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Energy education and the dilemma of mitigating climate change

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Abstract This study argues that enhanced energy education will help resolve the dilemmas of mitigating climate change and thus promote sustainability. Without enhanced energy literacy among both the energy workforce and citizens, society will be hard-pressed to make strategic choices about energy. We build on previous work that defined *energy literacy* and piloted programs to teach *Energy 101* classes. We present a Sankey diagram of the US energy economy as a novel way to orient students to the entire energy economy, not just individual fuels. Higher education must provide two distinct pathways, one for the general education of all students and one for students in programs that specialize in energy in preparation for joining the energy workforce. Four challenges face faculty and administrators: accommodating diversity in the student body, rewarding faculty, building new curricular pathways and courses, and integrating theory and practice. More concerted action is needed despite recent reports of reductions in carbon emissions and some growth of energy education. The changes to date are small, politically contested, and inadequately supported. Institutions need to build new programs and communicate their progress to peers. This paper's novelty lies in (a) the argument that inadequate energy education hinders the development of sustainability education, (b) the distinctions made between climate and energy education, (c) identification of major steps needed and challenges to be expected in energy education, and (d) the proposition that reform must jointly address both general students and students specializing in energy.

Keywords Energy education · Sustainability · Climate change

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Intensive use of fossil fuels silences all hope of building sustainable societies. For 300 years, these fuels have provided great benefits and shaped modern life. Climate science developed over the past 50 years, however, indicates that continued reliance on fossil fuels seriously threatens climate stability (Stocker et al. 2013). The likelihood of abrupt climate impacts raises even more concerns (National Research Council 2013).

Renewable energy, increased efficiency, and conservation offer great potential to mitigate climate change (Lovins 2011; Jacobson and Delucchi 2011; Delucchi and Jacobson 2011; Jacobson et al. 2013). Are renewables, efficiency, and conservation the right strategic choices, preferable to others? Advocates of nuclear energy see nuclear power as essential to mitigate climate change (National Research Council 2009; Stone 2013). Are they right? What about other choices less frequently mentioned, such as geothermal and hydrokinetic technologies?

These questions reveal a dilemma. On one hand, the society needs to move away from energy technologies that threaten climate instability. On the other, changing these technologies raises difficult choices and possible dangers. Humanity may be condemned to great hardship from climate change if it does not change energy technology, yet making the wrong choices or picking the wrong pathways may disrupt energy services and create serious risks.

We believe that citizens and leaders need increased energy literacy to resolve the dilemma by making changes in technology, policy, and behavior. In addition, a new energy economy will also need a workforce with new skills, knowledge, and perspectives (Cohen 2013). Energy-literate leaders in politics, labor, business, and religion must help citizens and the workforce cope with the challenges and embrace the opportunities of change.

Despite the needs for energy literacy, very few college and university students in the USA or elsewhere systematically learn about energy as part of their education. Many, perhaps most, students working on energy attend technical courses that inadequately address societal content and sustainability.

In contrast to its response to energy, higher education has responded to climate change in numerous ways. For example, in the USA, the American College and University Presidents' Climate Commitment began in 2006. Now, nearly 700 presidents have committed to change the curriculum, facilities, and practices (American College and University Presidents' Climate Commitment 2013). Education about climate change, however, is distinct from energy education and does not by itself revamp teaching about energy.

This article argues that inadequate energy education hinders development of sustainability education. New forms of energy education must become a fundamental part of undergraduate education, in the USA and everywhere else in the world. The article identifies early steps already taken in the USA, suggests a conceptual basis for making it interdisciplinary, and outlines the major challenges involved.

Energy challenges and first steps to interdisciplinary energy education

Energy clearly crosses the lines of many traditional academic disciplines. Linking sustainability to energy education makes an interdisciplinary approach imperative but thereby also poses challenges to long ingrained academic habits.

The University of California, Berkeley (Norgaard 2004), and the University of Delaware (Center for Energy and Environmental Policy 2013) pioneered programs in interdisciplinary energy studies in the 1970s and 1980s, respectively. More recently, other universities and colleges in the USA have started programs (U.S. Department of Energy 2013), but very few institutions offer any credentials in broad, interdisciplinary energy studies. In 2012, only 8 % (132 of the 1,638 US colleges and universities according to a census by the National Council for Science and the Environment) offered such broad energy education programs. Only 25 universities currently offer a total of 37 such degree programs in this area (Vincent et al. 2013a). Thus, the challenge lies in moving energy education from purely a technical field into an arena encouraging many kinds of students and faculty to examine all aspects of energy technology and its relation to society.

The U.S. Department of Energy led an extensive process of public engagement to develop *Energy Literacy*, a publication that identified seven foundational principles and associated concepts of energy education (Table 1, U.S. Department of Energy 2012). Formulation of these principles and concepts by a diverse group of energy and education stakeholders thus established the broad outline of content needed. Thirteen US federal agencies have endorsed *Energy Literacy*. More recently, the Association of Public and Land Grant Universities and others built a generic "Energy 101" class to develop these principles for classroom use, which the University of Maryland piloted in spring, 2013 (Association of Public et al. 2013).

The scale of the challenge now demands much more. Transforming energy use globally requires thinking at a systems level above the supply of and demand for individual fuels. Critical questions such as these will confront policy makers and require systems-level thinking:

- To what extent can a country or region use efficiency and conservation to reduce carbon emissions and energy use?
- What is the priority order for tapping different sources of efficiency? For example, efficiency of energy use can come from many sources including improved building designs, more efficient lighting and transportation, redesigned pipes, and better electric motors.
- Is carbon capture and storage likely to become safe, scalable, and cost-efficient?
- Can intermittent sources like wind and photovoltaic be integrated into a stable, reliable, electric grid?
- Are biomass fuels compatible with acceptable food prices and preservation of ecosystems?
- Is nuclear power acceptably safe, cost-efficient, and carbon emission-free?
- To what extent can injustice be avoided in the new energy economy?

Table 1 Principles of energy literacy

• Energy is a physical concept that follows natural laws.
• Physical processes on earth result from energy flow.
• Biological systems depend on energy flows.
• Various sources of energy and energy transformations power human activities.
• Economic, political, environmental, and social factors affect energy decisions.
• Social factors affect the total energy used by societies.
• Energy choices affect the quality of life.

Expanding interdisciplinary energy education

Bold responses must embrace a primary premise: a sustainable energy economy requires difficult choices among fuels and changes in energy budgets. An "energy budget" captures the idea that individuals, households, and nations use energy to satisfy demands for the services the energy provides. New technologies and policies can change both supply of and demand for energy; the challenge lies in marshaling resources and tools to create a new, safe, cost-effective, sustainable energy economy with minimal disruption to services.

Figure 1 portrays the US energy budget for 2013 (Lawrence Livermore National Laboratory 2013). It is a Sankey diagram with bar widths proportional to the amount of energy flowing to specific uses and sinks. The graphic shows relative magnitudes of fuels used, energy transformations, and waste associated with each end use. It helps faculty and students rise above "fuel trees" to see the big picture, an "energy forest." Transition to a new energy economy requires this change in perspective. Sankey diagrams of energy budgets in 2007 in all countries are available (Smith et al. 2011).

Energy budgets open new perspectives for interdisciplinary energy education. Instructors can use the diagram to introduce individual and household budgets and discuss particular aspects of energy use without losing the context of competing energy sources. Consider, for example, the question "Can shale gas extracted by hydraulic fracturing be a bridge to a sustainable energy economy?" Henderson and Duggan-Haas (2014) identified this subject as an important energy topic requiring an interdisciplinary approach plus focusing students' attention on comparing alternative energy options. Students can see in Fig. 1 the roles currently played by natural gas and can then discuss alternatives to gas, the contributions of gas extraction and use to climate change, possible dangers to groundwater supplies, other opportunities for investment capital, geopolitical implications of more gas production, and ways to turn the "bridge" metaphor to a realistic transition plan. Figure 1 focuses these questions toward understanding the challenges of changing the existing energy forest into a new pattern.

This example highlights two critical ideas about energy education. First, students—both those specializing in energy and those in other fields—must learn to see that every energy source has strengths and weaknesses. Second, no one discipline or perspective can claim complete authority.

Interdisciplinary approaches offer the best path forward and historically opened new avenues of study, such as biochemistry, physical chemistry, environmental studies, and biotechnology. Inherent in the development of each was the recognition that interesting problems lay between specialized areas and required juxtaposition of concepts and methods previously separated.

Energy education demands the same intrepid spirit. Those involved in teaching and learning about energy must develop

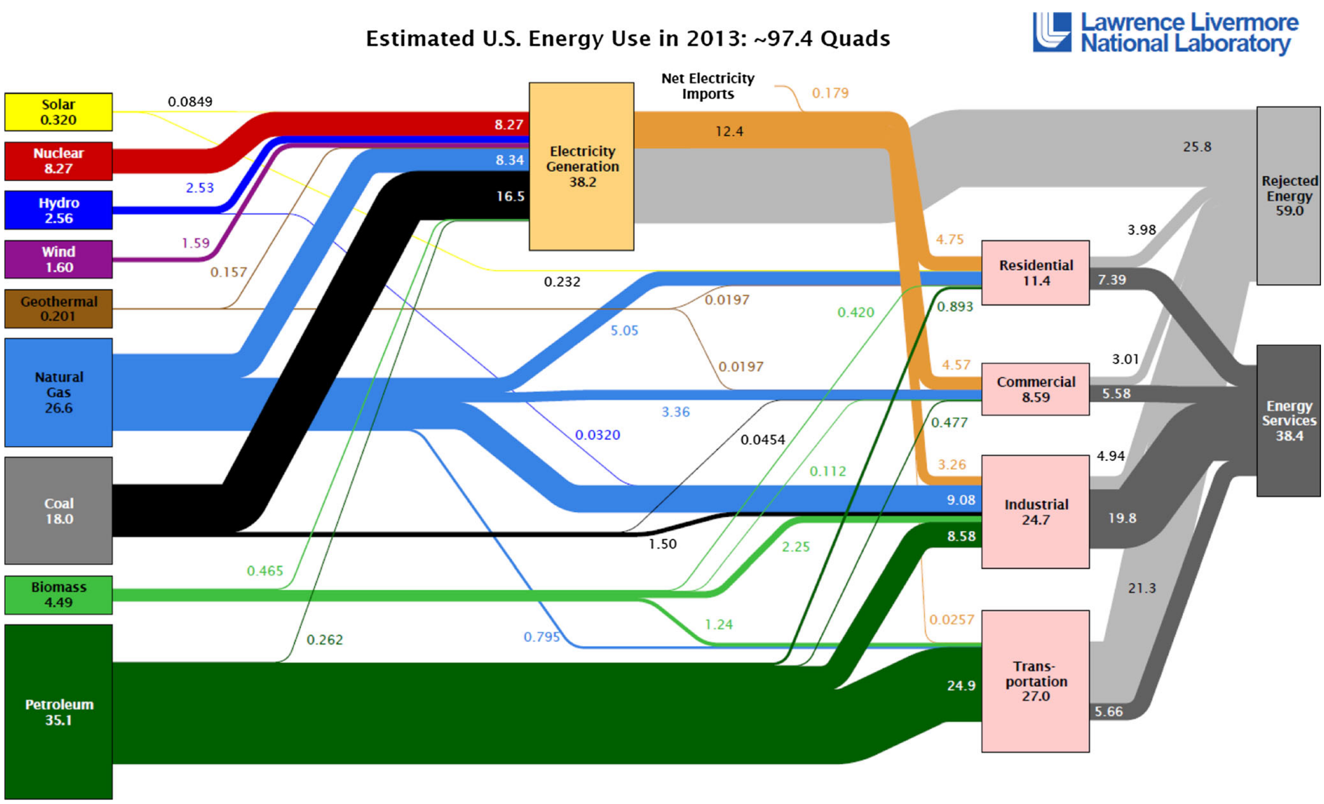

Fig. 1 Energy flow chart for the USA in 2013

a framework that identifies major problems, boundaries, concepts, definitions, theories, methods, and accepted facts. Numerous disciplines—such as physics, various engineering subjects, and economics—are essential, but holistic energy education must avoid constraints from any one discipline. For example, an economic approach can rightly emphasize costs and benefits, but some economic models overlook important considerations of distribution and social justice.

Pathways to a new energy education

We envision two pathways of expansion. First, opportunities must exist for all students to learn about energy use as a whole (energy budgets), why these use patterns must change, and the trade-offs involved. Environmental Studies programs often offer courses of this nature, but the number and reach of these courses must be scaled up considerably to enable many more students to enroll.

Second, students in engineering and other technical fields must gain greater breadth to see their specialized skills as part of the broader context of energy budgets. This could be accomplished by adding context to technical courses or through additional courses to supplement the technical classes. In either case, faculty in the technical fields should collaborate with scholars in the social sciences and humanities.

Faculty members who teach about energy often have labored in isolation. They need a community of scholars from multiple institutions with easy ways to share best practices. Such a community already has formed for environmental science and environmental and sustainability studies through groups including the Council of Environmental Deans and Directors (CEDD 2013), the Association for Environmental Studies and Science (AESS 2013), and the Association for the Advancement of Sustainability in Higher Education (AASHE 2013). These groups, however, have not focused on energy. The Council of Energy Research and Education Leaders (CEREL 2013) has begun a comparable effort to develop a community of scholars and leaders offering broad, interdisciplinary energy education as well as traditional technical education on energy.

Schools of engineering and geoscience departments currently produce most of the energy professionals, and their respective contributions will remain important. Some progress also already has occurred in the formation of broad and non-traditional energy education. The 2012 census of US institutions noted earlier identified more than 300 minors, concentrations, and certificate programs in the energy area (Vincent et al. 2013a). Many of these reside in engineering and other technical fields. Their number and enrollments must expand rapidly.

Regardless of undergraduate major, however, many students will work on energy after achieving postgraduate, professional degrees in fields such as architecture, business, law, public administration, and public health. Colleges and universities need to work with professional schools to create appropriate pathways.

Administrators and faculty face challenges in building interdisciplinary energy education. These include diversity, reward systems, curricular pathways, and meshing theory and practice.

Diversity American higher education has struggled to provide equal access to all students since well before the US Supreme Court's decision in 1954, *Brown* vs. *Board of Education*. Many other countries face similar challenges. Energy issues, however, touch everyone, so it is important to build programs that serve a highly diverse array of students. Both the professional energy workforce and citizen leaders must be able to work effectively with a multilingual, multiethnic population: the concept of "sustainable energy systems" explicitly depends upon equity and social justice.

Reward systems Institutions must outline clear pathways for successful academic careers for those who build interdisciplinary programs of teaching and research in energy. Faculty members need assurances that their efforts will be recognized.

Curricular pathways Students studying energy need an integrated curriculum. For example, a student may need to build knowledge and skills in physics, math, economics, history, environmental studies, anthropology, psychology, toxicology, materials science, communications, and project management. The knowledge needed may require new courses or new pathways in the curriculum.

Theory and practice Instructors should bring working professionals into their classrooms and build collaborative research projects. In addition, most students will benefit from internships or work experience in the private, non-profit, and governmental sectors. Colleges and universities can generate many opportunities for learning by creating student positions to promote sustainable practices within the institutions (Thomashow 2013; Kurland 2011; Cortese 2005; Miller 2005).

The challenges of energy education should not be underestimated. Each institution will need to solve questions of integration, coherence, prerequisites, general education, certificate programs, minors, and majors; collaboration among institutions will promote this process. The overriding mandate, however, lies in enabling student access to relevant courses and to certifying their achievements.

Actions needed

Is a special effort needed in energy education? The situation within each country is unique, but in the USA, for example, carbon emissions have decreased, but only modestly, since 2007 (Energy Information Administration 2013a). At the same time, programs in energy education have grown. Similarly, programs in climate change and sustainability have grown (Vincent et al. 2013b) and offer content on carbon emissions and energy. Will changes currently underway in technology and educational practices in the USA be sufficient to promote more sustainable energy budgets?

Three factors lead us to suggest that current changes underway are insufficient. First, low-carbon energy sources are still minor compared to energy from fossil fuels (Energy Information Administration 2013b; Fig. 1). Multiple sources also indicate significant opportunities to enhance energy efficiency exist but have not been implemented (American Council for an Energy-Efficient Economy 2012; Laitner 2009; Lovins 2011). Carbon emissions will remain dangerously high for too many decades, despite rapid growth of wind and photovoltaic (Wiser and Bolinger 2012; U.S. Energy Information Administration 2013c), two important but still very minor non-carbon sources. The US energy budget is far from what it should be to stabilize atmospheric levels of carbon dioxide.

Second, growth of carbon-free energy sources remains fragile and politically contested in the USA and many other nations. The scientific consensus about climate change has attracted concerted efforts to discredit it (Brulle 2013; Cook et al. 2013; Oreskes and Conway 2010; Oreskes 2004), and the doubts sown have inhibited needed policy developments. As a result, existing programs in energy education remain insufficient to drive the innovation needed for significantly reduced emissions from fossil fuels. Energy-literate citizens will better understand energy dilemmas, the costs of transition, and the costs of failing to make a transition.

Third, investments by the government in the USA remain woefully insufficient. The Department of Energy (DOE) and the National Science Foundation (NSF) are the key federal agencies that have already made important contributions. DOE has led in promotion of new technology and advancing energy literacy. NSF has made major contributions by supporting research in engineering, other sciences, and sustainability, but NSF lacks a program focused on energy education. More is needed, and universities and colleges also need to consider putting more existing resources into energy education.

Each institution and country must assess the adequacy of its own programs in energy education. It is likely, however, that the inadequacies in the USA also exist elsewhere. At the same time, we recognize that colleges and universities already have many challenges. Why add another task when institutions already are struggling with multiple mandates, many underfunded?

There are two reasons: first, the quality of life in the mid- and late twenty-first century will depend on decisions made about energy investments in the next 20 years. Second, both the skilled energy workforce and citizens involved in decision-making about energy require broad knowledge. In short, energy literacy is vital to human well-being and uniquely depends upon the outcomes of educational programs.

Energy presents us with stark choices and unprecedented challenges, but the barriers are surmountable. Without more energy-literate graduates, however, the world will be hard-pressed to resolve the dilemmas of building new energy economies that mitigate climate change without losing vital energy services or generating unacceptable risks. Sustainability education is not complete without energy education.

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