Energy Alternatives and Conservation

December, 2006

A Report By

The Connecticut Academy of Science and Engineering

For

The Connecticut General Assembly
Commerce Committee
Energy and Technology Committee
Environment Committee

Energy Alternatives and Conservation

A Report By

The Connecticut Academy of Science and Engineering

Origin of Inquiry:	Connecticut General Assembly commerce committee energy and technology committee environment committee
Date Inquiry Established:	May 1, 2006
Date Response Released:	December 31, 2006

This study was initiated at the request of the Commerce Committee, Energy and Technology Committee, and the Environment Committee of the Connecticut General Assembly on May 1, 2006. The project was conducted by an Academy Study Committee with the support of David Pines, PhD, Project Study Manager and Tom Filburn, PhD, Study Consultant. The content of this report lies within the province of the Academy's Energy Production, Use and Conservation Technical Board. The report has been reviewed by Academy Members A. George Foyt, PhD and John P. Cagnetta, PhD. Martha Sherman, the Academy's managing editor, edited the report. The report is hereby released with the approval of the Academy Council.

Richard H. Strauss
Executive Director

MEMBERS OF THE CONNECTICUT ACADEMY OF SCIENCE AND ENGINEERING STUDY COMMITTEE ON ENERGY ALTERNATIVES AND CONSERVATION

Michael F. Ahern
Vice President, Utility Group Services
Northeast Utilities Service Company

Robert Birge, PhD (*Academy Member)*
Harold S. Schwenk Distinguished
Professor of Chemistry
University of Connecticut

Daniel M. Kammen, PhD
Professor, Energy and Resources Group;
Professor of Public Policy, Goldman
School of Public Policy; and Director,
Renewable and Appropriate Energy Laboratory
University of California, Berkeley

Roger E. Koontz
Senior Attorney
Environment Northeast

Lee S. Langston, PhD (*Academy Member),*
Chairman
Emeritus Professor of Mechanical Engineering
University of Connecticut

C. Stephen MacKenzie
Vice President, Business Development,
Connecticut Economic Resource Center

Matthew S. Mashikian, PhD (*Academy Member)*
Professor of Electrical Engineering
University of Connecticut (ret.)

Francis R. Preli, Jr., PhD *(Academy Member)*
Vice President of Engineering
UTC Power

Kenneth L. Reifsnider, PhD *(Academy Member)*
Pratt & Whitney Professor of Design and
Reliability; and Director,
Connecticut Global Fuel Cell Center
University of Connecticut

RESEARCH TEAM

STUDY MANAGER
David Pines, PhD
Associate Professor and Chair of Civil, Environmental, and Biomedical Engineering
University of Hartford

STUDY CONSULTANT
Tom Filburn, PhD
Assistant Professor of Mechanical Engineering
University of Hartford

EXECUTIVE SUMMARY

STUDY OBJECTIVE

The Commerce, Energy and Technology, and Environmental Committees of the Connecticut General Assembly asked the Connecticut Academy of Science and Engineering (CASE) to conduct an assessment of energy alternatives and conservation actions which have the potential to reduce reliance on oil and fossil fuels over the next ten years; which are applicable to Connecticut; and which would spur innovation, diversity and consumer choice. To conduct this assessment, CASE assembled a Study Committee of both in-state and national experts on energy efficiency, conservation, and alternative energy.

The study was conducted in the following three phases:

1. The historical trend of energy consumption in the state, fuel mix diversity, and sector energy demand was reviewed. Also, the effectiveness of existing energy efficiency and conservation programs and the extent to which the state is already using renewable and non-fossil fuel resources were analyzed.

2. Programs and initiatives that other states and countries have used to reduce their consumption of fossil fuels were identified and considered.

3. The Study Committee then selected those conservation and energy efficiency measures that were deemed to be the most significant in reducing the state's dependence on fossil fuels. These formed the basis for a comprehensive strategy for reducing Connecticut's reliance on fossil fuels both in the short and long term.

BACKGROUND

The state's total energy consumption increased approximately 80% from 1960 to 2004, with electric power (37%) and transportation (32%) currently being the largest energy-consuming sectors. About 80% of Connecticut's energy in 2004 came from fossil fuels. The primary non-fossil fuel source was nuclear power, with much smaller contributions of 0.5% from hydroelectric and 2% from biomass, primarily from direct combustion of municipal solid waste. Compared to the state's total energy consumption, there was no significant contribution from solar or wind power. The requirement that gasoline contain 10% ethanol by volume is expected to decrease the state's dependence on fossil fuels by up to 3%, depending on the source of the ethanol.

The state's annual per capita energy consumption has been relatively constant since the late 1980s at 250 million BTUs (75 MWh). That figure is

- significantly lower than the US consumption rate of 340 million BTUs (100 MWh).
- higher than the consumption rate of 225 million BTUs (65 MWh) for New York and California. It is also interesting to note that California has been able to reduce its annual

per capita energy consumption from 290 million BTUs (85 MWh) in the late 1970s to the current consumption of 225 million BTUs (65 MWh).

- higher than the annual per capita energy consumption of United Kingdom, France, and Germany, which was about 175 million BTUs (50 MWh) in 2004.

Similarly, Connecticut's annual per capita electricity consumption of 9,000 kWh is lower than the US average of 12,000 kWh, but higher than New York's and California's annual per capita electricity consumption of 7,200 kWh.

A variety of conservation programs are currently being implemented through a number of state government departments and nonprofit organizations. One of the most effective is the Connecticut Energy Efficiency Fund (CEEF), which is funded by a small charge on consumers' electric bills. A review of CEEF's 2005 programs by the Energy Conservation Management Board (ECMB) estimated that the annual and projected lifetime savings of the installed energy efficiency measures was 318 million kWh and 4.4 billion kWh, respectively. This is equivalent to a lifetime savings of $550 million, assuming an average price of $0.125 per kWh, compared to the $65 million cost to operate these programs. In comparison, the natural gas conservation program is relatively small; there is no similar program for conservation of heating oil.

To promote renewable energy, the Connecticut General Assembly passed a law in 1998 creating a Renewable Energy Investment Fund, currently named the Connecticut Clean Energy Fund (CCEF). The CCEF is charged with promoting the development and commercialization of clean energy technologies and is funded through a surcharge on electric ratepayers' utilities bills. The other effort to raise public awareness of clean energy is a program adopted by the Department of Public Utility Control (DPUC) and promoted by SmartPower that provides electric ratepayers the option to purchase 50% or 100% of their electricity from clean energy sources.

SUMMARY OF FINDINGS AND SUGGESTIONS

The Study Committee suggests that many of the state's existing programs be expanded and new initiatives be implemented to meet the goal of reducing Connecticut's dependence on fossil fuels. Aggressive efforts are required to increase the market penetration of energy efficiency technologies, and long-term investments are needed to develop renewable and non-fossil fuel energy sources. Both energy efficiency and non-fossil fuel sources are essential, but their time frame (short-term versus long-term) and financial commitment are quite different. Many of this study's suggested conservation and energy efficiency initiatives and programs use existing technologies and have benefits that can be obtained immediately. Furthermore, the resources invested in energy efficiency incentives and education/outreach are more than offset by a reduction in energy expenditures by the state's citizens and businesses, and savings in infrastructure costs, such as transmission lines and new power generating facilities.

In contrast, the technology for most of the renewable and non-fossil fuel alternative energy supply sources needs to be developed. Therefore, it should not be expected that initial investments will be cost effective, but rather they are suggested as part of an overall plan with a goal of helping to increase the competitiveness of these non-fossil fuel alternatives.

Energy Efficiency and Conservation

Review of annual per capita total energy consumption and electric consumption indicates that an increased investment in energy efficiency and conservation can lead to significant energy consumption reductions. Connecticut should be able to reduce its per capita energy consumption to that achieved by New York and California (e.g., 10% total energy consumption and 20% electrical consumption), with a goal of having per capita energy consumption similar to that of the United Kingdom, France, and Germany (e.g., 30% reduction). These conclusions are supported by an independent assessment of Connecticut's conservation and efficiency potential that was prepared for the ECMB by GDS Associates in June, 2004. This study found that Connecticut has a maximum achievable cost-effective potential for energy efficiency of 12% by 2012 at a cost of less than $0.05/kWh based on 2003 energy consumption. It was estimated that the annual investment required to achieve these savings is between $82 million and $148 million, with an estimated net present savings of $1.78 billion.

Many of the energy efficiency measures suggested by the Study Committee have very short payback periods of less than five years, and are sound investments that will have the added benefit of strengthening Connecticut's economy. These initiatives are

- **Combined Heat and Power (CHP)**: Increase outreach to promote the market penetration of CHP systems. It is estimated that there is the potential to replace 1,670 MW of power plant generating capacity with new CHP systems. Very good incentives are currently available for distributed generation, but should be tailored to CHP systems that have efficiencies of up to 85% when a system uses natural gas as its fuel source. Programs such as "Distributed Generation$" sponsored by DPUC and the Connecticut Department of Environmental Protection (DEP) should be expanded to include electric and heating load assessments for businesses that have potential CHP applications.
- **CEEF**: Restore funding of the CEEF to at least $90 million with consideration given to increasing it to $148 million. The state should adopt the principle that energy resource needs will first be met through all available energy efficiency and demand reduction resources that are cost effective, reliable, and feasible. The 2004 independent assessment performed for the ECMB should be updated periodically to reflect current market conditions for the energy efficiency measures that meet these criteria. Also, the ECMB should oversee expanded natural gas and heating oil conservation programs that are funded by users of these energy sources.
- **Compact Fluorescent Light Bulbs**: Aggressively market compact fluorescent light bulbs because of their significantly higher efficiency as compared to incandescent light bulbs and the very attractive cost of conserved electricity of less than $0.03/kWh. In addition to the currently available incentives, a fee should be added to the sale of incandescent light bulbs at the wholesale level when a compact fluorescent light bulb has comparable lighting characteristics. Consider developing and implementing a statewide fund raiser for all schools in Connecticut to sell compact fluorescent light bulbs. The program would have an education component. Students would benefit from the educational effort and from funds raised, which could be used to support student activity programs. Establish a statewide sales target, such as 1 million light bulbs.

- **Advanced Metering – Three-Tier Electricity Rate Structure:** Switch from a one-tier electric rate to the use of advance metering with time-variant rates within the next five years. Electric rates should reflect the actual cost of generating electricity. A revenue neutral, three-tier rate structure which includes a peak daily rate, reduced off-peak rate, and a surcharge on the peak daily rate during peak electricity demand is suggested. The expected direct benefits are lower peak demand and more efficient use of generating facilities and the electric grid.

- **Fuel-Efficient Car Purchase Incentives:** Provide consumer incentives for the purchase of fuel-efficient cars by modifying both the initial sales tax and the subsequent property tax via a Fuel Efficiency Adjustment (FEA) based on the formula FEA = $(100 – 4*MPG). The formula should be modified in subsequent years to make it cost neutral to the state. Also, the Study Committee suggests eliminating all sales tax on the purchase of hybrid cars and applying a property tax only to the gasoline portion of the car. To further promote fuel efficiency, incentives should be provided for having properly inflated tires, which can increase gasoline efficiency by up to 7%. This program could be implemented as part of the state's emissions testing program. Car owners would receive 5% off the cost of the emissions test if their tires are properly inflated, and would pay 10% extra if they are not.

- **Lead by Example Program**: Expand the "Lead by Example" program with the goal of having all schools and state buildings achieve an average benchmark of 50 based on EPA's Energy Star Portfolio Manager rating system (a scale of 1-100) within five years. This investment is estimated to save $46 million annually based on 2006 energy costs.

- **Green Building Initiative**: Adopt a program similar to California's Green Building Initiative with a goal of reducing energy in privately owned commercial buildings by 20% over the next 15 years, using 2006 as the benchmark.

- **Energy Use Reduction Incentive Program**: Adopt an incentive program to encourage residents to take the initiative to reduce their own energy consumption. A model for this program is California's 20/20 program, through which residents receive an additional 20% reduction in their electric bills if they reduce their summer electrical consumption by more than 20%.

The Study Committee also supports investment in energy efficiency and conservation measures that have a longer time frame. They are

- **Focused Mass Transit Initiatives**: Continue to invest in mass transit in regions of the state where population and employment density makes this a viable alternative. The Study Committee supports initiatives in the area of "smart growth" and livable communities passed by the 2005 Connecticut General Assembly, including Public Act 05-205. Also, legislation adopted in 2006 provides for two significant mass transit projects: the development of the New Britain to Hartford busway and a New Haven–Springfield, MA commuter rail service. Even though the investment in mass transit will be significant, the success of these initiatives will have the greatest impact in reducing the consumption of energy in the transportation sector.

- **Education Effort Expansion**: Include "Energy Transfer and Transformation" and "Science and Technology in Society" themes in the Connecticut Core Science Curriculum and add a course to the curriculum at the high school level that is devoted to the thermodynamics of energy, energy conversion and energy economics. Mastery of these fundamental concepts will give high school students the background to understand the need for alternative energy and conservation initiatives, to be responsible energy users, and to encourage tomorrow's leaders to further develop these initiatives.

- **Public Awareness Campaign**: Over time, education of the state's K-12 students will have a significantly greater impact on conservation and energy efficiency. It is also critical to educate the general public about these topics on a continuing basis through a mass media marketing campaign. The campaign should emphasize the importance of reducing overall and peak energy consumption, and provide information on incentives available to both residents and businesses to meet the state's energy reduction goals. Several initiatives to increase public awareness and conservation among the public, especially during peak load periods, should be considered, including

    - development of a Real-Time Energy Report for use on television and by other media as a part of daily weather reports

    - establishment of a voluntary E-Mail and Cell Phone Energy Alert System to inform the public of the need in real-time to reduce energy use

- **State Oversight and Accountability**: To more effectively promote conservation and energy efficiency, task one organization with monitoring the progress of state programs and activities aimed at achieving the annual targets that are needed to reach the state's long-term goals. This will enable Connecticut's policy makers to annually assess the funding and effectiveness of individual programs and to quickly develop new strategies to meet the long-term milestones. In addition, this organization should be responsible for providing Connecticut citizens and businesses with comprehensive information about all of the state's energy programs in a variety of formats, such as the web, print and mass media.

ALTERNATIVE AND RENEWABLE NON-FOSSIL FUELS

The state also should consider investing in efforts to increase the use of non-fossil fuels. The technology for most of these alternative energy supplies needs to be further supported and developed. Therefore, it should not be expected that initial investments will be cost effective, but rather they are suggested as part of an overall plan with a goal of helping to increase the competitiveness of these non-fossil fuel alternatives compared to traditional fossil fuels. The most plentiful source for renewable energy within Connecticut is biomass, which can be used as a fuel for generating electricity or transformed into a liquid fuel such as biodiesel or ethanol. The initiatives supported by the Study Committee are

- **Biomass:** Maximize the state's electricity generation from biomass. Currently, a 37.5 MW power plant that utilizes a biomass gasification technology is expected to be built in Plainfield, CT. This power plant is expected to use 1,000 tons/day of biomass material, including construction and demolition (C&D) waste, trimmings from tree and brush

removal, and used wood pallets. It has been estimated that this plant will utilize approximately 50% of the biomass material of these types that is available in Connecticut. Therefore, it appears that a power plant of similar magnitude may be justified, pending further analysis to verify the availability of an adequate supply of biomass material to support the plant's operation.

- **Biodiesel**: Perform a study to determine the location of available farm land where crops such as soybean, sunflower, canola, could be grown and then converted to biodiesel using a locally sited, centralized biodiesel plant. Because of the greater energy yield of biodiesel as compared to corn-based ethanol, it is suggested that additional farm land resources in Connecticut should be used to grow crops to produce biodiesel instead of corn, for the production of ethanol. Additionally, importing vegetable oils from other states to produce biodiesel fuel at biodiesel production facilities in Connecticut should be encouraged. It is suggested that economic and tax incentives for the production of biodiesel fuel at Connecticut biodiesel production facilities should be provided.

- **Cellulosic Ethanol:** Align Connecticut's energy policy to take advantage of advances in the development of an economically competitive cellulosic ethanol production process. This is one of the most promising areas with the potential to make a significant impact on reducing Connecticut's dependence on fossil fuels. Cellulosic ethanol has more promise than ethanol produced from corn because it has a higher energy yield value. Because the US Department of Energy (DOE) is already funding $14 million annually to develop a process to economically produce cellulosic ethanol, and has set a goal of displacing 30% of gasoline usage with cellulosic ethanol by 2030, the Study Committee does not believe that additional investment by the state is necessary. Due to the substantial potential quantity of biomass which could be grown in the state and the continuing need for a non-fossil liquid fuel for transportation, the state should appoint an agency/organization to be responsible for following and reporting on the latest developments in cellulosic ethanol to the General Assembly and the Governor.

LOW-HEAD HYDROPOWER

The Study Committee supports the further study of the potential of low-head (small elevation) and low-impact hydroelectric power. A recent study by DOE (January 2006, DOE-ID-11263) indicated that Connecticut has the potential to produce approximately 100 MW of new hydropower available from a variety of sites. While the DOE study investigated the technical viability of these installations, no detailed economic or environmental impact study has been performed. Therefore, it is suggested that these assessments be performed on the Connecticut sites identified in the DOE report.

SOLAR ENERGY

Connecticut receives a very significant amount of solar radiation energy per day, but only about 700kW of electricity is generated through photovoltaic (PV) cells. Because of the potential for this clean energy source, the Study Committee supports the state's continued efforts in providing incentives for PV systems of up to $5,000/kW based on system performance, and supports cost-effective incentives for solar thermal systems (i.e., hot water and space heating). Efficiencies of these systems are much greater than for PV cells and their reliability has improved dramatically since the 1970s. Increased market penetration of solar thermal systems will directly reduce

consumption of heating oil, natural gas, and electricity currently being used for hot water and space heating applications.

GEOTHERMAL AND ADVANCED HEAT PUMP SYSTEMS

The Study Committee recommends that an assessment be made of the cost effectiveness and efficiency of geothermal and other advanced heat pump systems and appropriate conditions for their use. This initiative should be part of a larger program that promotes non-fossil-fuel-based heating systems and more efficient heating/cooling systems as compared to stand-alone systems that use heating oil, natural gas, or electricity.

WIND POWER

While larger wind systems do not appear to be a viable option for Connecticut, it is suggested that cost-effective incentives for installation of small-scale, localized wind farms be provided. Businesses and residents should have the option of selecting the best renewable energy source that meets their needs for their specific geographic location. The state's energy policy should equally promote all renewable energy sources and let the market and individual preferences determine the best source for each installation. The state and its residents should continue to support regional wind farm initiatives that will reduce New England's dependence on fossil fuels through programs like Smart Power and collaborative investment for New England wind turbine installations.

NUCLEAR POWER

Even under the most optimistic projections for production of ethanol from cellulosic material, generation of electricity from biomass, and adoption of energy efficiency and conservation measures, there will likely be a need to have other alternative energy supplies available to substantially reduce the state's dependence on fossil fuels. While the availability of new sources of nuclear power in Connecticut does not meet the ten-year time frame of this study, this is one option that may meet the long-term goals for achieving the state's energy independence. Because of the long lead time for the design, permitting and construction of nuclear power plant projects and the very large investment required, the Study Committee suggests that the state begin the process of determining if nuclear energy should play a major role in the state's energy policy. Some issues which need to be addressed are

- the safe disposal of hazardous nuclear waste, and reprocessing of spent nuclear fuel to reduce the volume of high-level radioactive material that requires long-term storage
- siting of nuclear power plant(s)
- optimum plant size due to the impact of building very large power plants (greater than 1,000 MW) on the reliability and stability of the electric grid
- investigation of new technologies, such as the pebble bed modular reactor, which can be constructed in smaller sizes of about 200 MW with reportedly improved safety characteristics
- an assessment of the international use of nuclear power

CONCLUDING REMARKS

The state's energy efficiency and conservation programs are achieving reductions in energy consumption as shown by its lower per capita energy consumption as compared to that for the United States. However, the state can achieve even greater reductions by aggressively implementing the suggestions provided by the Study Committee. At a minimum, the state should establish a goal to reduce the state's per capita energy consumption to that of California and New York. Looking toward the future, the state should consider adopting a more ambitious goal of achieving a per capita energy consumption that meets that of the most energy-efficient countries in the world, such as the United Kingdom, France, and Germany. The state should also actively pursue opportunities for the use of non-fossil fuel alternative energy sources such as biomass, low-head hydroelectric, solar, and local wind farms for electricity generation. Also, biodiesel should be promoted as an alternative liquid fuel with the potential of producing biodiesel fuel either from state-grown crops or from vegetable oil imported from other northeastern states. Additionally, the state should actively monitor the progress made in commercializing the production of cellulosic ethanol. Finally, alternatives to traditional heating and cooling such as combined heat and power systems, solar thermal and geothermal heat pump systems should be promoted.