U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE
SUBCOMMITTEE ON ENERGY

HEARING CHARTER

Renewable energy technologies – research directions, investment opportunities, and challenges to commercial application in the United States and the developing world

Wednesday August 2, 2006
12:30 pm - 2:30pm
San Jose City Hall
200 East Santa Clara Street
San Jose, CA 95113

1. Purpose

On August 2, 2006, the Subcommittee on Energy of the House Committee on Science will hold a field hearing entitled *Renewable energy technologies – research directions, investment opportunities, and challenges to commercial application in the United States and the developing world*.

2. Witnesses

- **Dr. Steven Chu** is the Director of the Lawrence Berkeley National Laboratory and a 1997 Nobel Prize winner in Physics. He is currently spearheading a new Laboratory research initiative focused on solar energy.
- **Dr. Arno Penzias** is a Venture Partner with New Enterprise Associates in Palo Alto, CA While at Bell Laboratories he won the Nobel Prize for Physics in 1978. Today he is a venture capitalist with interests in renewable energy technologies.
- **Mr. Christian Larsen** is Vice President for Generation for the Electric Power Research Institute in Palo Alto, CA. His division provides data on cost and performance analyses and for renewable, distributed, and hydropower energy generation technologies to the electricity industry.
- **Mr. David Pearce** is President and CEO of Miasolé, a Santa Clara, CA based company that manufactures industrial-scale solar products using thin film solar cell technology developed in Department of Energy national laboratories.
- **Mr. Ron Swenson** is cofounder of ElectroRoof, a solar equipment installation company, and EcoSage, an educational services company developing a program to build solar-powered satellite teaching centers in remote areas of the world in conjunction with solar education programs in schools.

3. Overarching Questions

The hearing will address the following questions:

1. What is the current state of adoption of renewable energy sources in the United States? What factors are limiting the rate of adoption of renewable energy technologies?
2. What is the outlook for potential improvement in market penetration of renewable energy technologies? What are the main research efforts that could improve that outlook?
3. What should the federal government be doing (or not doing) to encourage the commercialization of, and demand for, new renewable energy technologies? How well aligned are the Department of Energy's activities with what the investment community is doing?
4. What opportunities and challenges exist for the sale and use of renewable energy generation in developing countries? How do these opportunities and challenges differ from those in developed countries?

4. Brief Overview

Because renewable energy relies on natural and recurring flows of energy, rather than gradual depletion of a geologic stock created over millions of years, there is less risk of exhausting the resource. Renewable energy can significantly reduce the environmental impacts of energy production, and in most cases is produced domestically (even if the technology that produces it is imported.) The United States is becoming increasingly dependent on imported energy, and many analysts contend that our foreign policies are distorted by that dependence. Although the United States has only two percent of the world's oil reserves and three percent of the world's natural gas reserves, U.S. renewable energy resources are vast and largely untapped. Renewable energy can reduce the demand for imported energy, reducing costs and decreasing the variability of energy prices. By using domestic renewable energy resources, the United States can reduce the amount of money sent into unstable regions of the world.

In addition, some renewable energy technologies have other unique advantages. For example, solar energy, while difficult to store, generally follows the changes in demand during the day: its peak output is in the middle of the day, about when air conditioning and other demands also peak. Because utilities tend to use their least efficient (and often most polluting) plants at peak load (they want to run them as little as possible), energy market experts say that small reductions in peak demand can result in very large reductions in price and emissions.

5. Background

Current state of renewable energy

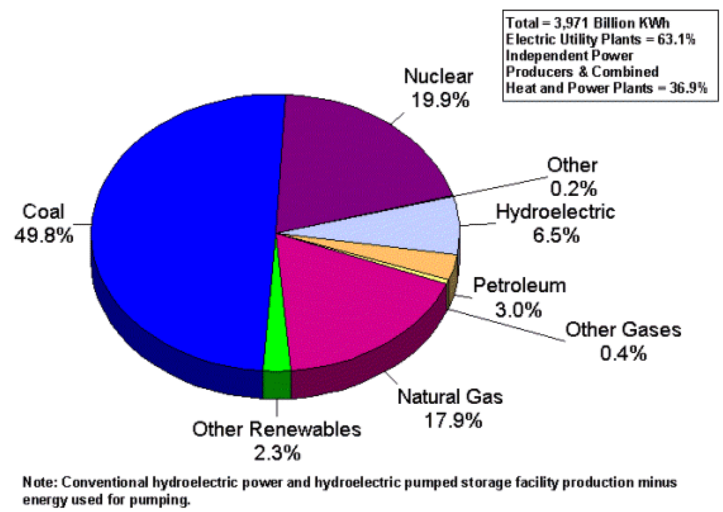
In 2004, the United States consumed nearly 4 billion kilowatt hours (KWh) of electricity.[1] Of that total, 6.5 percent came from hydroelectric power plants and only 2.3 percent came from all other renewable energy resources combined, including geothermal, solar thermal, photovoltaic,

[1] see http://www.eia.doe.gov/cneaf/electricity/epa/figes2.html

wind, ethanol and other biomass sources. Given the large number of resources that are added to reach this value of 2.3 percent, the total installation of each type is quite small. The total U.S. installation of solar electric generation, for example, was only 340 MW peak,[2] and the output of that capacity was a negligible fraction of the total electricity consumed nationwide that year. (See Figure 1.)

Renewable energy sources also play a small role when compared to the overall U.S. domestic energy consumption, including transportation. Energy from renewable sources constituted six percent of all energy used in the U.S. in 2004, with biomass and hydroelectric power making up the bulk of that total. Wind energy accounted for two percent and solar energy accounted for just one percent of all renewable energy used that year. (See Figure 2.)

Figure 1. U.S. Electric Power Industry Net Generation, 2004



Source: Energy Information Administration, Electric Power Annual 2004 Edition

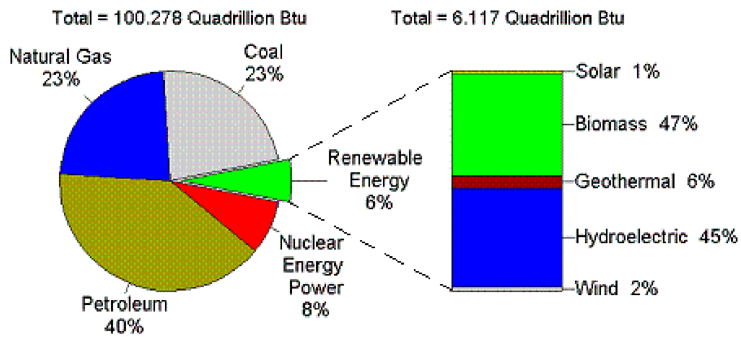
Projected Growth in Total Energy Usage by 2030

According to the Energy Information Administration (EIA), total U.S. energy use will increase by about 27 percent from 2004 to 2025, or about 1.2 percent per year. Oil demand is projected to grow at about the same rate, by 26 percent, or around 1.1 percent per year; but natural gas use is expected to grow by only 20 percent, or around 0.7 percent per year. Electricity demand is forecast to grow faster than overall energy demand, by 1.6 percent per year, or a growth of 40 percent to 2025. Broken down, electricity demand is expected to grow by 75 percent by 2030 in the commercial sector (due to rapid growth in the service industries), by 47 percent in the residential sector, and by 24 percent in the industrial sector. These growth rates assume that

[2] Solar Energy Industries Association: *Our Solar Power Future – The U.S. Photovoltaics Industry Roadmap Through 2030 and Beyond.* Peak wattage is the output of energy when sunlight conditions are favorable; most solar devices can operate during cloudy conditions at reduced output.

some efficiency gains will be realized in both the residential and commercial sectors as a result of new standards in the Energy Policy Act of 2005 and higher energy prices that prompt more investment in energy-efficient equipment.[3]

Figure 2. The Role of Renewable Energy Consumption in the Nation's Energy Supply, 2004



Source: Energy Information Administration Renewable Energy Annual 2004 Edition
http://www.eia.doe.gov/cneaf/solar.renewables/page/rea_data/rea_sum.html

In electricity generation, the natural gas share of total production is projected to increase from 18 percent in 2004 to 22 percent around 2020, before falling to 17 percent in 2030. The coal share is projected to decline slightly, from 50 percent in 2004 to 49 percent in 2020, before increasing to 57 percent in 2030. Nuclear electricity is projected go grow by 10 percent over the period, or about one-half percent per year. (Very little oil is used for electricity production.) Under this scenario, emissions of carbon dioxide are projected to rise by 29 percent.

Projected growth rates for renewable energy, in contrast, are relatively high, but because renewable energy is a small part of the mix, the high growth rates projected still result in a relatively small contribution to the mix. Ethanol demand is projected to rise over 300 percent, or about five percent per year; after this increase ethanol will constitute about five percent of the total gasoline demand. Photovoltaic solar generation is projected to rise 26 percent per year in the utility sector, and 10 percent for electricity that is not sold into the grid; however, EIA projects that the percentage of solar photovoltaic power supplied to the grid would still be far less than one percent of the total supply by 2025.

Potential for renewable energy

Renewable energy industry representatives and other advocates, unsurprisingly, argue that the potential is much greater and the prospects much better for renewable energy than EIA predicts.[4] Critics of EIA forecasts point out that EIA is limited by its assumptions: EIA forecasts assume no changes in current policy and a rate of technological improvement that is unaffected by the

[3] Energy Information Administration: Annual Energy Outlook 2006

[4] This is true of other industries as well. The nuclear industry also believes that EIA's forecasts do not reflect the prospects for nuclear. However, it is worth noting that EIA has little choice but to assume current policy will continue.

level of research and development (R&D) investment. Critics note that changes to these assumptions would produce different results. They also note that EIA's models do not allow for market penetration of technology if its output price is not competitive, even if other attributes are more important in niche markets. For example, solar energy has made inroads in applications where tying to the grid is costly, such as remote or portable power supplies.

Given these limitations and their perspective on the current state of the technology, the Solar Energy Industries Association's *U.S. Photovoltaic Industry Roadmap* projects that installed peak solar electric generation can increase to 200,000 megawatts (MW) by 2030, up from only 340 MW in 2004, with the industry installing 19,000 MW of new generation per year.[5] In this case, solar power would be a substantial share of U.S. peak generating capacity. (For comparison, 2004 installed capacity for coal was about 335,000 MW; however, solar needs a larger capacity to achieve the same total annual output of kilowatt hours, since its output is only during the day.)

Others analysts depict the need to ramp up solar energy use as a matter of physical necessity if we are to meet overall demand. For example, Dr. Nathan Lewis, of the California Institute of Technology, has performed an analysis of the potential generating capacity that different renewable energy sources could supply in hopes of meeting the worldwide demand of 28 terawatts (TW) expected by 2050 and 40 TW by the end of the century.[6] (A terawatt equals one billion kilowatts.) According to his findings, hydroelectric power has a technically feasible potential of 1.5 TW, onshore geothermal power could produce approximately 11 TW per year until the wells "run out of steam," (projected to be five years for the average well.) U.S. land-based wind production could produce about 0.5 TW, and biomass may produce 5-7 TW. He concludes that solar energy, with a potential of 120,000 TW and a practical capacity of around 600 TW worldwide, is the only renewable resource that could single-handedly meet not just U.S. electricity needs, but could power the entire globe. Lewis emphasizes that his analysis is an accounting of technical potential, not necessarily what is practical based on price without significant breakthroughs in technology and deployment patterns.

U.S. Actions in International Perspective

Renewable energy is a growth industry around the world. However, the United States has not been investing as heavily as other countries, and has been losing market share in many renewable industries, especially in the solar power industry. Since 1996, the U.S. market share in the solar industry dropped from 44 percent of the world market to 13 percent in 2003. In 2003, the U.S. government spent $139,000,000 for research, development, demonstration, and commercial application and other incentives; in the same year Japan spent more than $200,000,000, and Germany provided more than $750,000,000 in low cost financing for solar photovoltaic projects. Germany and Japan each had domestic photovoltaic industries that employed more than 10,000 people in 2003, while in the same year the United States photovoltaics industry employed only 2,000 people.

Current Federal Activities in Energy Efficiency and Renewable Energy R&D

In the State of the Union address, the President announced the Advanced Energy Initiative, an initiative focused primarily on domestic production of energy and energy efficiency. That

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[5] Op cit., *Our Solar Power Future*

[6] http://nsl.caltech.edu/energy.ppt

initiative included increases for R&D on biomass, solar and wind energy, and batteries for energy storage (especially targeted at high-mileage plug-in hybrid electric cars). The President also asked for large increases in hydrogen research, a fuel that must be derived from other sources, including potentially from renewable energy sources.

House and Senate Appropriators have endorsed the President's support for key renewable energy programs, including solar energy and biomass, in the fiscal year 2007 (FY07) budget request. The House approved the requested increases of 65 percent for biomass R&D and 79 percent for solar energy R&D. The full Senate has not yet voted on FY07 appropriations, but the Senate Appropriations Committee also approved large increases for biomass (more than doubling funding to $213 million), and solar energy (up 79 percent to $148 million). In addition, the Senate Committee mark would preserve the geothermal R&D and hydropower R&D programs ($23 million and $4 million, respectively), which the Administration and the House have proposed to eliminate. The Senate mark would also sustain the wind energy program at the FY06 funding level of $39 million. (See table below.)

Federal Funding for Energy Efficiency and Renewable Energy R&D

	FY 06 Enacted	FY07 Request	FY07 House	House v. Enacted	FY07 Senate Committee Mark	Senate mark v. Enacted
Efficiency and Renewable R&D	530	670	**730**	*200*	**994**	*464*
- Hydrogen Technology	*156*	*196*	***196***	*40*	***190***	*34*
- Biomass and Biorefinery Sys.	*91*	*150*	***150***	*59*	***213***	*122*
- Solar Energy	*83*	*148*	***148***	*65*	***148***	*65*
- Wind Energy	*39*	*44*	***44***	*5*	***39***	*0*
- Geothermal Tech.	*23*	*0*	***0***	*-23*	***23***	*0*
- Hydropower	*0*	*0*	***0***	*0*	***4***	*4*
- Vehicle Tech.	*182*	*166*	***178***	*-4*	***180***	*-2*
- Building Tech.	*69*	*77*	***93***	*24*	***95***	*26*
- Industrial Tech.	*57*	*46*	***52***	*-5*	***48***	*-9*
- Congressional projects	*158*	*0*	***55***	*-103*	***54***	*-104*

How Will Solar Energy Achieve Greater Adoption?

There are several barriers to the adoption of solar energy systems – primarily cost, efficiency, and the intermittency of sunlight. The energy crisis of the 1970's saw the beginning of major interest in using solar cells for power, but prohibitive prices (approximately 30 times current prices) made most applications unfeasible. These prices have declined to the point where electricity from solar energy is about double the cost of retail rates. For a number of reasons, prices are expected to continue to decline. First, manufacturing efficiencies should allow improved prices, that is, as production volume increases, cost will continue to decrease. This economy of scale benefit may see short-term blips caused by shortages of materials used in photovoltaic technologies. For example, the availability of single-crystal silicon is currently a concern to the industry. Industry projections indicate that market growth coupled with the adoption of favorable public policies could result in electricity costs of 5.7 cents per KWh by 2015, a cost that is lower than current retail rates for many customers.

In addition to driving down costs, advances in materials will increase the efficiency of photovoltaic systems. New technologies such as plastic solar cells, nanostructured materials, and dye-sensitized solar cells offer the potential to move well beyond the efficiency of current materials systems, dramatically lower cost and raise performance. The *Photovoltaic Industry Roadmap* projects a doubling of conversion efficiency for individual solar cells, of modules made up of multiple cells, and for systems as a whole by 2030.

Improvements in battery technologies for electricity storage are helping to deal with intermittency—an ever present problem for solar energy. Early generation solar systems were only useful during the daytime, but advanced batteries can store electricity generated by the sun for later use, thus making photovoltaics a more reliable energy source.

The Role Renewable Energy Can Play in the Developing World

Much of the increased demand for energy worldwide is anticipated to come from developing nations, as economic growth drives energy consumption toward levels in the developed countries. EIA estimates project the developing world's energy consumption to almost double in the next 20 years, driven largely by economic growth in China and India. Cost-effective renewable energy sources such as solar and wind may present a cleaner way to bring electricity to the poorest regions of the world, and meet the demands of rapid economic expansion of others. World Bank figures indicate that approximately 1.6 billion people worldwide are "energy poor," having no access to electricity (70 percent of Sub-Saharan African and 59 percent of South Asian populations are in this category), with hundreds of millions more using only intermittent, unreliable or heavily polluting sources of energy.

Greater adoption of renewable energy technology in the developing world can benefit developed countries as well. U.S. companies can reap the rewards of manufacturing and exporting technologies. If rapidly growing economies can offset growing thirst for fossil fuels with renewable technologies, they will help to reduce global competition for—and therefore prices of—fossil fuels. Furthermore, renewable technology adoption in developing countries can avoid increases in carbon dioxide emissions.

6. Witness Questions

Dr. Steven Chu

1. What are the limitations of current renewable energy technologies? Are these limitations inherent to the kind of technologies that are being used? What types of technologies can overcome these limitations?

2. What is the long-term potential for renewable energy technologies? What research and development work needs to be performed to lay the groundwork for the commercial application of a new generation of renewable energy sources?

3. What is the appropriate division of labor for this work among government, industry, and academia? How much money do you estimate these efforts will cost?

4. What steps is your lab taking to improve its ability to move technologies from concept through development and to the marketplace?

Dr. Arno Penzias

1. Are companies that are developing advanced renewable energy technologies generally viewed as good investment opportunities by the venture capital community?

2. What kinds of technologies are seen as good short-term investments and as good long-term investments by venture investors?

3. What role do you think the federal government can play to encourage growth in this sector?

Mr. Christian Larsen

1. What is the electric utility industry's perspective on renewable energy generation? Which renewable technologies have been most widely adopted by the industry to date?

2. What is the utility industry's plan for the future adoption of renewable energy sources? Does that plan depend on any changes in current policies, perhaps such as the regulation of greenhouse gas emissions? If it does, please explain the policy changes you are taking into consideration in your planning.

3. What is the electric utility industry's view of distributed generation, either as a business model or as a means to provide stability to the grid and avoid transmission bottlenecks?

Mr. David Pearce

1. What are the limitations of today's renewable energy technologies? Are these limitations inherent to the kind of technologies that are being used?

2. What types of technologies can overcome these limitations? How soon do you expect to see the widespread commercial application of the next generation of renewable energy technologies?

3. What challenges do companies like yours face in bringing a new technology from the laboratory stage to manufacturing? Are there particular challenges inherent in locating your manufacturing in the United States, specifically the Bay Area?

4. Is there additional research and development work that should be performed to expand the range of technology options for renewable energy sources? What is the appropriate division of labor for this work among government, industry, and academia? How much money do you estimate these efforts will cost?

Mr. Ron Swenson

1. What kinds of projects have you been involved with to deploy renewable energy in developing economies? Which renewable energy technologies did these projects use?
2. Are there challenges to widespread application of renewable energy technologies in developing economies that do not exist in the U.S.? How have government agencies, non-governmental organizations, industry, and academia here and abroad been involved in these projects? What role do you feel these sectors have to play in encouraging the greater use of renewable energy sources?
3. How important is education in expanding the use of renewable energy? How do you think these efforts should be structured and undertaken?
4. Does the distributed nature of renewable energy electricity technology have any particular advantage in developing economies? What impact might this have on the political and socioeconomic systems of those countries? How might this affect the willingness of governments and industry to encourage the use of renewable energy? How might this affect export opportunities?