The National Workshop on
Clean Energy Education

Recommendations
and Strategies

Full Report
THE NATIONAL WORKSHOP ON
CLEAN ENERGY EDUCATION

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
OCTOBER 13, 2011

Full Report
Clean energy education is an enabling foundation with far-reaching benefits to the nation. We need to advance our economic and industrial competitiveness, assure a long-term energy supply that is secure and affordable, and reduce the impact of energy use on the climate. These goals all require that our energy system – from sources to transmission to end-use efficiency – benefit from the highest levels of scientific and technological innovation, the most efficient development of human capital, and the most forward-looking business and policy strategies that we can develop.

In the 21st century, we need a technological workforce that is prepared with the knowledge and skills to address the complex issues surrounding sustainability and clean energy challenges. The National Science Foundation has several programs that support interdisciplinary research and education in this area. It sponsored the National Workshop on Clean Energy Education to identify opportunities and help facilitate a coordinated effort to develop clean energy education nationwide. This report provides insights that will assist educators, scientists, engineers, executives and policymakers to formulate specific pathways that advance the contribution of their sector towards the national goals. The recommendations of the report also support and inform the NSF initiative in Science, Engineering and Education for Sustainability (SEES).

We hope that reading this report will inspire and assist your organization to collaborate and contribute solutions to the national goals as you advance your own enterprise. If you have suggestions concerning clean energy education, please convey them to the authors of the report.

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Note: Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.
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ACKNOWLEDGMENTS

The Organizing Committee gratefully acknowledges the help and support of the following:

- The Graduate College at the University of Illinois at Urbana-Champaign for launching the Clean Energy Education initiative and for its financial and staff support as well as financial support from the Edward William and Jane Marr Gutgsell Professorship at the University of Illinois at Urbana-Champaign.

- The National Science Foundation for supporting this workshop under Grant 11-31192, which was co-funded by the CBET Environmental Sustainability Program in ENG and the Division of Graduate Education in EHR, and for supporting the ‘stakeholder alignment’ survey under Grant NSF-VOSS 09-56472.

- We also thank the many other people and organizations that contributed to this workshop in numerous important ways. In particular, we extend our gratitude to Christopher G. Kennedy, Chair of the University of Illinois Board of Trustees.
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The ability of our nation to meet the present and future challenges related to energy, including the transition to clean energy sources, requires an investment in human capital. This report identifies the fundamental motivations, challenges, and pathways toward a national program of Clean Energy Education (CEE) which will inform citizens, workers, managers, and policymakers about the impact of energy choices. Investing in CEE will enable our nation to adopt a system of energy sources, distribution and use which is resilient, affordable, and can help mitigate the risks associated with climate change.

We note that an energy-educated citizenry is not one in which every person is an energy expert. Rather, it refers to an informed public that is capable of connecting public or private energy use and policy to environmental, social and economic consequences. It will prepare our current and future workforce to innovate, manufacture, install and operate clean energy systems in a wide variety of settings.

We also note that CEE strongly supports common goals in American educational systems, especially 1) promoting and improving Science, Technology, Engineering and Mathematics (STEM) education in K-12 schools, 2) upgrading workforce training for new and evolving occupations, and 3) engaging college and university students to solve societal problems using core and interdisciplinary skills.

A NATIONAL WORKSHOP ON CLEAN ENERGY EDUCATION

A national workshop on CEE, sponsored by the National Science Foundation, was held in Urbana, Illinois on October 13, 2011. It was organized by the University of Illinois at Urbana-Champaign in collaboration with the University of Chicago, Northwestern University, the University of Illinois-Chicago, Argonne National Laboratory and the Illinois Green Economy Network of Community Colleges. The goal of the workshop was to frame answers to the questions, “What are the crucial elements in a national program of CEE?” and “What are the best practices a national CEE program must adopt?”

The approximately 100 participants included faculty from about 30 universities, community colleges and schools, as well as leaders from industry, government agencies, and non-governmental organizations. It was the first in a series of planned activities that will bring together experts in energy education to lead the nation in creating an energy-literate citizenry for the 21st Century.

In addition to attending plenary talks, workshops, and panel discussions, participants divided into six breakout sessions to draft recommendations on the following topics:

- Energy-literate citizenry
- K-12 CEE education
- Interdisciplinary and cross-institutional CEE
- CEE and workforce development
- CEE and industry
- CEE and international engagement
Their findings are summarized in the following workshop report and are intended to inform decision-makers about the educational needs that, if met, will most expeditiously move the country toward a more secure energy future. The following section summarizes the conclusions of the full report.

**PRIORITY RECOMMENDATIONS**

Four crucial directives for promoting a national CEE program emerged from the breakout sessions:

1. **Develop systems thinking and an understanding of clean energy systems.**
   Thinking about energy requires a systems approach in which complex problems are evaluated from a range of perspectives. Energy systems in particular require consideration of cost, supply, environmental, and security issues. However, studies have shown that systems thinking demands a skill set that is difficult to teach and learn. Educational tools such as computer-based simulations, professional role-playing and mentoring from multiple disciplines are essential for developing systems thinking. It is also important to note that CEE crosses traditional boundaries between disciplines and across vertical strata in educational organizations.

2. **Cultivate active stakeholder networks.**
   CEE is interdisciplinary and involves diverse sets of stakeholders from several domains. Effective CEE will occur only when the stakeholders in a given domain engage, dialogue, and align around themes with relevance both for the immediate term (such as job creation) and long term (such as energy literacy and public policy). To address the complexity of such educational issues, stakeholder groups are needed that represent inter-institutional, local, regional, and national interests. Network relationships do not just happen by themselves, however. Incentives must be aligned, appropriate forums and communication mechanisms must be established, and barriers must be overcome. The process of developing network relationships should be facilitated by experts on stakeholder relationships and effective communication.

3. **Define multiple literacies.**
   Energy literacy is comprised of multiple literacies that differ in content depending on the needs of the constituency. What the energy-literate citizen needs to understand is different from what an engineer, a business decision-maker, or a policymaker needs to understand. Defining the contents of various energy literacies involves two challenges:

   i. Each literacy must recognize and embrace different knowledge (epistemic) frameworks and sets of values. The underlying complexity will not be resolved simply by adding more knowledge, but by forming authentic, creative, and inclusive partnerships among the social, natural and engineering sciences.

   ii. Concepts and information from one domain, such as a research lab or engineering firm, must be translated in order to be understood in a different domain, such as the classroom, the boardroom, or the living room. Moreover, individuals operating within one domain must appreciate the origins and legitimacy of viewpoints from other domains.
4. Facilitate institutional transformation.
The topic of clean energy has relevance in K-12 schools as a means to teach STEM subjects and to prepare the future STEM workforce; in colleges and universities as a means to engage cross-disciplinary thinking; and in industry as a pathway to enhance the bottom line by reducing the costs associated with energy consumption and emissions. But for CEE to take hold in these environments, institutional transformation must take place. This requires a process of stakeholder alignment and establishing incentives and rewards that validate CEE. In K-12 schools, for example, the subject of clean energy must be recognized, understood and incorporated at all levels: the school board, curriculum developers, principals, teachers, parents, and students. At universities, different disciplines must have a recognized institutional space under which to develop interdisciplinary CEE courses, programs, and joint degrees. Businesses and non-profit corporations, along with state and federal agencies, must establish the means to work collaboratively amongst themselves and to financially support the interdisciplinary work of CEE.

STRATEGIES

The breakout groups formulated specific recommendations pertinent to their domains. The most salient are listed below.

ENERGY-LITERATE CITIZENRY: Provide systematic and collaborative education in energy systems and technologies to all citizens using a clear, common definition of “clean energy.”

K-12 EDUCATION: Include CEE in the standards for science education as a core topic in STEM instruction and expand the educational and training opportunities for K-12 teachers in CEE.

MULTIDISCIPLINARY EDUCATION: Form authentic, creative, and inclusive partnerships among diverse disciplines through integrated and creative pedagogic strategies that identify and assess benchmarks for CEE competency, certification, and desired skill-set outcomes.

WORKFORCE DEVELOPMENT: Develop and widely disseminate clean energy career pathways using comprehensive, cross-agency governmental collaborations to identify and educate for different kinds of energy literacies related to workforce development.

BUSINESS AND INDUSTRY: Educate and engage all members of the business community in clean energy systems and provide significant economic incentives that promote action through public-private partnerships.

INTERNATIONAL ENGAGEMENT: Create international partnerships between universities with a focus on regionally-based energy education and establish international energy studies as a new field of academic research and teaching as a mechanism to identify and propagate best practices.
ADDITIONAL WORKSHOPS: The organizing group of the first workshop will be expanded to include a broader set of advisors including representatives from Europe and Asia in the fields of education, business and government. A series of globally-oriented meetings is planned. These will be structured as working groups, each of which will engage in a specific initiative and report on progress at the following meeting.

A FIRST ROUND OF ACTIONS: The workshop participants recommend the following specific steps in order to set the process of CEE in motion:

**Colleges and Universities:** Create and support cross-disciplinary opportunities for CEE and training.

**Government Funding Agencies:** Align funding streams to strategic CEE needs.

**K-12 Policymakers:** Incorporate CEE into state learning standards.

**K-12 Curricular Leaders:** Partner with college and university faculty to create CEE-focused educational materials that meet the goals of K-12 curricula.

**Business and Industry:** Engage and support networks to create coordinated pathways for CEE and workforce development.

**NGOs (Educational, Environmental, Informal and Lifelong Learning):** Promote an energy-literate citizenry for individuals not yet or no longer in formal educational settings. Instill an appreciation of the earth, its resources, and the role of energy systems in our lives.
GLOBAL CHALLENGE

Although the worldwide resources of coal, oil and natural gas are sufficient to provide power to the earth’s growing populations throughout the 21st century, the continued use of fossil fuels carries with it consequences that threaten the prosperity of our nation and the world. These include escalating costs as fossil fuels must be extracted from increasingly remote locations; national security issues inherent in the mismatch between the suppliers and users of fuel, notably the reliance on crude oil from the Middle East; environmental risks in fossil fuel extraction and transportation (as illustrated in the recent massive Gulf of Mexico oil spill and the Exxon Valdez disaster of 1989); pollution due to fossil fuel combustion products; and the ultimate effects of climate change on earth systems and the frequency of extreme weather events, which can undermine the political stability of lesser developed nations.

These issues are exacerbated by the accelerated demand for fossil fuels by developing countries – most notably, India and China – and the problem of greenhouse gas emissions. The extraordinary problems posed by fossil fuel use call for a definitive response: our nation and the world must make a long-term commitment to a transition to clean energy.

CLEAN ENERGY

Today, clean energy encompasses a broad suite of technologies in combination with rapid progress towards greater efficiency in our entire system of energy use. The broad appeal of truly renewable resources – including photovoltaic, biofuel, wind and wave energy – is tempered by the fact that they afford low power per footprint area and remain expensive relative to conventional sources. In addition, the lack of economically viable storage schemes for electricity impedes the widespread connection of renewable energy sources to the electric power grid.

TRANSITION

A realistic transition to cleaner energy might include technologically safe nuclear power, the development of large-scale carbon capture and storage (as with clean coal), and a preference for fuels that are less carbon-intensive per unit of combustion energy (natural gas replacing coal and oil, for example). Our nation has witnessed major shifts in energy technologies during its history, most notably wood-to-coal and coal-to-oil. Whereas these earlier transitions were motivated by availability and utility, as with liquid fuels for automobiles and airplanes, the transition to clean energy is strongly motivated by the need to stabilize energy supply and avoid disrupting the planet’s various climate systems. The long lifetime of capital investments in energy systems implies that this transition will occur over several decades.

However, the transition to clean energy is not simply a matter of shifting technologies. It will only take place if consumers demand clean energy and business, policy and regulatory environments facilitate the adoption of new approaches over the business-as-
usual strategy of combustion. Such a change will require a profound level of understanding that adopting clean energy is a cornerstone of building a secure future at the lowest overall cost. CEE is an enabling component of a larger, generational transition that will require the highest levels of American expertise and innovation.

NATIONAL NEED
Progress in clean energy requires that each stakeholder have a depth of understanding and a breadth of appreciation for the issues that affect other stakeholders. Educational programs at all levels — K-12 schools, colleges, universities, workforce training programs, communities, businesses and government — are needed to promote informed decision-making about competing energy alternatives. We need an energy-educated citizenry. Comprehensive programs in CEE are needed, then, to guide the nation towards a future in which our system of energy sources, distribution and use is resilient, affordable, and reduces the risks associated with climate change.

ENERGY EDUCATION
A focus on energy does not detract from the need to improve the performance of American students in science, technology, engineering and mathematics (STEM). Rather, clean energy is an engaging and inspiring challenge that motivates students to master and apply knowledge from these fundamental disciplines. The escalating demand for energy in the developing world also implies that well-informed diplomacy about clean energy will play a role in efforts to stabilize international relationships.

Moreover, energy education prepares those in the workforce — especially at the local level — to innovate, manufacture, install and operate clean energy systems. Community and technical colleges will play a key role in clean energy workforce development by means of (among other things) coordinated interactions with four-year colleges and universities. The myriad issues and problems of energy provide important opportunities to create multidisciplinary curricula and research environments.

PRESENT STATUS
Several national reports in closely related fields contain the same conclusion reached in this workshop: that a comprehensive and nationwide educational effort is needed to position our country favorably in terms of technology choices, job creation and international competitiveness. In Appendix IV, we summarize the conclusions of four exemplary reports: the U.S. Department of Energy’s Energy’s Energy Literacy and its 2011 Strategic Plan; the National Research Council’s Framework for K-12 Science Education; and the National Commission on Energy Policy’s Task Force on America’s Future Energy Jobs. Additional relevant reports are cited in Appendix V.
Although many energy-related offerings are sprinkled throughout our college campuses and some energy materials can be found in K-12 curriculums, the nation lacks a coordinated and sustained effort on the scale needed to accomplish the goals articulated here. A laudable effort has been launched by the U.S. Department of Energy to define and promote a common energy-learning standard under the title *Energy 101*. As indicted in this report, bringing efforts such as *Energy 101* up to scale will require a committed national program.

**GUIDING PRINCIPLES**

Any proposal to allocate resources — funding, professional time, and the focus of institutions — to the task of CEE must be justified in terms of the benefits to the nation that will result. The evaluation component of any educational initiative is critical. This workshop was limited to the development of goals and strategies. Implementation plans must be developed in which the outcomes can be measured. Preliminary analysis indicates that the return on investment can be substantial.

**THE PATH AHEAD**

The CEE Workshop was intended to initiate a national dialogue and catalyze the formation of CEE programs nationwide. The workshop brought together government leaders, industry representatives, academic experts, teachers and workforce trainers to chart the way forward. It addressed energy education opportunities in K-12 schools, community colleges, universities, workplaces, and other environments.

Detailed recommendations include the need for institutional partnerships, collaborations with scientific research facilities, the energy industry, and government. In addition to classroom learning, students will greatly benefit from service learning, internship, and international engagement opportunities.

**A NATIONAL WORKSHOP ON CLEAN ENERGY EDUCATION**

A national workshop on CEE, sponsored by the National Science Foundation, was held in Urbana, Illinois on October 13, 2011. It was organized by the University of Illinois at Urbana-Champaign in collaboration with the University of Chicago, Northwestern University, the University of Illinois-Chicago, Argonne National Laboratory and the Illinois Green Economy Network of Community Colleges. The goal of the workshop was to frame answers to the questions, “What are the crucial elements in a national program of CEE?” and “What are the best practices that a national CEE program must adopt?”

The participants included faculty from approximately 30 universities, community colleges and schools, as well as leaders from industry, government agencies, and non-governmental organizations. It was the first in a series of planned activities that will bring together experts in energy education to lead the nation in creating an energy-literate citizenry for the 21st century.
The workshop opened with welcoming remarks from Deba Dutta, Dean of the Graduate College, University of Illinois at Urbana-Champaign; Michael Hogan, President, University of Illinois; Phyllis Wise, Chancellor, University of Illinois at Urbana-Champaign; Morton Shapiro, President, Northwestern University (by video); and Eric D. Isaacs, Director, Argonne National Laboratory (by video).

The following set of speakers articulated the value of CEE, the inherent challenges of CEE, and the roles of specific stakeholders in the promotion of CEE:

George Crabtree, Distinguished Fellow at the Argonne National Laboratory, discussed the role of the National Laboratories in CEE. (Dinner Lecturer)

Carl Wieman, Associate Director for Science at the White House Office of Science and Technology Policy and Nobel laureate, gave the keynote address about science education (by video link).

Juergen Scheffran, Head, Research Group on Climate Change and Security, University of Hamburg, Germany, presented European and international perspectives on energy education.

Mathew Inman, Albert Einstein Fellow at the Department of Energy, discussed the U.S. Department of Energy initiative to promote energy literacy.

Joel Cutcher-Gershenfeld, Dean of the School of Labor and Employment Relations at the University of Illinois at Urbana-Champaign, summarized the results of stakeholder alignment survey (given in Appendix 3).

A five-member panel discussed the goals and challenges of CEE from diverse viewpoints. The session was moderated by Joel Cutcher-Gershenfeld. The panel members were:

Theresa Maldonado, Director, Division of Engineering Education and Centers, National Science Foundation.

Paul Ritter, President-elect, Illinois Science Teachers Association and 2011-12 National Environmental Science Teacher of the Year.

William Goran, Director, Center for the Advancement of Sustainability Innovations, U.S. Army Construction Engineering Research Laboratory.

Jeff Walk, Director of Science, the Nature Conservancy in Illinois.

David Schejbal, Dean of Continuing Education, Outreach and E-Learning, University of Wisconsin-Extension.

Participants then divided (according to self-identified expertise) into six breakout sessions to draft recommendations on the following topics: an energy-literate citizenry; K-12 education; interdisciplinary and cross-institutional education; workforce development; business and industry; and international engagement. These breakout sessions compiled action items, which are included in the Priority Recommendations section of this report.
1. Develop systems thinking and an understanding of clean energy systems.

Thinking about energy requires a systems approach in which complex problems are evaluated from a range of perspectives. Energy systems in particular require consideration of cost, supply, environmental, and security issues. However, studies have shown that systems thinking demands a skill set that is difficult to teach and learn. Educational tools such as computer-based simulations, professional role-playing, and mentoring from multiple disciplines are essential for developing systems thinking. It is also important to note that CEE crosses traditional boundaries between disciplines and across vertical strata in educational organizations.

2. Cultivate active stakeholder networks.

CEE is interdisciplinary and involves diverse sets of stakeholders from several domains. Effective CEE will occur only when the stakeholders in a given domain engage, dialogue, and align around themes with relevance both for the immediate term (such as job creation) and long term (such as energy literacy and public policy). To address the complexity of such educational issues, stakeholder groups are needed that represent inter-institutional, local, regional, and national interests. Network relationships do not just happen by themselves, however. Incentives must be aligned, appropriate forums and communication mechanisms must be established, and barriers must be overcome. The process of developing network relationships should be facilitated by experts on stakeholder relationships and effective communication.
3. Define multiple literacies.

Energy literacy is comprised of multiple literacies that differ in content depending on the needs of the constituency. What the energy-literate citizen needs to understand is different from what an engineer, a business decision-maker, or a policymaker needs to understand. Defining the contents of various energy literacies involves two challenges:

a. Each literacy must recognize and embrace different knowledge (epistemic) frameworks and sets of values. The underlying complexity will not be resolved simply by adding more knowledge, but by forming authentic, creative, and inclusive partnerships among the social, natural and engineering sciences.

b. Concepts and information from one domain, such as a research lab or engineering firm, must be translated in order to be understood in a different domain, such as the classroom, the board room, or the living room. Moreover, individuals operating within one domain must appreciate the origins and legitimacy of viewpoints from other domains.

4. Facilitate institutional transformation.

The topic of clean energy has relevance in K-12 schools as a means to teach STEM subjects and to prepare the future STEM workforce; in colleges and universities as a means to engage cross-disciplinary thinking; and in industry as a pathway to enhance the bottom line by reducing the costs associated with energy consumption and emissions. But for CEE to take hold in these environments, institutional transformation must take place. This requires a process of stakeholder alignment and establishing incentives and rewards that validate CEE. In K-12 schools, for example, the subject of clean energy must be recognized, understood and incorporated at all levels: the school board, curriculum developers, principals, teachers, parents, and students. At universities, different disciplines must have a recognized institutional space under which to develop interdisciplinary CEE courses, programs, and joint degrees. Businesses and non-profit corporations, along with state and federal agencies, must establish the means to work collaboratively amongst themselves and to financially support the interdisciplinary work of CEE.
ENERGY-LITERATE CITIZENRY

• Create a clear, common definition of “clean energy.” In the absence of consensus on “clean,” just refer to “energy education.”

• Provide systematic education about energy processes and technologies to all citizens – youth and adults.

• Offer non-value-laden teaching to both youth and adults; offer education, in other words, not propaganda or advocacy.

• Encourage and provide opportunities for collaborations among and between K-12 educators, university professors, college instructors and K-12 students.

• Encourage interdisciplinary education of energy systems in post-secondary education; find ways to convey knowledge about energy systems to less technically-minded individuals.

• Develop train-the-trainer workshops for K-12 educators.

• Fund energy fellows who would provide workshops and classes to communities on an as-requested basis.

• Provide literature and information in common areas, such as public libraries.

• Offer education to adults through TV, radio and public transit public service announcements.

• Create a national online “Energy Dashboard” which would help people understand their local energy consumption as well as local, national, and global energy grids.

K-12 EDUCATION

• Expand the role of national and government-funded laboratories to educate and train teachers through institutes or workshops.

• Create and offer online courses and curricular materials, including models and simulations, on energy to train K-12 teachers.

• Expand and strengthen the online availability of high-quality resources in energy education for K-12 teachers.

• Increase the requirement for K-12 energy education outreach in federally funded projects.
MULTIDISCIPLINARY EDUCATION

- Form authentic, creative, and inclusive partnerships among social, natural, and engineering sciences from the formulation to the implementation stage of CEE.

- Support energy education at all levels and types of institutions.

- Promote CEE using integrated and creative pedagogic strategies at a diverse and networked suite of educational and non-educational institutions.

- Develop and implement a means of attracting and sustaining resources for CEE programs.

- Identify and assess benchmarks for energy education competency, certification, or desired skill-set outcomes.

- Encourage cooperation, collaboration, and possible restructuring within and among involved funding agencies.

WORKFORCE DEVELOPMENT

- Develop and widely disseminate career pathways maps for those interested in clean energy development, implementation, and education.

- Facilitate dialogue among the stakeholders – employers, future workers, and educational institutions.

- Articulate the types of workforce literacies and identify the systems interaction among them.

- Create comprehensive skills standards in partnership with business and industry.

- Define a system of credentials that can be earned by individual workers and an accreditation mechanism for meeting skills standards.

BUSINESS AND INDUSTRY

- Educate all members of a business – from executives to line workers – in clean energy principles, technology options, performance characteristics, selection criteria, implementation practices, operating procedures, and environmental and social impacts.

- When a company receives business or innovation incentives from government, it should be required to give back to society by contributing professional expertise towards CEE in schools.
• Provide business leaders with skills relevant to clean energy, including marketing, financing, communication, government policy, social sciences, and general business (assets, liability, accounting) policy.

• Promote industry-university and industry-community college partnerships and collaboratively create CEE incubators.

• Educate students and make them familiar with the issues surrounding both conventional and clean energy systems.

• Young alumni working in clean energy fields should go back to their colleges after a few years of experience and inform the schools of the skills and education components that would better prepare future students for clean energy jobs.

• Faculty should be encouraged to collaborate with business and industry in clean energy and take what they learn from such collaboration back to the students.

INTERNATIONAL ENGAGEMENT

• Create sister universities that would offer energy curricula at a similar level and for reciprocal credit that presents national and regional perspectives of energy history, resources, challenges and aspirations.

• Develop and promote year-abroad exchanges of students with a focus on energy, allowing them to experience personally the energy practices and culture of different regions.

• Offer lifelong learning courses and workshops on new developments in global, regional and national energy issues for reciprocal credit.

• Establish “International Energy Studies” as a new field of academic research and teaching. This field would be interdisciplinary and focus on the distinctive characteristics of each nation or region that shape its energy culture, practices, attitudes and aspirations. It would include studies of energy-embracing technology, economics, society, policy, business, history, and other subjects.

• Create a mechanism within international energy education to identify and propagate best practices to other regions.

• Identify and codify common principles of workforce clean energy training and K-12 CEE for international implementation.
This national workshop was organized in response to the challenges of developing a comprehensive program of CEE. It took place at the University of Illinois at Urbana-Champaign in October of 2011. Approximately one hundred experts in energy research and education participated in a discussion on the need and way forward to a national CEE program.

Drawing upon the expertise of its participants, the workshop yielded several dozen specific recommendations, many of which involved the development of teaching materials, strategic support, and train-the-trainers efforts. Four principal needs in energy education emerged from the discussions:

First, because the required knowledge is inherently interdisciplinary, networks must be created that can link the necessary stakeholders and facilitate the dialogue between energy experts, educators, and students. The networks must, however, be guided by research on stakeholder alignment and the communication dynamics that assist or hinder the success of the network.

Second, because the necessary knowledge involves systems thinking, we must develop means to teach systems relationships as the framework within which energy knowledge becomes meaningful.

Third, because CEE encompasses multiple audiences with varied educational background experiences, multiple literacies that differ in content depending on the needs of the recipient must be defined. In order to define multiple literacies, authentic, creative, and inclusive partnerships among the social, natural and engineering sciences must be formed, and a process of translation must occur in order for concepts and data from one domain to be understood in another.

Fourth, institutional transformations must be encouraged to advance CEE’s relevance in K-12 schools as a means to teach STEM subjects and to prepare the future STEM workforce; in colleges and universities as a means to engage cross-disciplinary thinking; and in industry as a pathway to enhance the bottom line by reducing the costs associated with energy consumption and emissions. These transformations will require a process of stakeholder alignment and establishing incentives and rewards that validate CEE.
MOVING FORWARD

The organizing group of the first workshop will be expanded to include a broader set of advisors, including representatives from education, business and government from Europe and Asia. A series of globally-oriented meetings will be held. These will be structured as working groups, each of which will engage in a specific initiative and report on progress at the following meeting.

The workshop participants recommend the following first round of actions in order to set the process of CEE in motion:

**Colleges and Universities:**
Create and support cross-disciplinary opportunities for CEE and training.

**Government Funding Agencies:**
Align funding streams to strategic CEE needs.

**K-12 Policymakers:**
Incorporate CEE into state learning standards.

**K-12 Curricular Leaders:**
Partner with college and university faculty to create educational units focused on CEE.

**Business and Industry:**
Engage and support networks to create coordinated pathways for CEE and workforce development.

**NGOs (including Educational, Environmental, Informal and Lifelong Learning):**
Promote an energy literate citizenry for individuals not yet or no longer in formal educational settings. Instill an appreciation of the earth, its resources, and the role of energy systems in our lives.
APPENDIX I: WORKSHOP AGENDA

OCTOBER 12, 2011
Illini Union Room 314A

6:00 p.m.  Reception
6:45 p.m.  Dinner Lecture
George Crabtree, Distinguished Fellow, Argonne National Laboratory

OCTOBER 13, 2011
Illini Union Rooms A/B

8:30 a.m.  Welcome
Debasish Dutta, Dean, University of Illinois at Urbana-Champaign
Michael Hogan, President, University of Illinois
Morton Shapiro, President, Northwestern University
Eric D. Isaacs, Director, Argonne National Laboratory

9:00 a.m.  Federal Address
Carl Wieman, Associate Director for Science, White House Office of
Science and Technology Policy, and Nobel laureate

10:00 a.m.  UI Perspective
Phyllis Wise, Chancellor, University of Illinois at Urbana-Champaign

10:05 a.m.  Break

10:15 a.m.  Panel Discussion
Theresa Maldonado, Director, Division of Engineering Education and
Centers, National Science Foundation
Paul Ritter, President-elect, Illinois Science Teachers Association and
2011-12 National Environmental Science Teacher of the Year
William Goran, Director, Center for the Advancement of Sustainability
Innovations, U.S. Army CERL
Jeff Walk, Director of Science, the Nature Conservancy in Illinois
David Schejbal, Dean of Continuing Education, Outreach and
E-Learning, University of Wisconsin-Extension
Moderator: Joel Cutcher-Gershenfeld, Dean, School of Industrial and
Labor Relations, University of Illinois at Urbana-Champaign

11:15 a.m.  EU Perspective
Juergen Scheffran, Head, Research Group on Climate Change and
Security, University of Hamburg, Germany
12:00 p.m.  Close of Morning  
John Abelson, Chair of the Clean Energy Education Initiative and co-Director of the Energy and Sustainability Engineering Initiative, University of Illinois at Urbana-Champaign

12:15–1:30 p.m.  Posters  
Energy Education and Student Engagement

12:15 p.m.  Lunch  
Illini Union Room C

12:45 p.m.  Energy Literacy  
Mathew Inman, Albert Einstein Distinguished Educator Fellow, U.S. Department of Energy

1:05 p.m.  Stakeholder Survey  
Joel Cutcher-Gershenfeld, Dean of the School of Labor and Employment Relations, University of Illinois at Urbana-Champaign

1:15 p.m.  Breakout  
John Abelson

1:30–4:00 p.m.  Breakout Sessions  
Illini Union 4th Floor

Energy-literate Citizenry  
K-12 Education  
Interdisciplinary and Cross-Institutional Education  
Workforce Development  
Business and Industry  
International Engagement

4:15–5:15 p.m.  Plenary Report-back from Breakout Sessions  
Illini Union Rooms A/B

5:30–6:15 p.m.  Reception  
Levis Center, 2nd Floor

6:15 p.m.  Concluding Dinner  
Levis Center, 2nd Floor
APPENDIX II: WORKSHOP PARTICIPANTS

John Abelson, University of Illinois at Urbana-Champaign
Firas Akasheh, Tuskegee University
David Allen, University of Texas
Weslynne Ashton, Illinois Institute of Technology
Susan Barker, Southwestern Illinois College
Stephen Bell, Illinois Green Economy Network
David Bergandine, University Laboratory High School
David Blockstein, National Council for Science and the Environment
Douglas Brauer, Richland Community College
Allessandra Cairo, Illinois Green Economy Network
Bridget Calendo, Northwestern University
Thomas Canam, Eastern Illinois University
Dale Chapman, Lewis and Clark Community College
Michael Chimack, University of Illinois
George Crabtree, University of Illinois-Chicago/Argonne National Laboratory
Jay Curtis, Illinois Department of Natural Resources
Susan Czerwinski, Lewis and Clark Community College
Harry Dankowicz, University of Illinois at Urbana-Champaign
Noah Davis, Solar Energy International
Brian Deal, University of Illinois at Urbana-Champaign
Karen Decker, University of Illinois at Urbana-Champaign
Lizanne DeStefano, University of Illinois at Urbana-Champaign
Maryalice Drain, Northern Illinois University
Debasish Dutta, University of Illinois at Urbana-Champaign
Robert Ehrlich, George Mason University
Julie Elzanati, Illinois Green Economy Network
Torsten Fransson, Royal Institute of Technology
Cassie Freeman, Climate Cycle
William Goran, U.S. Army Corps of Engineers
Amanda Graham, Massachusetts Institute of Technology
Sallie Greenberg, Illinois State Geological Survey
Bruce Hamilton, National Science Foundation
Jeff Henderson, Northwestern University
Robert Herendeen, University of Vermont
Doug Hermann, AECOM
Katie Hicks, Orpheum Children’s Science Museum
Franklin Holcomb, U.S. Army ERDC-CERL
Larry Holloway, University of Kentucky
Robert Hotes, Center for Workforce Development, Southern Illinois University
Matthew Howard, Argonne National Laboratory
Kristen Hughes, University of Delaware
Nick Hylla, Midwest Renewable Energy Association
Matthew Inman, U.S. Department of Energy
Bert Jacobson, Kankakee Community College
Jin Jo, Illinois State University
Ellen Kabat Lensch, Eastern Iowa Community College District/Advanced Technology Environmental and Energy Center
Michael Kaminski, Argonne National Laboratory
David Kennell, Illinois State University
Rob Kerr, Illinois Community College Board
Cynthia Klein-Banai, University of Illinois-Chicago
Paul Komor, University of Colorado, Boulder
Frankie Laanan, Iowa State University
David Larrick, Richland Community College
Richard Lawrence, North American Board of Certified Energy Practitioners (NABCEP)
Gary Letterly, University of Illinois at Urbana-Champaign
Allan Levandowski, College of Lake County
Brian Lilly, University of Illinois at Urbana Champaign
Tim Lindsey, University of Illinois at Urbana-Champaign
Peter Liu, Eastern Illinois University
Marcia Lochmann, Lewis and Clark Community College and the National Great Rivers Research and Education Center
David Loomis, Illinois State University
Theresa Maldonado, National Science Foundation
Josh Manders, Lane Community College/Northwest Energy Education Institute
Cathy Manduca, Carleton College
Christopher Miller, Heartland Community College
Liz Moyer, University of Chicago
Jeff Oder, Lake Land College
Tim Ohno, Colorado School of Mines
Gwen Pollock, Illinois Science Teachers Association
Ruth Porter, Rico Enterprises
Melur Ramasubramanian, National Science Foundation
Bill Reany, Southwestern Illinois College
John Rico, Rico Enterprises
Loretta Roberson, University of Puerto Rico, Rio Piedras
Jim Roberto, Oak Ridge National Laboratory
Massoud Rostam-Abadi, Prairie Research Institute
Joe Sarubbi, Interstate Renewable Energy Council
Juergen Scheffran, University of Hamburg
David Schejbal, University of Wisconsin-Extension
Julia Schroeder, John A. Logan College
Thomas Seager, Arizona State University
Brent Shraiberg, Clean Energy Trust
Andrew Skipor, Argonne National Laboratory
Scott Sklar, GWU, The Stella Group, Ltd, Sustainable Energy Coalition
William Sullivan, University of Illinois at Urbana-Champaign
Mitchell Thomashow, Second Nature
Tod Treat, Richland Community College
Jeff Walk, Illinois Chapter of The Nature Conservancy
Chris Walti, Acciona Energy
Timothy Wilhelm, Kankakee Community College
Scott Willenbrock, University of Illinois at Urbana-Champaign
Aida Sefic Williams, University of Illinois
Scott Williams, University of Wisconsin-Madison
J. Russell Willis, Grambling State University
Dave Wilms, Adlai E. Stevenson High School
Jason Zielke, Clean Energy Trust
APPENDIX III: STAKEHOLDER ENGAGEMENT AND WORKSHOP SURVEY RESULTS

What are the strengths of the workshop?

- The partnership of universities + Argonne putting this together – real strength and commitment and thoughtfulness apparent.
- Dedicated steering committee and facilitators/scribes
- Valuable plenaries (Crabtree, Wieman) to establish common foundation
- Facilitated discussion was good
- Wieman’s presentation was excellent, but even he tended to equate energy with physics
- Panel discussion – innovative and informative
- Breakout sessions – useful to provide materials up front
- Key goals and objectives CLEARLY outlined
- Tight schedule and flow of presentations, then worked
- Great group of interdisciplinary stakeholders
- Diversity of opinions and experiences. I got a good list of people that I can follow up with.
- It was great to hear the speakers – there was a good variety of views and high level of expertise.

What issues were overlooked in the presentations and discussions?

- Was glad the energy literacy working group problematized “CEE” title. That, in many minds, is the equivalent of renewables and that misses efficiency, demand side, and how to craft pathways from 85% reliance on fossil fuels.
- Finite globe. Equity aspects of energy policy (or non-policy), economics (prices as driver of energy consumption and of industry response). Explicit time scales.
- That the “other” literacies (ocean, climate, environmental, scientific, etc.) and clean energy literacy all contribute to this systems thinking that ought to be over-arching for whole conference effort with a starting point of clean energy and how it fits into the science system.
- Capitalism and energy can be at odds.
- Energy is only part of the bigger sustainability picture.
- It would have been nice to have had a business speaker in the morning session to talk about how they perceive importance of CEE.
- Contact and information with lay people – how can we make sure we reach them effectively.
- More K12 science teachers (teach leaders, maybe some from K12 teach associations, etc.) representation.

What were the weaknesses of this workshop?

- Capture and documentation. Always a challenge with an engaged and passionate group! Students could help capture – have one or two transcribing in real time, to aid or relieve faculty-level leads/scribes. The words of the group matter.
- Too short: Not enough time for participants relaxed enough to convey agendas and concerns. Too much formal presentation relative to breakout sessions. Technical orientation (new energy supply
technology) was stressed over society-wide perspective. Almost no reference to global problems. Too many administrator welcomes.

- More interaction time at lunch. And more time at breaks to see the posters.
- Need better representation from all players in the energy education system.
- There should have been more time for the workgroups.
- Lack of humanities/social science involvement
- The breakout sessions were not allotted sufficient time to discuss all the issues we wanted to cover – need to follow-up discussions.
- Too academia-focused, introduction/welcome too long, presentations were too basic for audience. Needed much more time for main objective of workshop! Breakout sessions should have been almost all day for us to get even close to meeting the objectives.

What type of follow-on activity would advance CEE?

- More working time on key common principles and/or recommendations to flesh them out. Specific engagement of/with humanities, arts, social sciences, education research, interdisciplinary research into education (e.g., Lisa Lattuca, Julie Thompson-Klein, possibly Roland Shultz re: trandisciplinarity).
- I was in the K12 breakout group. How do we do “clean” energy education, ground water, climate change, etc. Yes, energy touches the topics I listed – we need to address the entire science curriculum.
  1) Based on national priorities
  2) With the policy people (no child left behind) and NSF people pulling in the right/same direction
  3) To make sure that colleges and universities are not just herding K6 teachers through physics 101, chemistry 101, etc.
- If energy is a priority – and it should be – what do we most want a teacher at grade 3-6 to focus on. Then, restrict or beg the university to offer training on the national priorities and key concepts – increase the content for teachers in grade 7-10, etc. Like EMTs, medical care begins with them; energy ed begins at 3rd grade or so.
- We can’t make every K6 teacher as “well-qualified” as a high school teacher. The K6 teacher has to have had “useable” training in so many areas – they can’t be “expert” in all. If they know enough content and inquiry-based practices/activities, we can progress from there.
- Continuing contact with attendees/invitees; draft proceedings sent electronically.
- Have a group look at new potential uses of the video streaming and conferencing for advancing clean energy concepts.
- Working groups – perhaps cross-cutting themes.
- The workgroups should meet again to continue and expand discussion.
- Open discussion to workgroup participants, even if they did not participate in a specific group – allow overlap, since it occurs in the field.
- There need to be consortia among all stakeholders to meet regularly to share information and best practices.
- Emailed news updates, teacher training workshops, funding clearinghouse online.
APPENDIX IV: COMPLIMENTARY CEE RESEARCH AND REPORTS

1. U.S. DEPARTMENT OF ENERGY - ENERGY LITERACY: ESSENTIAL PRINCIPLES AND FUNDAMENTAL CONCEPTS FOR ENERGY EDUCATION.

The Energy Literacy: Essential Principles and Fundamental Concepts for Energy Education report was released in March 2012. The development of the document began at a workshop sponsored by the U.S. Department of Energy (DOE) and the American Association for the Advancement of Science (AAAS) in the fall of 2010. Multiple federal agencies, non-governmental organizations, and numerous individuals contributed to development of the guide through an extensive review and comment process. Discussion and information gathered at AAAS, WestEd and DOE-sponsored Energy Literacy workshops in the spring of 2011 contributed substantially to the refinement of the guide.

Below are several incepts from the document that align with the recommendations and perceived challenges stated during the CEE workshop and presented in this report.

“The Essential Principles of Climate Science presents information that is deemed important for individuals and communities to know and understand about Earth’s climate, impacts of climate change, and approaches to adaptation or mitigation. Principles in the guide can serve as discussion starters or launching points for scientific inquiry. The guide aims to promote greater climate science literacy by providing this educational framework of principles and concepts. The guide can also serve educators who teach climate science as a way to meet content standards in their science curricula.”

“To protect fragile ecosystems and to build sustainable communities that are resilient to climate change – including extreme weather and climate events – a climate-literate citizenry is essential. This climate science literacy guide identifies the essential principles and fundamental concepts that individuals and communities should understand about Earth’s climate system. Such understanding improves our ability to make decisions about activities that increase vulnerability to the impacts of climate change and to take precautionary steps in our lives and livelihoods that would reduce those vulnerabilities.”

To download this guide and related documents, visit www.climatescience.gov.

2. U.S. DEPARTMENT OF ENERGY - 2011 STRATEGIC PLAN.

“National energy goals will be achieved only through economy-wide energy transformation. The Department will use its technical expertise and analytic capabilities in a transparent and unbiased manner to inform decisions in government policy-making, the marketplace, and households. Because today’s young generation are tomorrow’s world leaders, we will champion outreach through competitions, project-based learning, interactive gaming, and social media. By using today’s technologies to inspire the country’s most aspirational and imaginative citizens, we will create the momentum necessary to meet our energy goals.”

“Excellent scientists, technologists, and engineers are the creative engine of the Department. The
Department and its national laboratories must cooperate to create conditions that allow today’s researchers to be as productive as possible, as well as to ensure an adequate supply of tomorrow’s researchers. Investments will help develop the next generation of scientists and engineers to support Department missions, administer its programs, and conduct the research that will realize the nation’s science and innovation agenda. These investments will enrich the diversity of the STEM pipeline so that it is more inclusive of women, minorities, and persons with disabilities while mentoring the next generation of scientists, technologists, and engineers.”

3. COMMITTEE ON CONCEPTUAL FRAMEWORK FOR THE NEW K-12 SCIENCE EDUCATION STANDARDS, NATIONAL RESEARCH COUNCIL - A FRAMEWORK FOR K-12 SCIENCE EDUCATION: PRACTICES, CROSSCUTTING CONCEPTS, AND CORE IDEAS.

“The Committee on a Conceptual Framework for New K-12 Science Education Standards was charged with developing a framework that articulates a broad set of expectations for students in science. The overarching goal of our framework for K-12 science education is to ensure that by the end of 12th grade, all students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology.”

“To support students’ meaningful learning in science and engineering, all three dimensions need to be integrated into standards, curriculum, instruction, and assessment. Engineering and technology are featured alongside the natural sciences (physical sciences, life sciences, and earth and space sciences) for two critical reasons: (1) to reflect the importance of understanding the human-built world and (2) to recognize the value of better integrating the teaching and learning of science, engineering, and technology.”

“The broad set of expectations for students articulated in the framework is intended to guide the development of new standards that in turn guide revisions to science-related curriculum, instruction, assessment, and professional development for educators. A coherent and consistent approach throughout grades K-12 is key to realizing the vision for science and engineering education embodied in the framework: that students, over multiple years of school, actively engage in science and engineering practices and apply crosscutting concepts to deepen their understanding of each field’s disciplinary core ideas.”
4. NATIONAL COMMISSION ON ENERGY POLICY - TASK FORCE ON AMERICA’S FUTURE ENERGY JOBS: EXECUTIVE SUMMARY AND POLICY RECOMMENDATIONS.

“As a starting point, Task Force members shared a common recognition that the electric power sector faces near- and long-term workforce challenges. Its workforce is aging and will need to be replaced. Facing a wave of retirements over the next decade, the electric power industry will need to expand hiring and training programs just to maintain the level of qualified workers required to operate existing facilities. In fact, new workers will be needed to fill as many as one-third of the nation’s 400,000 current electric power jobs by 2013. In the face of this surge in demand, companies are finding that applicants for open positions at electricity companies are not as prepared as they were in decades past. Companies are finding that U.S. students are not graduating at the same rates in the relevant fields and with the same qualifications as in the past. While the Task Force focused on direct electric power sector jobs, the Task Force members recognize that other economic sectors, such as the manufacturing sector, face similar demographic, education, and training challenges.”

“In the long-term, the deployment of new technologies and generating assets— including new energy efficiency, nuclear, renewable, advanced coal with carbon capture, and smart grid technologies — will require new design, construction, operation, and maintenance skills. This is an important opportunity for new job creation and economic growth. If too few individuals with the necessary expertise are available when they are needed, workforce bottlenecks could slow the transition to a low-carbon economy regardless of the commercial readiness of the underlying technologies. If the result is to delay the efficient adoption of improved lowcarbon alternatives, workforce shortages would represent more than a lost opportunity – they could impose substantial costs, both in terms of economic burden and environmental damages and could damage U.S. global competitiveness.”
APPENDIX V: REPORTS FROM THE BREAKOUT SESSIONS

The following sections of the workshop report include the summaries of the individual workgroup reports. The reports were compiled by the moderators and scribes of each breakout group. The final version of the report was edited and was agreed upon by all work group participants.

ENERGY-LITERATE CITIZENRY WORK GROUP REPORT
MODERATOR: LIZ MOYER

INTRODUCTION
In the 21st century, societies are faced with increasing pressure on resources and must make astute choices about energy sources and their efficient use. Energy literacy is at a very low level in the United States, however — arguably worse than science literacy in general. Overall, the gap between people’s actual understanding and what they need to make and support informed decisions about energy is wide. Although the modern energy system is critical to maintaining our lifestyle, most Americans lack a conceptual understanding of that system. Many have no idea where the electricity they use comes from. The lack of understanding includes many politicians and news writers/reporters, which further hinders sensible decision-making.

Improving energy literacy is made more difficult by the fact that the modern energy system is not intuitively understandable. In pre-industrial times, the energy sources and flows that supported human life — food, animal power, wood-burning for heat and manufacturing, and water wheels — were visible, human-scaled, and something with which people had everyday experience. The modern energy system is large but not immediately visible: power plants, natural gas pipelines and refineries are generally placed far from population centers, and energy undergoes many complex transformations that are also non-intuitive. In order to understand the modern, intricate energy supply chain, energy literacy requires targeted training. Further, it is important to understand and address that there are multiple energy literacies, which share a common vernacular, depending on the responsibilities of those in question (citizens, workers, business managers, lawmakers, etc.).

While acknowledging multiple literacies and styles of learning, clean energy literacy should not focus on simple memorization of facts. Instead, clean energy literacy needs to promote a fundamental understanding of the energy system, which includes energy flows, lifetimes, and budgets. The main goal of creating an energy literate citizenry is to help individuals in various settings understand the energy implications in their life and better understanding how energy policies, uses, and economies affect their personal and professional lives.

This breakout group discussed the following challenge questions on the content, educational approach, and logistics needed to reach different segments of the population — traditional students in K-12 and post-secondary educational institutions, workforce, and overall citizens.

- What list of key concepts defines the needs for an energy literate citizenry, and how can they be tied together to promote real working knowledge?
- What is the best way to provide a systematic framework for understanding the modern energy system, e.g., in terms of flows, lifetimes, and budgets, rather than memorization of factoids?
- How can engineering science be taught to non-science students? (Within this, how can we overcome attitudes such as “math-phobia” that make people pre-suppose they lack the ability to understand a topic that includes quantities, ratios and flows?)
• How can we give adults the ability to read claims about energy technology critically and judge them with reference to the knowledge in their literacy? Can we imbue them with an appreciation for simple assessments of what is possible vs. what is deception?
• What is the right timescale for teaching about energy? What teaching belongs in elementary education, junior and high schools, college, or elsewhere?
• What is the best way to reach those adults who have a wider influence in transmitting ideas, especially teachers, newspaper reporters, politicians and their staffers?
• What is the best way to reach adults who are currently outside the formal education system?

STATUS
Based on the stake-holder alignment surveys completed by workshop participants, of all the subjects covered in breakout groups, energy literacy has the worst current state and the widest gap between the present and where we would like to be as a country. Students from elementary to high schools typically receive no training in energy systems, other than possibly an overview of natural energy flows in ecology classes, and no exposure to energy technology. At the university level, training is completely absent outside the physical sciences and engineering. Even science and engineering students typically receive information only on specific topics or technologies rather than on the broader worldview needed for systematic thinking.

While considerable effort will be needed to foster energy literacy in schools, a second formidable problem is to reach adults who have left the academic system. Once a person’s formal education is complete, knowledge of new scientific developments occurs only through informal (and sometimes inaccurate) channels, including the media and social networks. For the majority of the population, there is no clear path to remediating a lack of prior training or providing knowledge about new developments in energy. It would appear that improving energy literacy is a ground-up task, since we need to develop appropriate learning material that has a stable and sustainable role in the formal academic system, and we must identify a means to reach adults who have left the academic system.

Various efforts to improve energy literacy are currently ongoing and should be networked in a complementary manner. Several agencies and organizations have begun efforts to provide energy-based curriculum units, including a U.S. DOE effort to provide college teaching materials under the rubric of “Energy 101.” Multiple programs have been created to bring information about specific aspects of energy, usually “green” energy, to the public. Examples include the Big Green Bus, a rolling science lab and energy efficiency exhibit (including basic sustainable living practices such as energy efficient appliances to do-it-yourself biofuels, Eagan et al., p. 24) and the American Solar Energy Society’s National Solar Tour (Lung). Very little broad-based energy education exists, however, and tours sponsored by specific energy industries or interests may not provide a complete picture of energy challenges and opportunities.

NEEDS, OPPORTUNITIES, AND CHALLENGES
In order to achieve widespread energy literacy across the American and global population, a campaign should be launched by a cross-disciplinary group of stakeholders, which would reach a wide range of society, including people outside the formal educational system. In principle, the program should aim to reach all segments of the population. The effort cannot rely only on providing materials that people must seek out; it must also identify and devise means to engage people directly. It may be wise to tap into existing networks or programs for this purpose. By expanding the reach of clean energy education outside of the classrooms to individuals outside of the traditional educational environment, an increased number of individuals within the American population can be reached, increasing the clean energy literacy of the broader citizenry. Success can be measured through the frequency and use of resources. More importantly, energy literacy can be further evaluated through voluntary citizen surveys. Ultimately, increased energy education resources will provide citizens with more access to systematic understanding of energy processes and technologies, helping them better evaluate claims made by various sources, and further aid them in day-to-day energy-related decisions.

A challenge to creating an “energy literate citizenry,” is finding an agreed-upon definition of “clean energy.” Currently, this definition varies widely and greatly depends on an individual’s exposure to energy education and experience. In
order to create a common vernacular and common understanding of clean energy, educators and information givers must first define what the term “clean energy” entails. Furthermore, a crucial step in creating an overall energy literate citizenry is to tie the key points of individual literacies together to promote a real working knowledge of clean energy literacy. A review of the education materials provided by various stakeholders can be utilized to evaluate the commonality of language between various teaching groups and organizations. A clear definition of clean energy would ultimately impact the nation by sharing a common definition and vernacular, furthering the same knowledge and definitions throughout the population, creating a common energy literacy.

Traditional K-12 education should be provided with clean energy education resources that schools cannot generate themselves. By connecting K-12 schools to universities and community colleges, as well as each other, clean energy education can be expanded by sharing best practices, along with existing and revised curricula, teacher training, materials for hands-on labs, and contacts, as well as invitations for field trips. As clean energy education gains national traction, it is crucial for educators to work together to pool their resources, which would establish stronger relationships across various education systems; additionally, this would create a more efficient local, regional and national educational system where teachers can share educational materials, working together to reach the common goal of clean energy education literacy within the K-12 sector. The success of this plan can be measured through the number of regional and national collaborations, commonality between curricula, and students’ understanding of energy concepts. Finally, as energy is introduced to students at a younger age, they will be able to build upon that knowledge and make educated decisions in their professional and personal lives once their traditional educational career has concluded.

It is important to acknowledge that students will only be able to learn effectively if their instructors have a working knowledge of the concepts they are teaching. Therefore, it is integral to establish Train-the-trainer workshops for teachers, to include not only content but information on pedagogical methods. These workshops can be further strengthened through the funding of NSF Education Fellows who can offer both teacher training and/or classroom demonstrations. By effectively training the teachers who are responsible for delivering clean energy, a uniform national education plan can be developed, and clean energy education can be incorporated into the current curriculum seamlessly. Further, by educating the teachers, who further educate the students, more clean energy education will be dispersed throughout the population and reaching an overall wider audience of clean energy supporters.

For post-secondary educational institutions, sharing of curricular materials is helpful in creating a collaborative environment and spreading clean energy education to a wider population. Presently, energy education has been mostly concentrated within the sciences, isolating non-science and math majors and leaving them without an energy education. In order to reach a wider citizenry, clean energy education needs to incorporate inter-disciplinary education to less technically-minded students. To effectively reach both audiences, the subject matter should be approached by explaining scientific principles through vernacular common to both groups of students, and the education should focus on the fundamental understanding of the systems and their applications in today’s world, rather than fact memorization and further alienation of less technically minded students. A possible baseline and metric is to survey and rank universities according to the energy literacy or basic science literacy of students. Inter-disciplinary education can also be measured by evaluating the number of classes opened to a large audience of students from a variety of different professions. As both groups of students leave the traditional education system, they can make informed decisions throughout their life, affecting them individually, but also affecting the overall energy grid in the long term.

Since the focus is on clean energy education, it is important to think outside of the classrooms —clean energy knowledge should be disseminated to the overall population, youth and adults alike. Reaching traditional students is more straightforward, since they are already in classrooms; the main challenge clean energy educators face successfully reaching the adult population that is outside of the traditional classroom environment. Since these individuals make daily choices related to energy systems, educating them is vitally important. Therefore, a method for reaching such individuals, speaking to them in a manner that would interest them, and finally enriching them with broad-based energy knowledge is imperative. Success of clean energy dissemination can be measured through voluntary household surveys about clean energy and their applications in adults’ lives. Further, overcoming the burden of reaching the adult population and finding a way to successfully relay information to them is a critical step in educating the population in clean energy concepts. Significantly, an energy literate citizenry would be able to critically examine claims by various
sources and make informed personal and professional decisions based on their knowledge of clean energy.

A challenge of clean energy education is to encourage non-value-laden teaching, especially when teaching students outside of the traditional classroom environment. We caution that at present the term “clean energy” is ill-defined; this may present a problem, as it is crucial to avoid any semblance of implied judgments or political implications. Therefore, a national program should focus on energy education, with the perspective that students should come to their own conclusions. This approach will engage a larger number of citizens and increase the impacts with regards to consumer and policy decisions about energy.

Clean energy education presents a particular education challenge, since it is often much easier to teach facts and memorize numbers, rather than teaching a wider, systematic approach to energy. By simply sharing facts for individual to memorize, life-long learning of education systems is not supported. Therefore, human energy use should be placed in the framework of the Earth’s energy system and of mankind’s diversion of energy from natural energy flows. Students (traditional and non-traditional) should understand relative sizes of resources (renewable, fossil or nuclear) and be able to compare those to current human usage. Further, by providing a systematic approach to clean energy education, a citizenry more literate in energy could better define, understand, and impact energy standards and policies affecting their lives directly. Additionally, these individuals would understand that the present energy system is a construct, built by humans. It is important to emphasize current choices and their time spans of influence (typically the lifetimes of investments), the scale of the energy system, and the concept that changes are coming inevitably as resource depletion means that use must shift. In addition, a better systematic approach to clean energy education will instill confidence for non-technical people, who may currently shy away from energy-related topics and decisions, due to their lack of fundamental energy understanding.

NEW PROGRAM RECOMMENDATIONS

In order to facilitate clean energy education among adults who are outside of the traditional educational environment, we recommend the creation of regional clean energy education fellows who offer on-demand instruction or advising for civic groups, governments, workforce development programs, corporate workshops, farmers’ groups, church groups, and other requesting instruction. These positions are modeled on agricultural education agents, but might be on the postdoctoral level. They should tap into existing local resources and can serve as a resource for community development. Further community-wide educational tools aimed at increasing clean energy education include mini-courses available for community groups, government aides, reporters, and others. Agency funding would support the teaching (perhaps by clean energy education fellows) and possibly participation expenses as well. The success of these measures can be evaluated through website visitor counters, information about use of resources within the public sector, as well as community surveys. The success of these programs can be measured by the number of workshops held by the fellows, number of community members served, and other similar metrics. The creation of regional, fellows would aid community learning to interested groups, within an environment open to learning, providing additional non-value-laden support for a clean energy literate citizenry.

Further community-wide education for adults could include educational resources for use by the public (and by the energy fellows), which would include basic slide decks on energy flows and energy technologies, fact-sheets, wallet cards, maps of resource flows and energy use, and other tools (including conversion apps). This information can be disseminated through a well-designed website (including links to other resources) and public service organizations, such as public libraries. Further, clean energy education can also be dispersed by energy utility providers to local households, where clean energy education can be encouraged through fact sheets to be included with electronic and paper bills. Readily-available materials can serve self-motivated individuals who want to learn more about a topic and further aid in the dispersion of clean energy education throughout the nation.

Additional energy literacy strategies include public service announcements for television, radio, public transit system announcements and similar avenues that provide basic information in readily understandable form (e.g., “Your food energy consumption is like one light bulb”). New announcements should be modeled on popular and effective campaigns of the past (e.g., “Conjunction Junction,” “How a Bill Becomes a Law”). Again, it is important to ensure that announcements are education rather than propaganda and are not value-laden. The added knowledge of energy
facts and their applications can generate interest and then be used within a bigger framework for thinking about energy issues on a local, regional and national scale.

One way to increase clean energy education is by providing individuals with a better understanding of their own individual impacts of energy. By better understanding the energy impacts on their life, citizens would be more interested in the topic. Therefore, clean energy education and awareness can be raised by providing online energy visualization tools that use advanced computation and mapping: an “Energy Dashboard” that lets people see at any given time, where in the U.S. electricity is being produced (and how much). Additional information to include in the “Energy Dashboard” would be current flows in the grid; where oil is drilled, pumped, moved, and refined; flows of natural gas; and end-use. Further, the Dashboard should include zoom features that let people explore the network of energy infrastructure in the U.S. down to the local level, which would again help the average energy consumer have a better understanding how their individual choices, as well as the choices of their friends and peers, ultimately impacts the local, national, and global energy system. The inclusion of an “odometer” that shows immediate total power usage, electricity usage, consumption of oil, gas, and coal, for national usage (denominated in total and per capita) and for utility-scale regions could provide additional information and have a lasting impact on the Dashboard users. The success of this tool can be measured by the number of users visiting the online Energy Dashboard, as well as an optional survey on the Dashboard, detailing how people utilize the information they receive from the website. This tool could be used by traditional students, but it should also be advertised by students outside of the traditional learning environment, in order to expand their understanding of energy and help them identify how individual decisions shape the overall energy impacts.

In addition, field trips that allow groups of school students, as well as community groups, to tour energy facilities would further increase knowledge about how energy is created, and utilized. Field trips should span conventional and renewable energy sources, if possible. To provide a wider community benefit, it may be useful to work with utilities on educational outreach. In a similar vein, hands-on experiences can foster energy intuition and better understanding of clean energy concepts. People who lack experience with technology should be given a more intuitive understanding of it: opportunities to see, play, learn outside books, and experience technology in a direct way. These opportunities can start very early in the educational system (elementary school) but are useful at all levels. By measuring the number of field trips and hands-on events, as well as their attendance and target audience, educators would be able to better understand the audience and measure the success of such events. A greater number of community-wide field trips and hands-on experience could help students and all community members intuitively learn about clean energy, furthering their education and having a broader impact on their lives and future energy-related decisions.

Since many discrepancies or incorrect facts are reported through the media, an integral part of clean energy education would include the education of reporters. Educational services to the press should go beyond the web-based material already mentioned, provide funding for fellows to be on call to educate reporters or review newspaper articles or other media reports that have to do with energy to ensure accuracy and clarity. Periodic fact checks of various news sources could be used to evaluate the number of informational mistakes, whose corrections can be used to further educate the public. By providing increased factual accuracy in reporting, the overall public would become more educated as misinformation would be kept at a minimum.

**BENEFITS**

A clear definition of clean energy would impact the nation by sharing a common definition and vernacular, furthering the same knowledge and definitions throughout the population, creating a common energy literacy. Overall, the development of an energy literate citizenry will provide citizens with access to systematic understanding of energy processes and technologies, helping them better evaluate claims made by various sources, and further aid them in day-to-day energy-related decisions.

In order to spread clean energy education throughout our K-12 and post-secondary education institutions, teachers and professors need to work together to create a common curriculum and share their knowledge with one another. Increased collaboration between teachers across different educational levels would create a more efficient local, regional and national educational system. By providing an adequate platform, teachers can share classroom materials
and work together to reach the common goal of developing clean energy education literacy. As clean energy is introduced in K-12 schools and interdisciplinary classes on a post-secondary level, students will be better equipped to make informed energy-related decisions throughout their life, affecting them individually, but also affecting the overall energy grid in the long term.

Further, effective training of the teachers responsible for delivering clean energy education will aid in the creation of a uniform national education plan. Teacher training would further help clean energy education be incorporated into the current curriculum seamlessly.

An energy literate citizenry would be able to critically examine claims by various sources and assess their validity, possibility, and make informed personal and professional decisions based on their knowledge of energy. Further, a better systematic approach to clean energy education will instill confidence for non-technical people, who may currently shy away from energy-related topics and decisions, due to their lack of fundamental energy understanding.

The group recommends the creation of regional fellows, who would aid community learning to interested groups, within an environment open to learning, providing additional non-value-laden support for a clean energy literate citizenry. Their added knowledge of energy systems and their applications can generate interest and then be used within a bigger framework for thinking about energy issues on a local, regional and national scale.

Further, the creation of an “Energy Dashboard” would help individuals visualize and better understand the intricacies of the energy grid on a larger scale, as well as better understand energy distribution on a local level. Further, the citizens would gain a better understanding how their individual choices, as well as the choices of their friends and peers, ultimately impacts the local, national, and global energy system.

CONCLUSION
The creation of an energy-literate citizenry requires several important factors: Creation of a common definition of “clean energy,” cooperation of a multitude of stakeholders, and significant effort to expand the knowledge of students in traditional settings, as well as lifetime learners. A campaign should be launched by a cross-disciplinary group of stakeholders, which would reach a wide range of society, including people outside the formal educational system.

K-12 education should be facilitated through collaborations with other schools, teachers, as well as post-secondary institutions. More importantly, train-the-trainer workshops should be developed to include not only content but information on pedagogical methods. Further, post-secondary schools should focus on distributing clean energy education to multi-disciplinary audiences, including students who are traditionally less mathematically and scientifically inclined. The group also recommends the funding of NSF Education Fellows who can offer both teacher training and/or classroom demonstrations. Further, Education Fellows would also be responsible for classes and workshops that would educate the adult population, which may be challenging to reach.

To aid community teaching of youth and adults, the workgroup recommends the creation of mini-courses available for community groups, government aides, reporters, and others. Additional community-wide education for adults could include educational resources for use by the public (and by the energy fellows). Additionally, clean energy education and energy literacy can be raised by providing online energy visualization tools that use advanced computation and mapping: an “Energy Dashboard” that lets people see at any given time, where in the U.S. electricity is being produced (and how much). While these educational efforts could benefit the community at large, they are more helpful to community members actively seeking out this type of information.

In order to educate the general public who can benefit from clean energy education but is not actively searching for that type of information, public service announcements for television, radio, public transit system announcements and the like could provide basic information in readily understandable form. Finally, it is crucial to educate reporters and journalists, as they are the main educators for a large segment of the adult population. By providing journalists with correct facts and figures, and working with them to end the education gap of energy systems, we can reach our goal of an energy literate citizenry.
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INTRODUCTION
Creating a sustainable and secure American society, across all domains, begins with a knowledgeable citizenry. K-12 education is intended to prepare the nation’s children to become informed citizens who will make responsible decisions and take appropriate actions. Though the current K-12 science curriculum may not adequately prepare U.S. citizens to grapple with the growing concerns related to energy (AAAS, 2009), new approaches to K-12 energy education have the potential to broadly impact society. Although K-12 students represent only 20% of the U.S. population, they may influence the remaining 80% by acting as the levers of change in their homes, schools, and communities. For educational changes to be effective and sustainable, however, efforts must engage a range of stakeholders including K-12 students, teachers, administrators, community partners (e.g., private sector) and scientists. That engagement could occur through using dynamic, interdisciplinary energy education materials, participating in teacher training and/or building meaningful, productive partnerships among students, teachers, community members and scientists.

The topic of clean energy will not only engage students, but may increase their understanding of core science, technology, engineering, and mathematics (STEM) concepts, applications to the world, and their individual and collective decision-making responsibilities. Engaging students in STEM concepts may lead them to enter STEM fields where they may work towards developing a responsible, stable, and secure energy system.

NEEDS, OPPORTUNITIES, AND CHALLENGES
The topic of clean energy is inherently interdisciplinary and requires experience exploring and understanding complex systems and their interconnections. Though some complex systems-related concepts are found in K-12 school curricula in the physical and social sciences, such as evolution by natural selection, equilibrium, and homeostasis, the overarching interdisciplinary or cross-domain nature of these concepts is not currently identified let alone exploited (Jacobson & Wilensky, 2006). Further, little of the conceptual power embodied in the rapidly developing perspectives and tools of complex dynamical systems or informatics has informed the educational experience of our citizenry at any level, save that of graduate students in a few scientific areas (Jacobson & Wilensky, 2006). This absence from mainstream education creates many missed opportunities for building links between disparate elements of curriculum and providing unifying conceptual frameworks of coherence.

Whereas in 1996 the National Science Education Standards did not list energy as a subtopic, in the past decade a number of professional initiatives have recommended and mapped out the study of energy in some detail, and in some cases have generated resource materials for the K-12 teacher. These initiatives include:

- The International Technology Education Association, Standards for Technological Literacy (2007)
- The American Academy of Arts and Sciences, Project 2061 Benchmarks for Science Literacy, Atlas 1 and Atlas 2 (co-published with the National Science Teachers Association)
- The National Science Digital Library, Science Literacy Maps (derived from the AAAS Atlas 1 and Atlas 2)
- The National Energy Education Development Project
- The Energy Works Michigan Renewable Schools Program

While some K-12 energy education resources exist, a need remains to develop a framework for energy education and to populate that framework with engaging, innovative educational materials. For instance, the study of energy might be used to draw students into STEM fundamentals by challenging them to solve problems that relate directly to their lives. A consistent focus on energy in the K-12 schools could be a significant component in growing the number of STEM-ready students, many of whom will continue to build these skills in college and become the next generation of professionals needed to sustain America’s future.
Incorporating energy education into schools will require cooperation at a number of levels. K-12 teachers and administrators will need to be convinced that energy education is fundamental content. High-quality professional development opportunities, which include the dissemination of rich content knowledge and facilitate connections across and among seemingly disparate areas will build the groundwork for wide-scale engagement and implementation. Knowledge dissemination can be furthered through collaborations of universities, K-12 schools, and national laboratories.

By tying curricula to needs in local communities and the private sector, K-12 schools can serve as models for the community on how to adopt clean energy practices. Highlighting the benefits to involved companies could encourage private sector outreach at the K-12 level and help to foster the development of a skilled STEM workforce.

Participants in this national workshop on Clean Energy Education will lay the groundwork for energy education by building cross-disciplinary and cross-institutional networks of professionals. These networks will be the starting point for designing specific projects and raising support through the NSF, other agencies, or the private sector.

**BENEFITS**

K-12 energy education may interest students in STEM by challenging them to solve problems with implications that relate directly to their own lives. This authentic engagement may lead to an increase in the number of American students who choose to domestically study STEM disciplines. An increase in the U.S. STEM workforce would address the nation’s lack of STEM professionals and improve our national security.

Investing in quality teacher professional development may lead to a sustained national benefit of STEM education reform. If teachers and administrators are able to generate a meta-cognitive view of energy education and transfer that to their students, the community at large may ultimately better understand clean energy and make choices to improve energy efficiency.

K-12 energy education may also result in potential profit from the incorporation of the private sector in student and community engagement. Placing media pressure on industry representatives to motivate students and provide them with hands-on experience in energy related disciplines would generate monetary savings for business by having students work on real-world problems, increase student knowledge and application skills, and assist the community in generating a skilled workforce.

**RECOMMENDATIONS**

- Expand the role of national and government funded laboratories to educate and train teachers through institutes or workshops. This can include field trips to see energy research and installations at the laboratories.
- Create and offer online courses and curricular materials, including models and simulations, on energy to train K-12 teachers. These materials would be greatly enriched by involving – as co-authors with K-12 teachers – college and university faculty who have developed energy courses and are engaged in energy systems research.
- Expand and strengthen the online availability of high quality resources in energy education for K-12 teachers (e.g., in consort with the National Energy Education Development Project). Online availability of materials, accompanied by outreach and training, would greatly increase accessibility to energy education, particularly for schools in underserved areas. Such a resource should allow the use to search, evaluate and rank the materials.
- Increase the requirement for K-12 energy education outreach in federally funded projects, including a structured means to share and disseminate the results and best practices nationwide.
CONCLUSION

K-12 education is the foundation for establishing a scientifically literate citizenry and an energy efficient nation. The policies and procedures we implement today will shape the worldviews of America’s future scientists, government officials, and industry professionals. Therefore, it is our responsibility to include energy education as a fundamental component of K-12 education.

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INTERDISCIPLINARY EDUCATION WORK GROUP REPORT
MODERATORS: BRIAN DEAL AND JEFF BRAWN

INTRODUCTION
In the first part of the 20th century, educators attacked the narrow formulation of disciplinary study as a basis for education (See Dewey 1938). Since then, the role of interdisciplinarity in education has been an important and ongoing dialogue—especially in higher education. For example, Martin (1982) tried to build an improved curriculum that does not rely solely on the traditional disciplines in isolation and that finds a place for experiential learning and interdisciplinary education. Boyer (1987) analyzed the undergraduate experience, also criticizing the overemphasis on the disciplinary major to the detriment of general education. In 1991, the Association of American Colleges completed an in-depth study on the academic major with a focus on interdisciplinary studies (or the lack thereof).

It is important to consider the overall interdisciplinarity within the current educational system and how it specifically relates to the advancement of clean energy education. Often times, the current system has a tendency to focus on specific topics in individual silos, isolating communication between interdisciplinary groups of students and faculty. This problem is particularly evident within the realm of clean energy education. In post-secondary education, energy topics are primarily taught to students within the technical majors, while students who are outside the realm of mathematics- and science-related fields never interact with subjects discussing energy. This current state of divided education is no longer acceptable, because energy education and understanding is critical to the knowledge and development of an energy-literate citizenry, which includes the less technically-minded students. While their professions may not lead them directly to work with energy systems, the actions in their professional and personal lives have a profound effect on local, national, and global energy systems. Moving away from compartmentalized curricula to an integrated, system oriented educational experience is a critical need.

STATUS
Scholarship in energy and energy systems in the 21st century must be characterized by innovations that transcend historic, academic, and disciplinary boundaries. Federal funding for research is increasingly apportioned to crosscutting programs that create new opportunities for collaboration and discovery at the boundary, between traditional disciplines. Team-based, multi-investigator, multi-disciplinary research initiatives are viewed as central to remaining competitive in recruiting the best students and faculty. These new funding and educational efforts fit seamlessly with the development of clean energy education, which requires interdisciplinarity in educational backgrounds and experiences, as well as funding from a large cross-section of funding agencies.

A 2004 National Academy of Sciences (NAS) report titled, “Facilitating Interdisciplinary Research” identified some of the barriers to interdisciplinary education and research efforts: limited resources; the academic reward system; differences in disciplinary cultures; the pursuit of national rankings (based on traditional disciplinary categorizations); differences in policies and procedures across departments; and decentralized budget strategies that advantage departments over interdisciplinary programs as the major barriers. The challenges noted and lessons learned in broader interdisciplinary concepts can be easily applied to the expansion of clean energy education and creation of an energy-literate citizenry. Clean energy education in post-secondary education will face many of the interdisciplinary barriers mentioned above. Energy education courses are largely isolated within technical departments and are not open to non-technical degree-seeking students. However, efforts to increase interdisciplinarity between various undergraduate and graduate departments are developing on select university campuses. The creation of interdisciplinary clean energy courses, however, is complicated since the requirements, expectations, and courses policies differ on a departmental basis.

An often-recommended course of action to expand clean energy education beyond the physical classroom is to offer clean energy courses via online education. Online courses, however, often incur increased costs to the students, unintentionally discouraging them from these classes. However, since online education can provide a significant benefit in increasing clean energy education by expanding the courses to a wider national and international audience,
institutions must find ways to incorporate online education in their standard curriculum and therefore increase local and interdisciplinary knowledge and educational development.

In order to develop clean energy knowledge and address the diversity of viewpoints and perspectives within clean energy education, institutions need to address the following important questions:

- What specific disciplinary aspects and perspectives are needed for a comprehensive clean energy education program?
- Who are the stakeholders and clients for a multidisciplinary clean energy education programs and what disciplines are appropriate for clean energy education?
- What are outcomes that illustrate interdisciplinary thinking and problem solving in response to emerging clean energy issues?
- How do we identify issues both central and peripheral to the energy problem?
- What are some experiential learning opportunities in an interdisciplinary framework for clean energy education?
- What mode of delivery will be most effective for a clean energy education program? Should the mode be tailored for the target audiences? If so, how?

NEEDS, OPPORTUNITIES, AND CHALLENGES

Higher education is an especially important context and venue for clean energy education with respect to integration, synthesis, and delivery of material. To fully develop interdisciplinary energy education, collaboration of a diverse and networked suite of educational and non-educational institutions is essential with integrated and creative pedagogic strategies. Because of this, post-secondary institutions provide a unique opportunity for interdisciplinary energy education; they often have developed networks of inter- and intra-institutional networks of faculty, industry representatives, technology developers, and policy makers. Furthermore, higher education institutions can offer students a portfolio of educational opportunities through online courses, hands-on experiments, and vast network of clean energy practitioners, as well as a global perspective that is required for an effective clean energy curriculum. The success of network interdisciplinarity can be measured through the number of faculty, policy makers, and industry representatives who represent technical, as well as non-technical, fields of study.

In order to create a truly energy-literate citizenry, an inter- and multidisciplinary approach with the goal of creating new entities, constructs, and ways of thinking, teaching, and learning energy concepts is required. This approach can only be achieved through the creation of authentic, creative, and inclusive partnerships among social, natural, and engineering sciences. Rather than verbally creating partnerships and collaborations, institutions are responsible for the formation of active networks that truly meet, collaborate, and share ideas with one another with one common goal — energy education for the entire populous, regardless of educational background. By developing clean energy education within an active leadership and collaboration between stakeholders, students would gain substantial benefits in receiving a well-rounded education in energy concepts. The planning process would take a systems approach to energy education with defined goals and outcomes that included requirements form various disciplinary perspectives. The networks of instructors responsible for the development of multi-disciplinary clean energy education programs should be integrated from the formulation to the implementation stage of program development.

A truly interdisciplinary clean energy education system requires a cognitive and developmental strategy with a systems-oriented approach. Rather than focusing on the primarily technical aspect of clean energy production, it is crucial for clean energy education to encompass the impacts of energy from various perspectives, including business, environment, and society. System-wide education can be aided through an increase in student interdisciplinarity. Students with various educational backgrounds can offer their unique perspectives to clean energy technology developments, challenges, and opportunities. Further, increased classroom discussion and dialogue about various perspectives would help students better apply existing education to new knowledge, and also better understand others’ perspectives of the same problem. By increasing and successfully promoting interdisciplinarity within the student body involved in clean energy education, instructors will be able to receive in-depth input about their educational methodologies and find best practices to reach
a wide audience. In addition, by incorporating clean energy education to students with a wide range of educational backgrounds, students will learn to think outside of their comfort zones, as well as learn new perspectives they can take to their future careers. The interdisciplinarity involved in clean energy subjects can be evaluated by tracking the diversity in students’ scholastic backgrounds and fields of study. Outcomes that include communicative skills in energy systems would be measured through a certification or competency evaluation requirement.

Interdisciplinary clean energy education methods need to be long-standing and sustainable. Although clean energy education has been a recently popular topic within the educational circles, it is crucial that the methods developed for clean energy education are not only a transient interest. Instead, the educational networks, materials, and resources must encourage sustainable education and development. It is crucial that a means of attracting resources for clean energy education programs must be developed with a long-term mindset. Interdisciplinary clean energy education must truly become intertwined in the fabric of the current educational system. Most importantly, however, these educational practices will create generations of an energy-literate citizenry that have a system-wide approach to energy concepts, developments, and evaluation. The evaluation of interdisciplinary education can be measured through new interdisciplinary 5-, 10-, and 20- year planning and development plans. Furthermore, existing and newly-developed interdisciplinary clean energy education plans can be evaluated based on the creation and development of certificate programs, which will further encourage students to participate in clean energy education programs.

To encourage a fundamental understanding of clean energy concepts, experiential learning in the classroom and work environment with cross-institutional partnerships is critical. Since the goal of clean energy interdisciplinary education is to expand energy concepts to a wide audience including students in non-technical majors, instructors are required to find ways to communicate energy concepts in an easy-to-understand manner. Experiential learning allows students to gain hands-on experiences with clean energy and find applicable educational transformation between clean energy concepts and students’ existing subject knowledge. Experiential learning gives students the opportunity to see energy education concepts and interact with them in an applicable manner, thus giving students a deeper understanding and connection to the subject material. With a deeper understanding of energy concepts, the students would maintain the lessons more effectively and be able to apply clean energy knowledge in their personal and professional decisions. Incorporation of experiential learning can be measured through the number of laboratory or internship experiences provided to the students of clean energy classes.

In order to support the interdisciplinary education and research in the field of clean energy, funding organizations must be aligned at a core level. Similar to current higher education systems, funding agencies are often only interested in providing funding to research groups and organizations with a very narrow, but deep, focus. In order to incorporate interdisciplinary research in clean energy, funding agencies must restructure their support mechanisms to encourage collaboration across various disciplines and institutions; this will enable interdisciplinary clean energy education to grow inside individual institutions and spread across the national educational spectrum. Success of such measures can be evaluated through the number of funding agencies and cross-disciplinary funding opportunities.

**BENEFITS**

Inclusion of clean energy education in post-secondary educational institutions is easier to implement, due to existing networks of researchers, educators, policy makers, industry representatives, and technology developers. The involvement of active interdisciplinary planning teams will ultimately benefit the students, educators, and institutions and ensure success of truly interdisciplinary clean energy education programs. Increasing interdisciplinarity within the student body participating in clean energy education will allow for enhanced understanding of clean energy concepts, which would extend to students in both technical and non-technical fields of study. In addition, student interdisciplinarity will allow open discussion and allow students to bring various perspectives to the collective knowledge of the class, enhancing a system-wide thinking to clean energy concepts. Further, addition of experiential learning will allow students a deeper understanding of concepts and allow for a seamless transition into their professional careers. Finally, interdisciplinary education and research can only be fostered if funding agencies are fundamentally aligned to include the collaboration between various disciplines and institutions – a practice that is still in its infancy.
CONCLUSIONS

The idea of interdisciplinary teaching and learning is a powerful and appealing one in energy and related systems. We must, however, be careful to examine its limitations as well as its promises. Interdisciplinary knowledge can be used to enhance both theoretical knowledge while also promoting systematic problem-solving strategies. Interdisciplinary knowledge must be fostered from the beginning of the program planning stages to the class materials, as well as the interdisciplinarity of the students within clean energy classes. Post-secondary educational institutions provide an excellent starting point to the development of interdisciplinary clean energy education courses, because of existing and varied networks, as well as their access to a large student body with varying experiences, educational backgrounds, and mindsets. We do not advocate “a one size fits all” approach, however. Integration across disciplines is critical, but there is a strong need for varying approaches that are conditioned on the different goals and backgrounds of the faculty and students.

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WORKFORCE DEVELOPMENT WORK GROUP REPORT
MODERATOR: TOD TREAT

INTRODUCTION
Workforce development within clean energy education encompasses many different possibilities for students, employees, and interested citizens. Workforce development includes knowledge and skills for clean energy jobs in public and private sectors – large corporations, small entrepreneurial startups, and do-it-yourself consumer related activities. The necessary knowledge and skills range from enhanced consumer awareness, to construction materials and techniques, to complex energy systems. Workforce development in the area of clean energy education can include better utilization of existing energy systems or increased understanding of new systems in biomass, fuel cell, geothermal, wind, solar, and other clean energy innovations. The breadth and variability of providers, consumers, and systems make clean energy education in workforce development both a great challenge and an even greater opportunity. Accordingly, educational materials are expected to be diverse targeting the lay public, informal and noncredit activities for working professionals, and formal certifications and degrees for clean energy technicians, scientists, auditors, and management.

Energy education is key to development of a workforce that can innovate, develop, manufacture, install, and operate clean energy systems. Job creation at the local and national level is one of the primary goals of this educational focus. Community and technical colleges will play a key role in clean energy workforce development, since they provide a significant number of specific workforce training classes. In order to create nation-wide clean energy education and awareness, however, coordinated interactions with four-year colleges and universities will enhance both workforce development progress and a wider dispersion of clean energy education.

STATUS
There is an overall recognition that effective clean energy workforce development needs to identify appropriate audiences, prepare them for 21st-century clean energy jobs with transferable skills and knowledge, create effective...
recognition programs for those skills and knowledge, and partner across sectors to create formal and informal curricula to create industry recognized credentials aligned with a variety of emerging job opportunities. Many of these workforce needs have been identified for specific applications, including wind, solar, biomass for transportation, building, fuel cell technologies, and industrial technologies (Fox, 2009). The skills and competencies in these emerging jobs are continually changing and it is imperative for the success of our nation to maintain up-to-date education and prepare the workforce not only for the jobs available momentarily, but to also provide them with skills necessary for emerging jobs.

A wide variety of existing workforce development strategies are currently in operation. Strategies include increasing the knowledge base of the lay public on such issues as home installation and economic benefit of geothermal, photovoltaic, and other emergent consumer energy efficiency systems. Other strategies employ training of incumbent or displaced workers in noncredit situations and include courses that cover basic and advanced building sciences and weatherization; training services for energy efficiency auditors and contractors; and construction retrofitting techniques. Higher education institutions, particularly community colleges, have been creating certificate and degree programs in building energy technologies, as well as programs for wind, solar, as well as hydroelectric energy, technician programs, and other “near transfer” opportunity for skills building. At the same time, a growing number of bachelor’s and advanced degree programs seek to advance development of clean energy capacity and focus for scientists, engineers, policy makers, legal experts, city planners, and other careers (Illinois Workforce Investment Board, 2010).

Despite these efforts, gaps remain in terms of providing strong alignment between P-20, graduate, and noncredit/incumbent worker training. Career map and comprehensive skills standards are not in place, and job placement is hindered by both lack of recognition of clean energy certifications and a lack of “demand pull” into the market. The potential for workforce development in clean energy is high, but not yet realized.

NEEDS, OPPORTUNITIES, AND CHALLENGES

The potential scope and complexity of a workforce development strategy for clean energy requires recognition that energy literacy is essential to workforce development. The citizenry needs to have a fundamental understanding of the systems of energy, including creation, transportation, use and impact of energy systems, whether the source of the energy is carbon producing, carbon neutral, renewable, efficient, inefficient, or any combination thereof. The issue of literacy, in other words, is as much about “dirty” energy literacy as it is about “clean” energy literacy. Therefore, a step in creating a clean energy workforce first involves a nation-wide effort by educators (both in formal and informal settings) to educate the general citizenry about energy concepts, systems and technologies. A broader energy education would establish a foundation for clean energy workforce development, while also providing the citizenry with fundamental understanding of energy and clearer evaluations of energy policies.

A clear challenge for workforce development is better defining what we mean by “green jobs.” The value and reality of “green jobs” is a contested space. Defining green jobs and the skills needed in green jobs in a communication strategy that can help grow interest and demand in such jobs. On the other hand, David Schejbal (2011) and others have argued that green jobs do not exist, but that each of us needs to be considering our impact on energy, environment, and society. Additionally, there are clear segmentations that can be disaggregated to better inform the kinds of workforce development strategies we might employ as part of the energy space. For example, conservation-related activities require a different skill set than production, new installation, or distribution-related activities. These activities are significantly different than infrastructure skills. Therefore, there is significant value in disaggregating various market segments and discussing explicitly the needs related to the energy space for these kinds of jobs. Finally, a need exists to recognize that “new green jobs” will only be new for a period of time. Periodic reorganization of labor includes accelerations and plateaus in which new jobs become the existing jobs of the future and destruction accompanies job creation. A more thorough analysis of the market impact in the energy space would help set concrete targets related to the types of jobs and recognition that these new jobs may have negative consequences to existing jobs, on both a local and national level.

A vision of increased energy systems requires a skilled and prepared workforce with transferable skills. Some of the jobs related to the transition to a carbon-constrained economy will be new and will require new skill sets. But many
more will use skills that are already in demand today, such as those required for sheet metal workers, transmission line workers, and electricians (National Commission, 9). An emphasis on transferable skills differentiates “near transfer” training from “far transfer” education so that an individual can take learned knowledge and skills into a current job or transition to jobs that have yet to emerge. Education programs that incorporate and repurpose knowledge and skills from existing career tracks can be implemented more efficiently and effectively and can provide multiple entry points for incumbent workers into clean energy professions as they emerge and evolve.

Further, there must be recognition of complex and nonlinear relationship between preparation of a labor force, development of new markets, and increase in demand for clean energy products and services. An increase in the knowledge and skills of the workforce related to clean energy alone is insufficient to successfully develop a clean energy economy. Consistent involvement of policy makers and educators alike can help develop “push-pull” mechanisms to create and match prepared workers, job opportunities, and market demand. Therefore, stakeholder alignment and cooperation is critical in creating an energy-literate citizenry and a better skilled and prepared energy workforce.

Workforce development encompasses credit programs, noncredit courses, on-the-job training, and informal educational opportunities. A wide and varied array of opportunities enhances opportunities for lifelong learning by reducing barriers due to time, space, cost, or employment status. Colleges and industry need to create solid and diverse partnerships for the development of training programs, increasing the number of students who are job-ready and prepared for evolving job descriptions. Workforce development institutions also need to create informal and noncredit opportunities that are recognized by industry. These opportunities need to develop transferable skills that might meet today’s needs but also create scaffolding for on-the-job training later. These methods can be evaluated by analyzing the number of industry/education partnerships. Further, surveys of industry and recent graduate analyzing employee preparedness could provide feedback about the current education system, gaps within clean energy education, as well as improvement opportunities. A wide-range educational effort for workers at different ages and skill levels would increase overall energy education and offer increased job opportunities for a larger workforce population.

A substantial challenge to successful workforce development is the uncertainly of the overall labor market. Without a sense of future investment patterns or a clear policy path forward, it is difficult to predict the types of skills that will be needed and when new kinds of job opportunities become available. Furthermore, workforce bottlenecks due to a lack of technical skills could slow the transition to a low-carbon economy regardless of the commercial readiness of the underlying clean energy technologies (National Commission, 10). Finally, workforce training needs to be open to a diversity of target populations and include necessary components to effective career pathways that link workforce development with job placement (education, skills, certifications, internships, and placement).It is, therefore, crucial that business and industry, trade associations, and government agencies partner with educational institutions to invest in workforce development. Evaluation of these recommendations includes an annual multi-stakeholder analysis of current and predicted workforce needs, placements, and educational opportunities, as well as educational programs implemented to meet predicted workforce needs. Partnerships will clarify the needs and investment as well as increase the rate of development for a ready workforce matched to market demand for workers.

The opportunities for job creation in clean energy are expected to grow considerably. Job growth in clean energy is expected to continue to rise. In the area of electric generation systems alone, demand for skilled workers will increase steadily as new technologies come online to an estimated additional workforce of roughly 60,000 by 2030 (National Commission, 10). Given these statistics, it is imperative for stakeholders within industry and education to work together in order to define the needs for a clean energy workforce. These stakeholders need to work together through collaboration and open communication to find out what skills and assets industry needs, while also aligning with current skills the workforce is receiving. Through mutual collaboration, stakeholders will be able to better prepare the existing and upcoming workforce for clean energy jobs, increasing overall workforce readiness, and keeping America’s competitiveness in the global energy economy.

In order to meet the needs, challenges, and opportunities for workforce development for clean energy careers, the workshop participants identified and recommend a number of strategies. These include strategies for assuring quality and competence of the workforce, increasing workforce capacity, growing workforce literacies, and creating metrics for
realization of workforce development in clean energy.

STRATEGIES FOR ASSURING QUALITY AND COMPETENCE OF THE WORKFORCE

In order to ensure quality and competence of the clean energy workforce, it is important to create comprehensive skills standards through partnership with business and industry. Furthermore, the development of a new workforce requires the creation of better-defined career paths with effective on-ramps that will be mapped to programs of study. While the career path definitions will require significant efforts from educational institutions, schools and training facilities also need to work with industry representatives to ensure the career paths match actual job needs. Collaboration between business and educational institutions, as well as clearly defined skill sets and career paths, would better serve the students and increase their skill sets and preparedness within the clean energy workforce.

In order for workers to showcase and prove their skills to potential employers, workforce development institutions need to create accessible, affordable, and actionable credentials that can be earned by individual workers. Further, an accreditation mechanisms needs to be created for institutions that create credit and non-credit opportunities for meeting skills standards. Affordable, actionable credentials that address current needs must also be transferable to future needs. Assuring quality and competence can be addressed by comprehensive skills standards, third party certifications, such as the Institute for Sustainable Power, Inc., and accreditation by professional organizations, such as the Interstate Renewable Energy Council (http://irecusa.org). Success can be measured by monitoring the number of accredited programs and institutions, as well as the number of students who are receiving education through them. Accreditation standards and widely accepted and distributed workforce development would disseminate clean energy to a wider national population. Furthermore, a larger workforce trained in clean energy jobs would benefit the nation by providing opportunities for increased clean energy technology development and increased national energy security.

STRATEGIES FOR GROWING WORKFORCE LITERACIES

An added challenge of clean energy workforce preparedness is that energy literacies are multiple and contextual. For workforce development, energy literacy relates to consumer, policy, and organizational literacies. Consumer literacy might refer to individual behavior in the market based on informed choices as to what kinds of products to purchase or what sorts of energy systems or improvements to install. Policy literacy might refer to recognition of market choices on energy use and demand in the nation. Finally, organizational literacy might relate to the behavior of individuals in organizations and the impact of those behaviors on the performance of the company and impact on demand creation in the energy space. For example, we considered the impact of procurement on an organization strategy. While only partially conceived, the concept of multiple literacies for the energy space provides useful frameworks from which to consider energy education. Therefore, workforce development educators need to clearly articulate the variety of workforce literacies and effectively introduce the workers to the interactions and conflicts of various types of energy literacies. The introduction and explanation of workforce literacies will aid every citizen to realize the impact of their personal decisions to energy use and their relationship to workforce demand.

COMMUNICATIONS STRATEGIES

Communication strategies need to recognize and reduce potential tensions that can arise if energy education is linked to politicized elements. Energy literacy is in the interest of all, regardless of political or other affiliation. Contested terrain, such as the positives and negatives of nuclear energy options or carbon sequestration, needs to be framed in the context of scientific inquiry and consensus for educational purposes, not political purposes. Communications need to be tailored to meet a complex array of stakeholder needs, from recognition of what differentiates clean energy options from other energy options, value propositions for consumers, employment options for future and incumbent workers, and policy oriented material for decision makers in business, education, and government. By approaching workforce development in energy from a multi-stakeholder agreed perspective, students would benefit by receiving unbiased information. Furthermore, the nation and various stakeholders can work together to further a national education and strategy focused on clean energy education for all.

STRATEGIES FOR INCREASING WORKFORCE CAPACITY

An important aspect of workforce development is the increase in workforce capacity, since it can result in higher
employment rates for workers, while also providing workers who are able to transform the changing energy needs of the country. One way to increase the workforce capacity is to incentivize faculty at a variety of institutions (2 year / 4 year) to become involved with energy education. By providing interest among faculty, they will be more inclined to teach workforce readiness classes and therefore benefit the workforce and nation overall. Success of these programs can be measured by monitoring the number of classes offered in clean energy workforce development, as well as the number of students who have participated in this class and their level of preparedness after entering the job force.

In order to prepare the workforce, it is vital to align workforce development and job availability. First, industry should be involved in order to articulate recognized and needed skills required for employment within their organizations. Further, educators and industry must collaborate to recognize important workforce skills that should be further developed, and to recognize skills that will be in demand in a clean energy economy. Collaboration between the education and industry sectors is critical to developing successful programs and providing workers with applicable skills in the workforce. Success metrics for this join educational effort include surveys of industry regarding worker job competency and preparation, as well as tracking of industry time spent training employees. Only through collaboration of these two sectors will educators be able to predict and prepare their students for immediate and further future employment opportunities.

A diverse yet effective workforce will only be created when workers are able to analyze their current skills and determine new skills needed to further their career. Therefore, it is imperative to create a matrix of programs of study (POS) that include multiple paths across research and development, design and manufacturing, sales and marketing, installation and service, and regulations and policy. These paths need to recognize high, medium, and low skill sets so that individuals can map their goals and current skills to develop strategies for obtaining desired new experience in advancement of their careers. Institutions need to create mechanisms that allow individuals to gain access to these desired skill sets. Several career pathway models are currently in development, including National Science Foundation-ATE Center and the IR photovoltaic sector model (Illinois Workforce Investment Board, 2009, National Science Foundation), which can be used as guides in the creation of a clean energy POS. Success can be measured through tracking of different states’ development of POS programs, enrollment numbers and comparisons between the existing and future POS models, as well as industry surveys of worker preparation for employment. The creation of such a plan would benefit the workers, because it would allow them to tailor their education and training to their current skill sets, while taking into account time commitment availability, as well as their future career plans. Success metrics for the creation of revised POS includes the quantitative tracking of student enrollment and subsequent job placement rates. This would make workforce development more appealing and more widely available to the workforce, which may currently lack additional skill sets and education because of the complicated manner of the training and education system.

**BENEFITS**

A broader energy-literate citizenry would serve as the foundation for clean energy workforce development. Modification of the existing workforce training structure would include programs that incorporate and repurpose knowledge and skills from existing career tracks; this would allow clean energy training to be implemented more efficiently and effectively and provide multiple entry points for incumbent workers into clean energy professions as they emerge and evolve.

Industry and education collaboration is imperative for the development of clean energy education methods and tools. These partnerships will clarify the needs and investment as well as increase the rate of development for an energy-educated workforce. Further, industry/education collaborations can provide a thorough analysis of the market impact in the energy space and set concrete targets related to the types of required jobs, as well as their positive and negative impacts. Additionally, through mutual collaboration, stakeholders will be able to better prepare the existing and upcoming workforce for clean energy jobs, increasing overall workforce readiness, and keeping America’s competitiveness in the global energy economy.

The provision of a common, nation-wide energy educated workforce requires national stakeholder alignment, collaboration, and education accreditation. Accreditation standards and widely accepted and distributed workforce development would disseminate clean energy to a wider national population. Furthermore, a larger workforce trained in clean energy jobs
would benefit the nation by providing opportunities for increased clean energy technology development and increased national energy security.

Overall, the introduction and explanation of workforce literacies will aid every citizen to realize the impact of their personal decisions to energy use and their relationship to workforce demand. By providing interest among faculty, they will be more inclined to teach workforce readiness classes and therefore benefit the workforce and nation overall.

CONCLUSION
Ultimately, the aim of workforce development efforts in clean energy is to increase capacity for clean energy implementation. Workforce development can aid in the acceleration of workplace adoption and implementation of existing clean energy innovations, but cannot be a driver alone. Workforce development activities must work in tandem with “demand-side” efforts to align capacity and demand in growing clean energy workforce sector. Efforts to increase recognition of workforce competency of clean energy knowledge and skills will aid in job placement. Finally, underlying all of this activity is a need to increase workplace and consumer literacy.

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BUSINESS AND INDUSTRY WORK GROUP REPORT
MODERATOR: TIM LINDSEY

INTRODUCTION
Business and industry is responsible for many decisions with respect to the energy systems that we utilize. They play critical roles in choosing all aspects of the energy system, including: energy sources, production methods, delivery mechanisms, and utilization rates. These choices, in turn, influence impacts associated with the environment, economy, and communities. Business and industry will also design, manufacture, implement, capitalize, finance, operate, maintain, and manage the clean energy systems of the future. They will also play key roles associated with inventing clean energy systems and developing innovative strategies for bringing them to market.

Businesses and industry generally recognize that the key to being more sustainable is through developing and implementing better systems that reduce wastefulness through improved quality of products, processes and systems.
They tend to view clean energy systems as a long-term business strategy. They recognize that the competitiveness of the marketplace will lead to lower costs and expanded resources and markets with respect to future clean energy developments. Additionally, when making decisions regarding clean energy implementation, business and industry must consider both current and future policies and market conditions. Consequently, they are particularly concerned about making clean energy choices in the near-term that will be consistent with their business strategies for many years to come.

STATUS
A challenge of business and industry implementation of clean energy technologies is that business and industry leaders tend to view clean energy as a long-term opportunity because they do not think that most clean energy innovations are mature enough to be cost competitive compared to current state-of-the-art energy systems. The future of most clean energy innovations appears to be unclear to most business leaders because there appear to be no clear winners. They can point to previous predictions regarding the future of energy systems as examples of why there is so much uncertainty. For instance, only ten years ago, government officials were proclaiming hydrogen energy to be a leading technology in America’s energy future. Yet, ten years later, hydrogen energy is rarely mentioned as an option for the foreseeable future. Experiences like this leave business leaders to wonder if current endorsements regarding technologies such as wind, solar, geothermal, etc., will indeed deliver as promised, or will they produce results similar to what was experienced with hydrogen? Many promising clean technologies still have technical and/or economic shortcomings that reduce their current feasibility in the market. Until businesses can be confident that issues associated with aspects such as energy storage and resource availability can be effectively resolved, they will continue to hold back on investments in clean energy technology.

The uncertain future of clean energy technology is exacerbated by unclear government policies. Uncertainty associated with the amount and longevity of incentives for new technologies makes it difficult for industry to identify clear technology winners. Additionally, uncertainty with respect to future regulations for various alternatives, along with their by-products and associated impacts, makes the selection of clean energy alternatives very difficult. Even the term “clean energy” is not well defined from a business perspective and officials from government, academia, and the private sector frequently disagree with respect to what systems should or should not be considered “clean.” This extreme level of uncertainty also stifles innovation because it becomes nearly impossible to accurately estimate risks and rewards. This phenomenon creates a disconnect between ideas and investors, and it results in a shortfall with respect to financing for innovations. Business tends to be risk averse with respect to the uncertainty of new technologies, and there are few examples where this aversion to risk is more apparent than clean energy. In order to effectively incorporate business and industry in clean energy developments, multiple stakeholders must agree on the terms of clean energy, and businesses must be provided with clear government policies backing clean energy technologies.

At various levels of business organizations, specific skills are often lacking that prevent effective evaluation, implementation, and utilization of clean energy systems. For instance, many companies have recently created a position in their organization that is responsible for overseeing the company’s sustainability efforts, such as the Chief Sustainability Officer. This is a new role for most companies and the people who take on this assignment come from varied backgrounds such as safety or engineering, and they are often not well prepared to deal with the breadth of issues that surround clean energy. These individuals need considerable training associated with better systematic understanding of the company’s operations and how to incorporate clean energy principles.

The needs for clean energy education in business and industry are frequently not well coordinated with the capabilities of universities to meet those needs. Substantial differences often exist between their respective timelines regarding industry needs versus university offerings. The disconnect between business needs and university capabilities continues to widen as technology rapidly becomes more sophisticated. Universities are faced with training students for jobs that either do not yet exist, or at a minimum, will be very different by the time the students enter the workforce.

In general, university instructors tend to lack direct experience with business and industry that impedes their ability to make course content relevant to real-world applications. There is little recognition of the value of business experience
in most universities. In fact, in many universities, business experience is actually a detriment in terms of career advancement for faculty and staff because time spent in the private sector correlates to less time spent performing research and publishing.

A need clearly exists for energy-literate businesses that can provide clean energy sources, production methods, and delivery mechanisms. Additionally, businesses can play a critical role in ensuring that the energy is utilized efficiently. Energy-literate businesses could directly impact the energy production and utilization of their own operations as well as their employees and customers. All schools and education systems should be an incubator, and students should be designing and planning how their institutions work. Schools can serve as very practical living/learning laboratories and provide students with the practical “hands on” experiences they need to understand energy aspects and choices.

NEEDS, OPPORTUNITIES, AND CHALLENGES

In order to make good decisions regarding current and future clean energy choices, business and industry needs people to assess opportunities, develop strategies, and implement changes. For these individuals to be effective, they must be well-educated with respect to all aspects of energy systems. Therefore, educating the workforce regarding clean energy principles, technology options, performance characteristics, selection criteria, implementation practices, operating procedures, and environmental and social impacts is of critical importance with respect to clean energy education. This education needs to be incorporated into all aspects of the organization—from executives to line workers. Additionally, the public, which ultimately represents their customers, shareholders, and stakeholders, needs to be familiar with clean energy principles in order to understand the choices being made by business and industry and the impacts associated with those choices. Metrics to evaluate corporate clean energy education include number of internal classes offered to employees, number of employees attending industry clean energy courses, and implementation of clean energy projects and measures.

Industry experts need to become more engaged in formal education to ensure that students are learning the skills they will need to be more successful with respect to energy choices. They can utilize their practical experiences to provide information students can apply more readily to their daily lives. If a company receives significant incentives from a community or state to place their operations in a specific location, the company should provide access to key employees that would serve in public schools as part of the economic innovation package. In these cases, the operation’s business plan should be published publicly and there should be a performance review regarding the overall, financial, social, and environmental impacts of the business. These requirements would provide a symbiotic relationship between industry and the communities it affects. Success measurements of this plan includes quantitative measurement of companies who are offered tax breaks, number of employees actively participating in the community, as well as the number of students/community members they interact with on a weekly/monthly basis in their educational efforts.

Clean energy choices are frequently associated with engineering and economic characteristics of the various options available. However, choices associated with clean energy systems can affect virtually all aspects of an organization as well as their customers and the communities in which they operate. Therefore, it is important that decision makers possess relevant skills associated with marketing, financing, communication, government policy, social sciences, and general business (assets, liability, accounting) policy. More relevant coursework is needed to educate workers at all levels with respect to the practical choices available with respect to clean energy and the consequences associated with those choices. Clean energy courses and training can be taught to departments and employees at various levels within a company by outside accredited organizations. Increased clean energy and technology education would allow business employees to make better decisions in their daily operations and would make them more willing to comply with energy-efficient measures required through developing company policies. Additionally, further clean energy education would help current and future business leaders better understand and evaluate their organization’s operations, as well as gain a better understanding of their impacts on the overall energy grid. Success metrics the number of such training programs across the country, number of participating industry representatives, as well as their evaluation and implementation of topics learned during their clean energy training.

Executives need to be educated on various clean energy innovations that can affect major business decisions. Big-
picture innovations such as smart grid technology can affect a company’s ability to modernize and be competitive with regional and foreign competition. Likewise, incremental innovations that improve energy efficiency can readily improve the bottom line. It is important for executives to be skilled at quantifying the risks and rewards associated with various energy decisions. By providing continuous education courses, similar to those required for licensed professionals, executives would be able to refresh and expand their knowledge base and make more informed business decisions. The courses should be relevant to executives and be offered in a manner, such as shorter online courses, to better accommodate executive leader schedules and improve chances of increased education. Understanding how energy choices impact the environment and the community can help executives make sound decisions regarding their company’s status as a good corporate citizen. Further, more educated energy business leadership will lead employees and businesses toward a future with cleaner energy.

Overall, clean energy education needs to be interwoven more deeply within the post-secondary education system. Students need to develop an understanding of the entire life cycle associated with energy choices. They need to understand how changes to individual components (e.g., fuel choices) affect other system components (e.g., climate), and they need to understand these aspects from economic, environmental and social perspectives. Additionally, students need to develop an understanding of the relative risks associated with their choices and learn how to manage these risks. By providing industry-college partnerships and collaboratively creating education incubators, students can gain a better understanding of clean energy concepts and technologies, preparing them for the workforce. Success can be evaluated by the number of college-industry relationships, the creation and use of energy incubators created nationwide, and the number of students who participate in these educational programs. By providing more thorough clean energy education on a collegiate level, students will enter the workforce with a better systematic knowledge of energy and its applications within business and industry, effectively instilling overall energy understanding and considerations in the future leaders of business and industry.

Workers at all levels need to be educated in ways that make them familiar with all the issues surrounding both conventional and clean energy systems. In too many cases, students have been trained to optimize individual components of systems without regard to other system components. This has led to unintended consequences associated with environmental degradation, social injustice and resource depletion. Therefore, education on the K-12 level, as well as traditional and non-traditional post-secondary education should include a system-wide approach to science and technical education. By introducing this type of thinking at an early age, students will be accustomed to a system-approach to problem solving after entering the workforce. To educate students about the potentially unintended effects of technologies and design decisions, case studies, interviews, and in-depth questions should be offered within energy and technology education. By widening students’ perspectives to include populations and perspectives they may be less familiar with, they would become more conscientious about their larger business decision impacts, shifting future business thinking to improve not only processes, but to work together with others to create solutions that are best for the national and global population.

In addition, many recent graduates are deficient with respect to oral and written communication skills that can prevent them from effectively presenting a compelling case for making changes to clean energy practices. This frequently occurs even though the graduates are usually very bright and possess superior technical knowledge. Therefore, it is important to teach students not only the technical knowledge required for clean energy technology understanding, but soft skill development through group projects and public presentations. Soft skills will additionally prepare students to work in an environment where they not only have to understand clean energy technologies, but it will teach them to communicate more effectively with others. To develop these skills, programs should include curricular requirements for students to work in groups and present their work on a regular basis, instead of only focusing presentations to a short window once a semester. Success can be measured by enumerating classes requiring two or more presentations per semester, as well as the number of students participating in these courses.

Since a wide gap exists between industry expectations and actual student education, a relationship should be formed between young alumni and their educational institutions. After students have been engaged in the work force for several years, they should return to their schools and provide input with respect to the deficiencies that exist in the
education and training they received. They should also offer suggestions regarding additional topics, methods, and skills that need to be addressed. By providing open communications with young alumni, educational institutions and individual departments would not only be able to serve their current students better, but they would also increase their competitiveness in the ever-expanding education market.

Furthermore, real world business experience should be valued in instructors at all levels. The current model punishes educators with work experience, since it takes time away from research and other academic duties. Rather than encouraging the divide between academia and industry, post-secondary institutions should encourage such collaborations. Academic professors are unable to effectively prepare their students for the workforce if they are out of touch with industry needs. To close this gap, schools should work with industry to develop a working relationship between business professionals and academics; representatives from both can work together to adjust existing curricula, in order to increase student preparedness for industry positions. Further, professors should be able to take sabbaticals in order to work within industry, while experienced industry representatives should also be encouraged to teach applicable courses on the college level. Success can be measured through the number of industry-college partnerships, number of courses taught or co-taught by industry experts, as well as professors with industry experience through sabbaticals or other collaborative projects.

**BENEFITS**

The recommended adjustments to current business and industry models suggest increased education on every level of a business enterprise. Furthermore, increased partnerships between businesses, K-12 schools, and post-secondary institutions provide added benefits to business and industry, as well as students and their educators. Business and industry would benefit by increasing their employee’s understanding of clean energy concepts and their relation to the company’s business practices and overall larger global impacts. Understanding how energy choices affect the environment and the community can help executives make sound decisions regarding their company’s status as a good corporate citizen.

Increased clean energy education on a post-secondary education level will help students enter the workforce with a better knowledge of clean energy and its applications within business and industry. Further, students’ better understanding of business and industry will effectively instill systematic energy understanding and considerations in the future business leaders. Additionally, widening students’ perspectives will shift future business thinking to improve not only processes, but to collaborate with others to create solutions that are best for the national and global population. Stronger bonds with young alumni will further help colleges and other training institutions to better evaluate their education offerings and methods.

**CONCLUSION**

The status quo of current business practices needs to be readjusted to increase workforce training in clean energy within all aspects of the organization, including executives and line workers. Further, decision makers should possesses relevant skills associated with marketing, financing, communication, government policy, social sciences, and general business (assets, liability, accounting) policy. Executives need to be educated on various clean energy innovations that can affect major business decisions. In order to strengthen business education, internal and external education should be available to all employees, especially those responsible for steering business and industry decisions.

Businesses and industry should invest time in community education, especially if they are offered tax incentives to move to a particular region or location. Additionally, businesses should form collaborative relationship with post-secondary educational institutions and other training institutions to help students gain a better understanding of clean energy concepts and technologies, preparing them for the workforce. Furthermore, students need to be educated in ways that make them familiar with all the issues surrounding both conventional and clean energy systems. Students need to develop an understanding of the entire life cycle associated with energy choices. Since a wide gap exists between industry expectations and actual student education, a relationship should be formed between young alumni and their
educational institutions.

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INTRODUCTION

The nations of the world represent a wide diversity of perspectives, practices and attitudes toward energy. The differences are evident in the spectrum of national energy choices. Denmark emphasizes wind for 20% of its electricity; France uses nuclear energy for 80% of its electricity; Brazil relies on ethanol from sugarcane for transportation fuel;
and Iceland depends on geothermal for 87% of its space and water heating and on geothermal and hydropower for over 99% of its electricity. The differences are equally noticeable in the popular attitudes toward energy. Europe and Japan use half the energy per capita of North America; American personal transportation is dominated by large cars with relatively low gas mileage while small fuel-efficient cars, public transportation, and trains are more prevalent in Europe, India, and China. Global warming and the threat of climate change are widely accepted in Latin America but much less so in North America and Africa.

The differing national and regional attitudes toward energy create rich opportunities and challenges for cooperation in national and global energy education; policy; research; development and deployment of new energy technologies; energy service enterprises; and personal interactions across national borders. Exploiting these opportunities and addressing the challenges of international energy cooperation, however, requires an appreciation for differing national and regional perspectives that is not yet part of the consciousness of many nations. International energy education addresses this goal.

STATUS

The immersion of residents in news coverage and commentary on the energy challenges of their own country often creates a weak appreciation of the origins, trajectories, and strategies of other regions. This tendency is especially strong in North America with its long history of low-cost, abundant energy and its geographical and cultural distance from much of the world. Europe, with its diversity of densely packed countries and many cross-border personal interactions, has a higher sense of the diversity of international energy perspectives.

The highly developed economies of the US, Europe, and parts of Asia create a lifestyle gap separating them from the developing and undeveloped countries. In many of these countries, gathering food, water and fuel are dominant household activities rather than services provided by central infrastructures. Household collection of biomass without regard for replanting, known as “unsustainable biomass,” accounts for 13% of energy use in the developing world but has no analog in developed countries. Energy practices for the 1.4B people without access to electricity are quite different from those where reliable electricity is taken for granted. Without an electricity grid, a simple solar cell and battery for a household or community dramatically improve access to information, connectivity, and quality of life by providing light after sunset for reading and education, as well as power for radio, television, cell phones, and the Internet.

The energy trajectories of nations are shaped by their national aspirations as well as their degree of economic development and energy supply options. The primary goal of undeveloped countries may be launching the transition to a modern economy and to bring the benefits of international trade, communication, and rising quality of life. The goal of developing countries may be the health, education, and economic well-being of their citizens, the introduction of selected commercial enterprises to drive further economic growth, or the enhancement of their geopolitical standing and influence. For developed countries, the health of the global economy and stability of international order may be paramount. The disparity of national aspirations creates not only opportunities for cooperation but also sources of tension as nations and regions pursue their individual energy goals.

NEEDS, OPPORTUNITIES, AND CHALLENGES

Global energy trends are set by an amalgam of historical legacy folded into the three driving forces discussed above: available energy resources, stage of economic development, and national aspirations. Creating effective energy strategies going forward requires an appreciation of the international mix of attitudes, best practices, and broad wisdom contained in the energy experiences of other countries and regions. Defining and communicating this international mix of energy perspectives is one of the primary issues in international energy education.

The set of customers for international energy education includes government officials who will decide local and national energy policies; business leaders who will create and trade energy technologies in the global market; and private citizens who will provide the ultimate political justification for national energy decisions by expressing their opinions to their governments. The present generation of practitioners in each area, and the students who will become the future
practitioners, are each part of the customer base.

INTERNATIONAL TENSION
The pattern of international tension has shifted in the last half-century from military confrontation among a few dominant superpowers to the quest for economic growth among a host of players at various stages of development. Disparities in quality of life can breed a sense of frustration and resentment among some in less developed countries against those in developed countries, encouraging the rise of ideological movements that promote symbolic acts of destruction and terrorism. Quality of life and economic development are intimately connected to energy use, making understanding the disparities in national energy profiles a key element in reducing international tension and unrest. International energy education has the potential to raise appreciation of the range of energy disparities in the world and the opportunities to address them.

Many regions of the world have developed special energy practices that promote sustainable energy effectively but have not propagated beyond their borders. Rather than focus on the national differences in various regions of the world, there should be a mechanism within international energy education to identify and propagate these best practices to other regions. By opening the lines of communication and connecting international energy researchers, individual institutions would be able to build upon each other’s knowledge and experience.

SISTER UNIVERSITIES
The concept of Sister Universities offers a broad and flexible structure for education in international energy. Each participating university would select a sister institution in a foreign country to share in the development of mutually accessible energy curricula and programs including year-abroad student exchanges, internet-based university lectures with reciprocal credit, and lifelong learning courses and workshops. The curriculum would emphasize the energy and economic profile of the two countries, including energy history; the national portfolio of potential resources for fossil, nuclear, solar, wind and other kinds of renewable energy; the role of energy in achieving national aspirational objectives; social attitudes toward energy and environment; and the potential markets for importing and exporting energy technologies and services. The energy landscape is likely to change rather quickly requiring the curricula to be updated frequently. Lifelong learning opportunities provided through refresher courses and workshops for alumni and others would be an integral part of the structure.

Immersion in year-abroad student and faculty exchanges with Sister Universities provides the richest, most intense, and most effective international energy education. Regional energy practices emerge from a host of historical, cultural, and economic influences that are not apparent from a distance and are best learned first hand through living everyday life abroad. Such student experiences can set a lifetime pattern of awareness and sensitivity to international energy and cultural differences.

As a practical matter, however, financial and organizational constraints limit the number students who can experience year-abroad international energy exchanges. International distance learning, where the Internet provides two-way access between students in one country and lecturers in another, brings the international energy experience to a wider audience. The cost is low, the concept of distance learning is already well developed, and the number of international students that can be reached is large. The energy courses delivered in each direction by the Sister Universities would have common standards and parallel content; they should be developed by teams comprising members from both sides.

In a grander vision, the network of Sister Universities within selected regions such as America, Europe, or Asia could agree to develop energy courses with common targets for content, level, and reciprocal credit. This would allow students in one country to learn the energy practices, attitudes, and aspirations of a variety of other countries through courses taken from many Sister Universities.

The academic community should establish a set of principles and protocols for a network of Sister Universities that would offer energy curricula at a similar level and for reciprocal credit that presents national and regional perspectives of energy history, resources, challenges and aspirations. Further, protocols should promote year-abroad exchanges of
students with a focus on energy, allowing them to experience personally the energy practices and culture of the region. Finally, protocols must be created that will offer lifelong learning courses and workshops for reciprocal credit on new developments in global, regional and national energy issues. The success of such programs can be measured by the number of new sister university relationships created with a clean energy incentive, number of courses offered, as well as the number of study-abroad exchanges that are created based on this new relationship between universities.

INTERNATIONAL ENERGY STUDIES
There is a need for a new area of energy education: international energy studies. The worldwide diversity of energy histories, practices, and trajectories is rich with opportunities for scholarship, exposition, and comparative analysis. The pervasiveness, diversity, and complexity of international energy issues in technology, environment, and economics rival that of agriculture and finance, established disciplines with strong international focus. The depths of international energy dynamics remain to be plumbed.

The educational community should establish a new field of academic research and teaching: international energy studies. This field stresses an interdisciplinary approach to energy embracing technology, economics, society, policy, business, and history, with special emphasis on the distinctive characteristics of each nation or region that shape its energy culture, practices, attitudes and aspirations. Measures of success include number of such programs arising nationally and internationally, number of students enlisted in international energy studies, as well as the expertise of the students who participate in these studies. It is important that students who participate in this new research and teachings come from a variety of professional backgrounds, in order to provide different educational perspectives. The creation of international energy studies as an academic field of research and teaching would provide a diverse perspective dealing with international energy issues in technology, environment, and economics rival that of agriculture and finance.

WORKFORCE TRAINING
The rise of alternative energy technologies such as wind, solar, geothermal, and biofuels creates a need for workforce training to produce, install, and service the required infrastructure. These new technologies create an international market for export and import, requiring workforce training in foreign countries on systems designed elsewhere. Development of international standards for the installation, operation, and service of alternative energy technologies would streamline the international energy economy. Workforce training shares many common features across countries and regions can be coordinated to reflect internationally accepted standards. The number of international standards created, number of classes taught on an international level, as well as the number of people who participate in those classes will serve as the success metrics for these educational initiatives.

K-12 EDUCATION
The formation of attitudes toward energy begins in childhood influenced by culture and information absorbed at home and school. The basic principles of international energy, such as the distribution of energy sources, the effect of carbon emissions on climate, and the need for sustainable energy systems, should be taught in K-12 education. Energy should be considered a standard topic at the K-12 level, like arithmetic, language, and literature, with the basic content coordinated across the international community. Success can be measured by tracking the schools that incorporate clean energy education into their standard K-12 curriculum, as well as the value and number of hands-on energy activities.

BENEFITS
One benefit of international energy education is the propagation of best energy practices at the personal, institutional and national levels from one region to another. These practices, transmitted across borders by international energy education, have the power to accelerate the transition to more efficient, orderly and sustainable energy cultures.

Another key benefit of international energy education is promotion of international cooperation. Research and development of new energy technologies, the development of innovative global and regional energy policies, and expanding international trade of energy goods and services, are opportunities to accelerate the transition to an orderly,
robust, and predictable global energy economy. All countries benefit from a reliable energy supply at predictable prices, which promotes long range strategic planning over short-term crisis management. Understanding the national and regional implications of a given energy technology, energy policy, or business proposal is critical to formulating and executing successful international cooperation.

A third benefit of international energy education is the development of the vision to create new technology and policy that accommodates the energy aspirations of disparate regions. Creating national energy policies and strategic directions that are mutually reinforcing and beneficial requires education in the energy profiles and trajectories of other regions.

CONCLUSION

The international aspects of energy are underappreciated by the educational, business, and government communities, despite the broad impact of international energy on their domains. Energy is a truly international enterprise, where decisions of other countries restrict or expand the range energy options available at home. The dependence of much of the world on imported oil for transportation, for example, drives the electrification of cars, ever increasing fuel efficiency standards and the development of biofuels. The wide distribution of wind, solar and geothermal energy creates international markets for these emerging technologies. The subject of international energy studies is as rich in opportunities for technical and policy analysis and for discovery of new organizing principles as the established disciplines of foreign policy, economics, and law. Beyond these expert communities, there is a need for international energy literacy among the general population as a cornerstone of energy education, because viable national energy policies must acknowledge the larger international picture.

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