and inspire the next generation of the wind workforce. Promote the implementation and acceptance of wind energy across the country, Introduce K-12 and college students to wind energy to provide career opportunities in renewable energy Expand the existing WfS efforts from the current active 12 states WfS promotes collaboration in communities between private and public sectors, as well as between education institutions and schools all the way through K-12. It also promotes partnerships between institutions and private sector renewable energy companies that creates job opportunities for graduates. https://windexchange.energy.gov/windforschools

The KidWind Challenge seeks to engage 4th-12th grade students in the opportunities and challenges of a wind-powered society. The student teams that participate in the Challenge must construct a wind turbine that they test in a wind tunnel, document and present the process by which they researched and constructed the turbine, understand the consequences of how we generate and consume energy, and engage in a variety of instant challenges to gauge their on-the spot engineering and problem-solving skills.

The KidWind Challenge was developed by the KidWind Project, a leader in providing in-depth wind-focused curriculum and tools to educators all over the world. Since its start in 2002, KidWind has developed an award-winning suite of classroom wind energy kits and a wind-energy curriculum called WindWise. These are actively being used by thousands of teachers all over the world. In the past 14 years, our networks have trained 15,000 educators and impacted more than 800,000 students.

Since 2009, the KidWind Challenge Event has been successfully implemented in 22 states. Roughly 15,000 students have competed in 147 events across the country. In 2016-17, nearly 3,000 students competed in the KidWind Challenge Events and the REcharge Labs Wind Turbine Design Online Challenge. The 2017 National Kidwind Challenge was held at AWEAs wind power conference in Anaheim, CA and did not disappoint. Fifty-six teams and 430 students, coaches and parents came from 16 states and 1 US territory (US Virgin Islands). The participants made the event; we just bring together the right ingredients.

KidWind Challenge Goals: Get students excited about renewable energy— specifically wind power— and its relationship to global climate change: Create and deliver opportunities for students to build, test, explore, and understand wind energy technology; Introduce students— particularly girls and underrepresented populations— to careers in renewable energy STEM (Science, Technology, Engineering, and Math) ; Connect students to mentors and role models in the renewable energy industry; Help educators better understand wind energy technology and development, as well as its promise and limitations; Make effective educational resources accessible to teachers by providing low-cost materials and trainings. https://www.kidwindchallenge.org

The REcharge Academy is a week-long educator training workshop about renewable energy. The intensive training blends lectures from experts and tours of energy facilities with replicable hands-on K-12 lessons to give educators content as well as context. A REcharge Academy combines materials from REcharge Labs, WindWise, KidWind, and Vernier, as well as other materials we find applicable and useful in the classroom.

Our team has been holding REcharge Academies for 9 years (they used to be called WindSentors) and have trained over 350 REcharge Instructors through this intensive program. Each Academy has a slightly different focus, but the overarching theme is to help educators understand renewable energy science, how renewable energy can impact the world, and how educators can creatively share these concepts in the classroom.   This network of instructors has been responsible for training and impacting 1000s of more teachers all over the US. http://www.rechargelabs.org/rechargeacademy

- The Role of Art and STEAM in Energy Education, **Jonee Kulman Brigham**, Institute on the Environment, University of Minnesota

Personal relevance and audience engagement is important in educating the public and K12 students about energy. Energy itself, as well energy infrastructure can seem like abstract concept that are separate from everyday life or one's ability to influence them. The arts and education that integrates the arts into Science, Technology, Engineering, and Math (STEAM) can help engage learners in energy topics and make energy personally relevant to learner's lives, as well as offer a sense of agency in making a difference. The role of arts will be discussed and examples of proposed or implemented art and art-led energy education projects will provide ideas for how to engage art and artists in energy education work.

Jonee Kulman Brigham, is an architect, artist, and educator as well as a researcher at the University of Minnesota. She has presented about the arts and art-led environmental education at the conference for the Association for the Advancement in Higher Education (AASHE), the ESRI Education GIS Conference, the American Public Works Association (APWA) Minnesota Chapter conference, and at the Minnesota Association for Environmental Education conference. Her art-led environmental education curriculum model is place-based and experiential, and puts learning about infrastructure systems in the context of art and story. It has been applied to water systems in learning environments from pre-K-12, and in teacher training. She is currently working on a version of the model based on a journey from a point of power usage in the learning environment (such as a light switch) to explore the electric power grid. http://earthsystemsjourney.com She has also exhibited artworks that engage the public in energy issues referencing both electric power systems as well as natural gas infrastructure.

- Using the CLEAN educational resource collection for building three-dimensional lessons to teach the climate system, **Frank Niepold,** Climate Education Coordinator, Senior Climate Education Program Manager, National Oceanic and Atmospheric Administration

The impacts of climate change are a critical societal challenge of the 21st century. Educating students about the globally connected climate system is key in supporting the development of mitigation and adaptation strategies. Systems thinking is required for students to understand the complex, dynamic climate systems and the role that humans play within them. The interdisciplinary nature of climate science challenges educators, who often don't have formal training in climate and energy science, to identify resources that are scientifically accurate before weaving them together into units that teach about the climate and energy system. The Climate Literacy and Energy Awareness Network (CLEAN) supports this work by providing over 700 peer-reviewed, classroom-ready resources on climate and energy topics. The resource collection itself provides only limited instructional guidance, so educators need to weave the resources together to build multi-dimensional lessons that develop systems thinking skills. The Next Generation Science Standards (NGSS) science standards encourage educators to teach science in a 3-dimensional approach that trains students in systems thinking. The CLEAN project strives to help educators design NGSS-style, three-dimensional lessons about the climate system. Two approaches are currently being modeled on the CLEAN web portal. The first is described in the CLEAN NGSS "Get Started Guide" which follows a step-by-step process starting with the Disciplinary Core Idea and then interweaves the Cross-Cutting Concepts (CCC) and the Science and Engineering Practices (SEP) based on the teaching strategy chosen for the lesson or unit topic. The second model uses a climate topic as a starting place and the SEP as the guide through a four-step lesson sequence called "Earth Systems Investigations". Both models use CLEAN reviewed lessons as the core activity but provide the necessary framework for classroom implementation. Sample lessons that were developed following these two approaches are provided on the CLEAN web portal (www.cleanet.org).

3.4 Diversity workshop: Advancing Diversity in the Sustainable Energy Field

- **Felicia Davis**, Clark Atlanta University and Project InTeGRATE and
Donna Hope, Environmental Leadership Project

The workshop helped participants to identify their own implicit biases through use of a questionnaire that identified diversity in their own life. Participants discussed diversity goals and activities in their programs and institutions. Effective strategies include the EnvironMentors program of the National Council for Science and the Environment (NCSE) which engages high school students in a structured program involving cohorts, research, experiences, activities and mentoring at 13 university-based chapters. The NSF-funded InTeGRATE (Interdisciplinary Teaching About the Earth for a Sustainable Future) project led by the Science Education Research Center at Carleton College provides workshops and curricular modules and strategies at www.SERC.Carleton.edu

Responses to Post-Summit Survey

What are the biggest needs in energy education and workforce preparation?

- Connection and development of larger narratives. Sustainability, Equity, the Why behind energy education, and in a matter that engages the humanities. A science-based list of why it is important is not sufficient. Engage the cultural contexts and cultural change methods in which energy/science education resides.
- Teaching flexibility and that everything is always evolving, changing, and connected.
- Understanding of connections between technological and other factors: institutional, ecological, socio-economic.
- Those that are able to think about systems.
- A better understanding of what energy IS, where it comes from (both finite and renewable), how it is stored, transferred, used...and energy economics.
- Recognized programs for green energy education.
- More diversity and knowledge of the opportunities.
- More diversity in terms of race, gender, age and class. Educating people who understand the policy, social, and technical aspects of energy. Right now, we have a lot of people who understand one or the other.
- Linkages between education and practice, including practical experiences.
- There is a serious need for dissemination of fundamental information across all education levels (what is energy, where does is come from, how is it distributed?). Workforce preparation also needs to address fundamentals before moving to specific disciplinary training.
- Students will require skill in systems thinking to understand the complex interaction of energy systems, technologies, policies and regulations, and emerging market structures.
- What skills/degrees are needed for different types and sectors of jobs? (i.e. mismatch if solar installers only need an associate degree).
- Educating the recruiters.

What combinations of technical knowledge (primarily physics and engineering) and contextual knowledge (economics, societal context, environmental aspects and entrepreneurial skills) are appropriate for undergraduate students interested in energy careers?

- It depends on the student and the program. There should be multiple types of energy education, each of which offer exposure to the full context.
- The concept of a multi-disciplinary education must be enforced to the point that a class on a particular subject includes how it is related to other subjects as well. No one subject exists without being impacted by another and this must be taught to reinforce how everything is connected. Every action has a reaction, whether it is from the same field or not.

- All of these are important. Engineers should be required to learn about contextual issues, and non-engineers should be required to learn some basic technological attributes.
- I think that for many students, the technical knowledge can be motivated by the contextual knowledge, and that integrating concepts using real-world examples for students to work through and understand is essential.
- While both types of knowledge are important, undergraduate energy education should ensure a significant focus on contextual knowledge over technical knowledge. Students wishing to pursue technical knowledge will typically do so in engineering graduate programs.
- I think industries have to stop thinking educational institutions can produce students that are immediately ready to be productive in their field. Knowledge and skills are highly specific, but the ability to learn and adapt can be applied in many contexts.
- Physics, chemistry, engineering, computer science, economics, social and political science, business.
- I would be put solid engineering courses as a requirement. I use economic, social and environmental aspects as electives.
- Depends on the major, but students should get some of all of the above if they want to go into energy.
- All of them.

What educational and training approaches have shown success in attracting and retaining students and a workforce in sustainable energy fields?

- For students oriented to engineering, perhaps a technology, science, engineering focus works.
- Engineering education.
- I have heard about high schools (Colorado has a statewide program) that have apprenticeships for students that teach them skills, qualify for high school and college credit, and pay them. There is a lot of optimism attached to this method to filling the need for skilled workers, but I am not sure about the current use of it in the sustainable energy fields. That being said, I definitely think it could be a fantastic method to attract interest, especially with higher education costs where they currently are.
- Multidisciplinary projects that involve experiential learning.
- Practical experience; community impact.
- Alumni networks are critical, so energy education programs should receive the support they need to be long-term endeavors that can build strong networks for employment of future graduates.
- My students are really interested in the social justice aspects, showing that a career in energy is a responsible career in which they can improve the world, rather than a career that is just about hardware.

What methods should be used to attract and connect under-served communities and populations to energy education and workforce development opportunities?

- Women, and community-oriented cultures might find the role of contribution/meaning to society/community a good foundation/entry point with sci/tech in support of that mission.
- Interactive fairs at schools and community centers. High school apprenticeships to teach skills and provide access to a job and education.
- Free seminars or events in those communities and at libraries, grocery stores, and other free, easily accessed venues
- The comments made in one of the plenary discussions regarding very early recruitment and continued follow-up are important for attracting students to STEM. College is often too late for many.
- You can reach them through their teachers, but don't wait to start doing that till they are in college or even high school--start in middle and elementary school.
- Active mentoring and funding stipends and student activities.
- Seminars and training
- Energy institutes on campuses that include a focus on diversity and energy ethics, community engaged research and includes just processes for engaging these communities rather than speaking for them
- Underserved communities will only develop interest in energy transitions when the transitions are aligned with their community's needs and priorities. That isn't the case right now, as evidenced by the number of people in plenary sessions applauding grid defection (which at scale would have a devastating effect on underserved communities).

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