Help make a difference with education and outreach for the global energy challenge!

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High gasoline prices are one of the many symptoms that the global energy system is being challenged by the rising demand compared with supply. A stable and environmentally responsible energy supply is one of the major issues that confronts mankind in the 21st century. Our personal energy use, the development of novel energy resources, and policies adopted by government are all influenced by the awareness of the public of the choices that we face in our energy use and the consequences of those choices. For this reason, energy education and outreach is essential for making the public better aware of our energy situation. SEG members, in their roles as employees of energy companies, as government employees working in the geosciences, or as educators at universities, are well prepared to help educate the public about the challenges and opportunities that we face in our energy supply. Here we sketch those challenges and opportunities and give ideas on how one can assist in energy outreach and education. We have developed a public lecture, "The Global Energy Challenge," that is available for such outreach and education activities.

The global energy outlook

Energy consumption is ubiquitous in our lives, and energy is the lifeblood of the modern world. We use energy for heating and transportation, lighting, communication, manufacturing, water supply, enhancing productivity with information technology, and recreation; even our food industry relies heavily on energy. For example, in the United States, about 400 gallons of petroleum per person per year are used for food production (Pollan, 2006), mostly for producing fertilizer, for irrigation, and for transporting our food over an average distance of 2100 km. Every day we rely increasingly on novel uses of energy—from new flat screen TVs, security systems, and standby power for appliances, to motion-activated water faucets. The worldwide demand for energy is steadily growing. According to the Energy Information Administration (EIA), which provides the official energy statistics from the US government, global energy consumption is expected to grow by about 70% in the coming 25 years (Figure 1). Much of this growth is driven by developing countries whose inhabitants seek a standard of living that more closely resembles that of the developed world. Because of their large populations and rapid economic growth, China and India are major contributors to this growth in energy demand. But energy demand is also expected to grow in the developed world, up to 20% over the next 20 years in the USA.

According to the EIA, about 40% of the world's energy comes from petroleum, while coal and natural gas together provide another 40%. These fuels are aptly called fossil fuels, since they are remnants of buried organic-rich ecosytems that existed tens of millions year ago; for this reason those resources are finite and production will ultimately decline. The date when oil production peaks is a contentious issue; estimates of the date of peak oil production range from about today (Deffeyes, 2006) to 2045 in the most optimistic scenario of the EIA. In a time of growing demand, a constant supply or a decline in production leads to a demand-driven market, causing prices to rise. In a recent interview published in *Newsweek*, John Hess, CEO of Hess Corporation, remarked: "We've moved from a supply-led (petroleum) market to a demand-led one. In the past, the world has relied on OPEC's spare capacity, which in 1985 was 10 million barrels per day. Today that number is about 2.5 million barrels a day. We no longer have a safety margin to ensure price stability in the face of supply interruptions and demand spikes. Right now it's hard to see any relief in sight. Then there's demand. About 50% of oil demand is for transportation, and auto ownership in the developing countries is growing swiftly, especially in India and China.... Put those two things together—limited supply and increasing demand—and you get high oil prices."

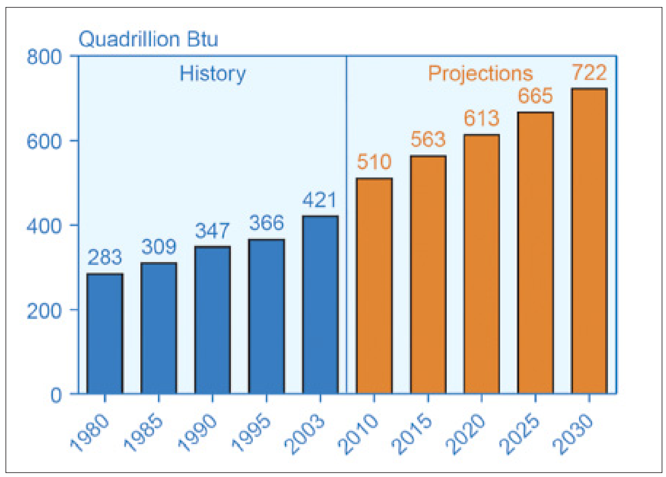

Figure 1. *World energy consumption as given by the Energy Information Administration (EIA).*

The rapidly growing demand for petroleum under conditions of limited supply has led to rapidly increasing prices of oil. The 2005 study *Oil Shockwave*, by the National Commission on Energy Policy, stated: "America must begin now to take steps that will reduce our oil dependence and the serious economic and national security risks that come with it." The committee lists public engagement and education as two of the four necessary steps.

The energy challenge is confounded by the consequence of emitting CO_2 into the atmosphere when fossil fuels are used. The Intergovernmental Panel for Climate Change concluded in 2007 that the absorption of infrared radiation by anthropogenically produced CO_2 is on track to produce between 2 and 4°C global warming over the 21st century, unless greenhouse-gas emissions are reduced dramatically, beginning now. Such global warming leads to life-altering regional climate change and a rise in sea level of about 40 cm. For low-lying developing countries, the consequences of such apparently modest changes are severe.

The world's population is strongly dependent on an affordable and reliable energy supply, and the infrastructure for providing this energy supply is as complicated as it is costly. Our current energy infrastructure—roads, gasoline stations, refineries, central power generating stations, electricity transmission lines, natural gas distribution lines, and all of the companies and institutions that together provide these valuable energy services—took over a century of investment. Changing this infrastructure on every scale—local, regional, and global—takes time and money, and a system this complex and costly is slow to change. But many things can be done now to begin to reduce energy demand, diversify our energy portfolio, and reduce costs of energy supplies with lower greenhouse-gas emissions. This will not happen, however, without a plan and the willingness to implement such a plan. Public engagement and education in dealing with the pressing challenges and opportunities are the key to getting started now.

Dealing with the energy challenge

Fortunately, petroleum is not the only source of energy. US coal reserves are expected to be sufficient to cover domestic demand for 90–120 years. The proven US supplies for natural gas are sufficient for about 10 years, but global gas supplies are expected to last 45–60 years (Weisz, 2004). Significantly more gas might be available from methane hydrate formations, onshore in the northern latitudes, and, more importantly, in offshore formations. In addition, there are significant reserves of unconventional oil, such as tar sands and oil shale. Tar sands consist of a sticky mix of tar and sand. Shallow deposits are mined in open-pit mines; for deeper deposits, the tar sand is usually heated with steam to mobilize the hydrocarbons, but this process consumes much energy. Oil shale must be cooked in the subsurface for several years to produce petroleum; this also is an energy-intensive process. The deposits of oil shale are believed to be considerable: the EIA estimates there are about 400 billion barrels of syncrude from oil shale in the USA, enough to meet current US demand for about 50 years. But it is not clear if this fuel can be extracted on an economic and environmentally sound basis.

In the absence of a strategy to reduce the use of hydrocarbons, coal and unconventional oil are likely to be the major source of energy for the coming century. Because of the relatively high carbon-to-hydrogen ratio of coal, this fuel produces more CO_2 per unit energy than petroleum or natural gas. The production of unconventional oil consumes more energy than does the production of conventional oil. This further increases CO_2 emissions and thus aggravates global warming. Technology to capture and sequester emissions of carbon dioxide from burning fossil fuels is being developed, thus providing the option to continue fossil fuel use even in a greenhouse-gas-constrained world. Given the high cost of carbon capture and storage, this option is, however, viable only when enforced by legislation. Education of the public is necessary to make such regulation palatable.

Abundant renewable energy from wind or solar energy resources can be generated without CO_2 emissions. These resources are both very large, and the cost of wind power is nearly competitive with other sources of energy. Solar photovoltaics and solar thermal energy production remain costly. Biofuels can also contribute to achieving these emission reductions, but only if they are grown and processed in a climate-protective manner. To avoid a competition between humans and their machines for calories, the ethanol needs to be produced from a feedstock that is not suitable for human consumption. Research and development continue to decrease the cost of renewable energy; particularly with increasing prices of hydrocarbons, renewable energy is increasingly competitive. Nuclear power can also provide a source of CO_2-free energy, and, for the first time in nearly two decades, with government incentives, plans are underway to develop several new nuclear power plants in the USA.

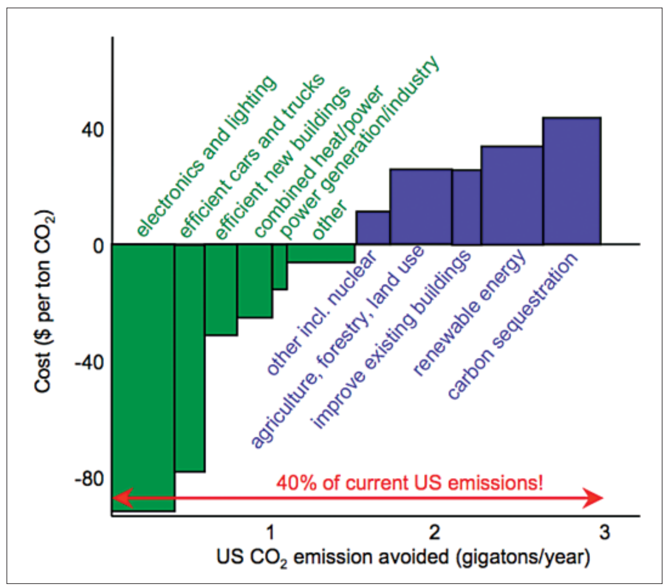

Figure 2. *The annual avoidable US CO_2 emissions (horizontal axis) in gigatons CO_2/year and the cost per ton (vertical axis). The total US CO_2 emission is about 7 gigatons CO_2 per year. Modified after the McKinsey analysis.*

Recently, McKinsey (2007) carried out a comprehensive study of the cost of reducing CO_2 emissions in the USA by a variety of different measures. The so-called abatement curve in the McKinsey report which shows cost versus avoided annually CO_2 emission is sketched in Figure 2. The study showed that about 1.4 gigatons of CO_2 emissions can be avoided at negative cost, that is, at reduced cost compared to taking no action! This is about 20% of the total CO_2 emissions of the USA. The measures that have a negative cost include efficient lighting systems, fuel economy packages for cars and light trucks, biofuels produced from cellulose, and combined heat and power industrial systems. This negative cost implies that money and energy resources can be saved by adopting these technologies. Also shown are measures to reduce CO_2 emissions with a positive cost; these include carbon capture and storage, thermal and photovoltaic solar systems, and solar and thermal hydrogen production and storage. Many of the measures proposed to reduce CO_2 emissions serve the additional purpose of reducing energy demand by increasing energy efficiency and switching to renewable energy.

Much research is being carried out on new energy systems that can help bring down the cost of measures that have positive cost in Figure 2. For example, a significant fraction of the cost of carbon capture and sequestration is the separation of CO_2 from air. Research focused on the use of nanotechnology might reduce the cost of CO_2 separation. Research serves the dual goal in photovoltaics by both increasing the efficiency and decreasing the price. With a lower cost, the actions with positive cost today can be made more attractive.

Impediments, moreover, exist to implement negative cost actions in Figure 2 to avoid CO_2 emissions. For several actions, such as the use of combined heat and power systems for commercial buildings, substantial capital investments precede the financial returns. For other steps, such as more efficient cars and light trucks, societal preferences for large and heavy vehicles need to shift to a preference for low-weight fuel-efficient cars. Financial incentives and regulation can help accelerate the implementation of such energy-saving steps, and education can play a key role in making these financial incentives and regulation politically more acceptable. The development and implementation of energy-saving actions implies that there are new opportunities for research, as well as career opportunities for a wide range of professionals, a point that is much appreciated by a young audience. As the cost of conventional energy sources rises, these opportunities become financially more attractive.

The need for education

Both our energy use and CO_2 emissions can be reduced by using and producing energy in different ways. Implementing these improvements is associated with changes in our technology and energy use. It has been shown that the public is, to a large extent, unaware of the essential role played by energy in society, of the challenges that we face with our energy supply, and the steps we can take to increase energy efficiency. A recent study has shown that the public largely believes in a number of myths regarding our energy use (Sovacool and Brown, 2007). These wrongly held notions include the idea that today's energy crisis is a hype, that efficiency improvements have reached their potential, that climate policy will bankrupt the US economy, and that the current global energy infrastructure is optimally efficient.

Achieving the reductions in CO_2 emissions listed in Figure 2 will require the support and cooperation of the public. In particular, taking advantage of the cost-effective achievable emissions will require the public to:

- develop a preference for purchasing energy-efficient appliances and automobiles,
- make capital investment on retrofits for improving heating and lighting efficiency, and
- support promulgation of standards for high-efficiency buildings and low-emission vehicles.

Without support of the public, we could well miss the opportunity to implement these negative cost options—and rely more heavily on higher-cost, but more centrally-controlled options that do not gain from the leverage of participation by so many people who take advantage of them.

Many steps to reducing CO_2 emissions can be realized at low-to-moderate cost, including increasing the amount of electricity supplied by wind farms and building new nuclear power plants. Gaining the support of the public for siting and building new wind farms and nuclear power plants will be needed to take advantage of these low-emission sources of electricity. Continued support for renewable-energy portfolio standards is also needed to help accelerate deployment.

Continuing to reduce emissions beyond those options with negative or low costs will require a new generation of low-carbon energy technologies. Many are under development—carbon-dioxide capture and storage of emissions from

Figure 3. *What is the mass of the CO_2 produced when the coal in one railroad car is burned?*

fossil fuels, solar-thermal systems for generating electricity, plug-in hybrid vehicles powered by electricity from renewable sources, advanced biofuels created from cellulose or algae, electricity grids with a large fraction of intermittent and distributed renewable energy sources, and grid-scale storage of electricity. Supporting research to lower the cost of these options will pay dividends in the future. Large-scale demonstrations are needed to gain the confidence of industry, permitting agencies, insurers, and financiers. Public support for government funding and commercial incentives for research and development will be needed, as will public support for taking chances on something new—new infrastructure, new ideas, and new technologies.

The public struggles to come to grips with the magnitude of numbers that is relevant to understanding our energy use and its consequences. As an example, consider a coal train of the type that can frequently be seen in the American west (Figure 3). We found that the question "what is the mass of the CO_2 produced when the coal in one railroad car is burned?" often leads to the reply "a few grams." The correct answer is about 300 tons, about three times the weight of the coal. (Each carbon atom is bound in CO_2 to two oxygen atoms, and carbon and oxygen have about the same mass.) The reason many people think the amount of CO_2 is negligible is that CO_2 is a gas, and therefore must be light. Indeed, it is difficult and confusing to understand the large numbers associated with our energy use, especially with the plethora of different units that are used.

Because we must develop a strategy for our energy use, combined with the widespread misconceptions about our energy system, it is essential that the public be informed and educated about energy. Such education also helps create public support for energy-related research. Providing balanced information to the public helps foster a mindset that is open to technological and social innovations needed for a stable and environmentally responsible energy system.

What can I do as physical scientist?

Some of us are involved in research that helps develop renewable energy sources or that paves the way for the increasing efficient use of nonrenewable sources. Educators can create a greater awareness of the challenges and opportunities associated with society's large appetite for energy by infusing their lessons with examples that help students understand aspects of the energy system. This also aids students with seeing the relevance of the topics in their courses. For most topics in physics, geoscience, chemistry, or biology, one can think of energy or climate-related examples that illustrate those topics. For those working in an academic environment, the American College and University Presidents Climate Commitment provides a suitable platform to raise the awareness of energy efficiency with the administration of the college or university.

As part of the outreach and education activities of the Global Climate and Energy Project at Stanford University, we have developed a public lecture, "The Global Energy Challenge." This PowerPoint presentation is freely available (*http://www.mined.edu/~rsnieder/Global_Energy.html*) and aims to be appealing and understandable for a broad audience. It can also be used for general undergraduate courses. Comment boxes in the PowerPoint presentation give ideas for a narrative. When speaking about energy, it is important to convey the challenges that we face without sketching doomsday scenarios. Such a negative approach merely generates denial that blocks further communication. The energy challenge comes with new opportunities, and it is important to convey these opportunities to empower people for taking action, whether in their career choice, their choices as consumers, or otherwise. The presentation gives ideas for positive action that teachers, students, businessmen, consumers, and citizens can take.

We have had good experiences giving this lecture at community colleges. Teachers of general science classes at these colleges often are grateful for societally relevant material that fits into their classes. The presentation can also be used for outreach and education in high schools; we found that teachers often welcome such a contribution. Service clubs, such as the Rotary or Kiwanis, are keen to host engaging speakers, and this presentation lends itself well for this purpose. The Internet makes it easy to establish contact with such clubs. Local churches, libraries, and community centers provide other opportunities to present this public lecture.

We encourage you to help raise awareness of the energy challenges we face and of the opportunities associated with developing and implementing new energy systems. It has been easy for us to engage audiences for this topic, and we have discovered that students at high schools, community colleges, and universities are intrigued by emerging career opportunities in the energy sector. Because of the importance of establishing a stable and environmentally responsible energy supply, one can make a difference by participating in energy outreach and education, for example through use of a variant of our lecture. In delivering this lecture, we have consistently received a positive response, finding this a rewarding activity. We invite you to make a similar contribution!

Suggested reading. *The Omnivore's Dilemma* by Pollan (Penguin, 2006). *Beyond Oil: The View from Hubbert's Peak* by Diffeyes (Hill and Wang, 2006). "Basic choices and constraints on long-term energy supplies" by Weisz (*Physics Today*, 2004). "Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?" (*http://mckinsey.com/clientservice/ccsi/pdf/US_ghg_final_report.pdf*, McKinsey and Company, 2007). *Energy and American Society—Thirteen Myths* (edited by Sovacool and Brown Springer, Dordrecht, 2007). "Oil shockwave from the National Commission on Energy Policy" (*http://www.secureenergy.org/reports/oil_shock_report_master.pdf*, Securing America's Future Energy, 2007). TLE

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