Advances in Nuclear Power Technology – Key Points

BACKGROUND

CASE performed this study on behalf of the CEAB with the goal of informing and assisting the leadership of the state in making decisions that are in the best interest of Connecticut citizens in regards to nuclear power in the 21st century and beyond.

SCOPE

The scope of this study was based on work items identified in the Nuclear Power Section of the CEAB's 2010 IRP and by the Nuclear Power Sub-Committee of the CEAB.

STUDY TOPICS

The report includes the following study topics: an overview of nuclear power; evolution of nuclear power technology; nuclear power operation; comparison of nuclear power to alternative energy resources; and considerations for a nuclear power plant in Connecticut. Additionally, the study includes:

- A detailed economic impact analysis entitled *"The Economic Impact of Nuclear Power Generation in Connecticut"* by DECD with support from CERC (see p. 6 of Key Points)
- A survey of Connecticut residents entitled *"Assessing Connecticut Residents' Opinions of Nuclear Power: Phone Survey results Report (December 2010)"* by CERC (see p. 7 of Key Points)

BRIEF STATEMENT OF PRIMARY CONCLUSION

- Nuclear power currently provides half of Connecticut's electricity and has been the primary source of emission-free electricity generation since 1970.
- Operating licenses of the two existing nuclear power plant units in Connecticut—Millstone Unit 2 and Unit 3—have been extended to 2035 and 2045, respectively.
- Many years of planning and approvals would be required for their replacements.
- Benefits of new or replacement nuclear power generating units:
  - Lower-cost baseload generation by replacing marginal cost electricity generators
  - Emission-free electricity generation
  - Fuel diversity in the ISO-New England Region
  - Creation of new jobs by expanding the highly trained workforce required to safely operate nuclear power plant units
- To achieve these benefits
  - Nuclear industry must successfully demonstrate that:
    - Plants can be constructed and delivered on budget and on schedule using advanced construction and modular manufacturing techniques
    - New and current nuclear plants can be operated at a high level of safety and security
  - State's leadership must:
    - Aggressively demand that the federal government meet its legal obligations regarding spent nuclear fuel by expeditiously providing storage, geological disposal, and funding of nuclear waste management

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SUMMARY OF FINDINGS AND RECOMMENDATIONS

- **Connecticut and New England Electric Rates**
  - Findings: Connecticut's electricity rates are among the highest in the U.S. with average rate of $0.164 kWh (as of February 2011), 69% higher than the national average. These high rates are likely caused by several factors:
    - Connecticut has no indigenous energy sources.
    - Deregulation legislation required power companies to sell their power plants and buy power on the wholesale market.
    - The region's dependence on natural gas as a primary fuel for power plants, means that these plants set the price for electricity 90% of the time. Lower cost fuels such as nuclear, coal, or hydroelectric power, rarely set the cost of power in the region.
    - Environmental regulations play a role in higher rates.
    - Connecticut is a relatively high-cost state in terms of salary, taxes, and land.
  - Recommendation: Connecticut should develop a plan that allows lower costs of generation from baseload plants to be passed on to consumers. Changes are needed in the "deregulated" market so that replacement of inefficient electricity generating facilities or the addition of new low-cost generation more fully translates into lower electricity prices.
- **Need for Additional or Replacement Baseload Generation and Impact on Electric Rates**
  - Findings:
    - There are no clear indicators for the direction (increase or decrease) in baseload demand in Connecticut or New England. However, an ISO-NE analysis found that the replacement of marginal units with a new low-cost plant will reduce electric rates.
    - Retirement of existing electricity capacity is also an important driver for new generation capacity.
    - Also, it may be determined that it is more cost effective for the existing baseload fossil fuel facilities to be retrofitted or refurbished instead of being retired and replaced.
    - Other factors to account for:
      - the potential importation of new baseload generation from other regions with likely associated transmission capacity requirements
      - improved economics and reduced vulnerability prompting a move toward distributed generation
      - uncertainty due to the fact that two natural gas/low sulfur oil facilities of about 540 MW each that are already in the permitting process could be favorably positioned to respond to a Connecticut RFP for new generation.
  - Recommendation: Connecticut should be proactive in developing in-state electricity generating facilities to meet the state's demand and consider potential benefits such as lower electricity prices through lower generation costs and electricity congestion charges, and potential job creation from becoming an exporter of electricity.
- **Comparison of Baseload Alternatives: Nuclear Power and Natural Gas**
  - Findings:
    - In 2009, 53% of the state's electricity generation was supplied by nuclear power.
    - New England's system-wide capacity is heavily dependent on natural gas, particularly during peak electricity usage.
    - Natural gas plants accounted for 41% of New England's total capacity in 2010 (ISO-NE 2011).
    - Provided the federal government begins to meet its nuclear spent fuel disposal obligations, natural gas and nuclear power are the most viable alternatives for a 1000 MW centralized power plant in Connecticut.

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- Factors affecting consideration of other alternative sources for 1000 MW of baseload generation in Connecticut:
  - Coal is not considered likely because of stringent air pollution standards.
  - Solar and wind power are not considered baseload sources because they generate electricity intermittently.
  - Biomass—specifically solid waste—is used as a baseload source in Connecticut. However, there is not enough solid waste disposed of to generate an additional 1000 MW of electricity.
  - Hydroelectric power produces 1.6 % of Connecticut's electricity (EIA, 2009), but future hydroelectric power will likely be small scale because of the environmental standards required for siting.

— Recommendation: Fuel diversity should be promoted by the state as both a strategy to stabilize electricity prices and a regional policy. Since deregulation, essentially all new electricity generation has used natural gas as its primary fuel. Overreliance on natural gas may lead to price instability and potential gas pipeline transmission constraints.

- **Advances in Nuclear Power Technology**
  - Findings: Advances include increasing safety and reliability while reducing construction costs and schedule for new nuclear power plants.
    - Passive safety systems that operate without auxiliary AC power
    - Deployment of only standard plant designs that are pre-licensed by the NRC
    - Use of a combined NRC construction and operating license process that streamlines approvals while providing a consolidated process and opportunity for public review
    - Modern construction techniques including module construction of plant components that reduce construction schedule
  - Recommendation: First-build construction of four Generation III+ nuclear facilities in US should be monitored to verify that advances of construction techniques have achieved anticipated benefits of lower construction costs and a shorter construction period with plants being delivered on schedule and on budget.
- **Advantages of Nuclear Power**
  - Findings:
    - Most significant lifetime costs of a nuclear power plant as compared to a CCGT power plant
      - Nuclear Power Plant: Construction, operation, and maintenance
      - CCGT: Fuel
    - Job Creation for construction, operation and maintenance of a nuclear power plant compared to a CCGT power plant
      - Nuclear Power Plant: Approximately 15,600 jobs per year would be created during the five-year construction phase of a nuclear power plant, with about 450 jobs created to operate and maintain an additional unit at Millstone.
      - CCGT Power Plant: 8,500 jobs per year during the two-year construction phase of a combined-cycle natural gas power plant, with 25 jobs created to operate and maintain the facility.
    - Since Connecticut does not have indigenous natural gas resources, the majority of the cost of operating natural gas generating electric facilities flows out of the state.
    - Fuel Diversification: Diversification of fuel supply helps to stabilize electricity prices.
    - Uranium Supply: There are sufficient known global supplies of uranium for at least 80 years at uranium recovery costs below $130/kg U.

- Natural Gas Supply: Significant reserves of natural gas are located in the U.S., but transmission pipeline constraints may limit availability during periods of high demand.
- The New England region's reliance on natural gas could increase vulnerability of sufficient supply, thus increasing the volatility of electricity prices.
- Nuclear power generates 69% of the emission-free electricity in the United States with hydroelectric power accounting for 22% and solar/wind/geothermal accounting for 9% in 2010. While natural gas has lower greenhouse gas emissions compared to coal, there is concern that the extraction of natural gas from shale deposits releases methane, which is a much more potent greenhouse gas than carbon dioxide.
- Nuclear Power Reliability: high reliability with US nuclear power plant capacity factors averaging about 90% over the last ten years.

— Recommendation: Nuclear power should be considered for baseload generation to balance the reliance on natural gas once the federal government has developed a permanent federal repository or a regional centralized interim storage facility for spent nuclear fuel.

➢ **Issues Facing the Expansion of Nuclear Power in Connecticut**

1. Disposal and Storage of Spent Nuclear Fuel

— Findings:

- Sec. 22a-136 of the Connecticut General Statues: Moratorium on Construction of Nuclear Power Facilities that states, "No construction shall commence on a fifth nuclear power facility until the Commissioner of Environmental Protection finds that the United States Government, through its authorized agency, has identified and approved a demonstrable technology or means for the disposal of high level nuclear waste."
- At the present time, the United States does not have a nuclear spent fuel disposal and storage program.
- 66 utilities have successfully sued DOE for breach of contract by not accepting spent nuclear fuel from nuclear power plants. Congress has started paying utilities for contract default with a potential cost to taxpayers that could exceed $11 billion.
- The Blue Ribbon Commission on America's Nuclear Future (established by US DOE) provided recommendations for developing a safe, long-term solution to managing the nation's used nuclear fuel and nuclear waste, including:
  - The United States should proceed expeditiously to develop one or more permanent deep geological facilities for the safe disposal of high-level nuclear waste.
  - Geologic disposal in a mined repository is the most promising and technically acceptable option available for safely isolating high-level nuclear wastes for very long periods of time.
  - Prompt efforts to develop one or more consolidated interim storage facilities as part of an integrated, comprehensive plan for managing the back end of the nuclear fuel cycle.
  - Access to the funds nuclear utility ratepayers are providing for the purpose of nuclear waste management (Nuclear Waste Fund)
  - A new, single-purpose organization to develop and implement a focused, integrated program for the transportation, storage, and disposal of nuclear waste.
  - A new approach that is consent-based, transparent, phased-in, adaptive, and science-based to site and develop nuclear waste management and disposal facilities.

— Recommendation: Connecticut should join other affected states and aggressively demand that the federal government meets its legal obligation regarding management of spent fuel and high-level nuclear waste. This

issue must be resolved before nuclear power can be considered a viable alternative to natural gas as a baseload source of electricity in Connecticut.

2. **Financing of a 1000 MW Nuclear Power Plant**
   - Findings:
     - The overnight cost and financing are the most significant factors impacting the levelized cost of electricity from a nuclear power plant.
     - Elimination of the nuclear financing premium makes the LCOE of nuclear power very competitive with that of a CCGT power plant.
     - However, in a deregulated market, it is unlikely that a merchant owner will decide that the financial risk is worth the potential benefits and/or be able to obtain financing at an acceptable rate for the construction of a nuclear power plant that is estimated to have an overnight capital cost of approximately $4-5 billion.
   - Recommendation: Stable policies that reduce financial risk and provide confidence to allow for private investment are needed. Examples include: loan guarantees beyond the first-build reactors; long-term contracts for the electricity generated; economic incentive for fuel diversification; economic incentives for emission-free electricity generation, e.g., product tax credits; appropriate public / private business models that balance risk

- **Nuclear Safety and Security**
  - Findings:
    - As a result of the 1979 Three Mile Island accident, the Institute of Nuclear Power Operations (INPO) was formed to continually improve and address operational procedures at nuclear power plants.
    - The safety record of the nuclear industry has improved dramatically since the late 1980s when data was first collected. Significant events (per US operating nuclear power plant) have decreased from about 0.83 in the late 1980s to about 0.02 on average over the last five years.
    - Lessons learned from the events that led to Japan's Fukushima Daiichi nuclear plant incident on March 11, 2011 will be used to support or strengthen existing nuclear power plant operating procedures and to develop new safety precautions, as necessary.
    - Security of large centralized power plants includes physical security of the site, fuel supply security, and cybersecurity.
    - Nuclear power plants are "hardened" facilities with substantial protection from a spectrum of external threats, both natural and manmade, because of their robust reinforced concrete structures. Also, nuclear power plants have a large visible security system as well as other not-so-visible measures to deter and stop a terrorist attack.
  - Recommendation: Safety must never be taken for granted. It is imperative that the state and federal government continue to monitor and assess the safety record of the nuclear industry. On-site inspections, simulated terrorist attacks, and incorporation of the latest safety technologies are examples of the continuing diligence needed to increase the trust and confidence of the public in nuclear technology.

- **Nuclear Fuel Reprocessing**
  - Findings:
    - In the 1970s, the United States decided to follow a once-through fuel cycle to reduce the potential of nuclear proliferation.
    - The Blue Ribbon Commission found: *No currently available or reasonably foreseeable reactor and fuel cycle technologies—including current or potential reprocess and recycle technologies—have the potential to*

fundamentally alter the waste management challenge this nation confronts over at least the next several decades, if not longer. The commission concluded that:

- It is too early to commit to any particular fuel cycle as a matter of government policy, but that research, development, and deployment should continue on a range of fuel cycle technologies that have potential to deliver societal benefits in the future.
- Safety, economics, and energy security are likely to be the most important factors in selecting a fuel cycle rather than waste management because a permanent repository will be needed regardless of whether or not it is decided to close the fuel cycle.

— Recommendation: The state should monitor federal activities with regard to development and implementation of a nuclear fuel cycle. Advances in this area have the potential to reduce the volume of high-level radioactive waste and increase the amount of energy that can be obtained from uranium reserves. The study committee concurs with the Blue Ribbon Commission regarding the urgent need to site and license a permanent repository for spent nuclear fuel.

➢ **Siting**

— **Finding:** Siting of electricity generating facilities in Connecticut and New England is a difficult process. This study's survey indicated that residents are more accepting of renewable energy, but reality has shown that these facilities (e.g., wind farm) are as difficult to site as a fossil fuel plant.

— **Recommendation:** Siting of a new nuclear facility in Connecticut should be located at the Millstone Power Station in Waterford or Connecticut Yankee in Haddam Neck. Millstone has the infrastructure already available, including cooling water intake structures, security force, dry cask spent fuel storage, significant switchyard equipment, etc., to support the operation of a new unit. While the decommissioning process has been completed, the Connecticut Yankee site still has some transmission infrastructure in place for future use and was once approved for nuclear operations.

The Economic Impact of Nuclear Power Generation in Connecticut

— DECD conducted the analysis with support from CERC

— Scope: Assess the economic and fiscal impacts of replacing or adding baseload generation in Connecticut
  - Replace existing nuclear unit(s) at Millstone with a 1,000 MWe nuclear or CCGT plant
  - Add 1,000 MWe nuclear or CCGT plant to Millstone or CT Yankee

— Overview of Findings
  - Plant Replacement: The economic and fiscal benefits from replacing an existing nuclear plant at Millstone with a new nuclear or CCGT plant are short-term employment gains and short-term state GDP with net state revenue spikes; with no changes in the wholesale price of electricity, employment or procurement because the assumptions are that baseload capacity does not increase, there are no changes in employment or procurement or electricity sales because electricity demand remains intact.
  - Plant Addition:
    - Adding baseload capacity confers long-term benefits in the form of a reduced wholesale price for electricity in the region and that in turn increases employment, business-to-business activity and taxes in the economy as a whole.
    - New jobs and procurement from building an additional plant in Connecticut are not net-new jobs to Connecticut unless displaced marginal generating units are located outside of Connecticut. Assumption of no net-new jobs in Connecticut provides for most conservative analysis.

- The economic impact analysis of adding a nuclear or CCGT plant for the construction and operation of the plant by merchant owners and operations from 2009 – 2050 is provided (see report and "Fact and Figures" handout for details.)

Assessing Connecticut Residents' Opinions of Nuclear Power: Phone Survey results Report (December 2010)

The survey was designed to assess the attitudes of the general population in Connecticut regarding nuclear energy, particularly as it relates to cost, environment and safety. A telephone survey was completed of 600 residents who were at least 18 years old and evenly distributed among Fairfield County, Hartford & New Haven counties, New London County and the rest of the state.

— Findings:
  - Respondents were unaware of many energy issues and 84% of respondents had never looked for information about electric energy issues.
  - The majority of respondents (almost 70%) thought that fossil fuels account for most of the electricity generated in Connecticut, even though this is not the case.
  - Respondents were generally very concerned about climate change issues and the need to reduce the state's reliance on fossil fuels for generating electricity.
  - 48% of the respondents indicated that there weren't any nuclear power plants operating in Connecticut or were not sure if any nuclear power plants were operating in Connecticut.
    - Of those that indicated there were operating nuclear power plants in Connecticut, only 51% were aware that the plants were located in Waterford (or Millstone).
  - Only 22% of the respondents were very favorable or extremely favorable toward nuclear power while 45% were not favorable.
    - Respondents in New London County, where Millstone is located, were the most supportive of nuclear.
    - Only 25% of the respondents were very favorable or extremely favorable to electricity generation from fossil fuels
  - Respondents favored green/renewable energies over fossil fuels and nuclear

— **CASE Study Committee Recommendation:** Energy education — in the K-12 state curriculum, as well as in seminars at state colleges and universities, and through public service announcements—is needed so that the public can be more informed about the state's energy future in regard to nuclear power, fossil fuels, renewable energy, and conservation.

➢ **Concluding Remarks**

— Nuclear power has provided economic benefits and an emission-free source of baseload electricity for Connecticut since 1970.

— Reliability of the current fleet of nuclear power plants has increased significantly with capacity factors averaging about 90% over the last ten years and significant safety events averaging only 0.02 per plant over the last five years.

— Continued safe operation and success of the new generation of nuclear power plants is also essential to further establish public trust and confidence in this technology.

— Advances in nuclear technology have improved safety system design by decreasing the calculated core damage frequency by about a factor of ten.

— Completion of the first-build power plants in the United States will determine if improvements in design standardization and construction techniques have reduced construction costs and construction time sufficiently to allow new plants to compete in deregulated markets like Connecticut.

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- Two challenges must be addressed before nuclear power can be a viable alternative for baseload electricity generation in Connecticut.
  - The federal government must establish and implement one or more consolidated interim storage or permanent deep geological facilities for the safe disposal of spent fuel and high-level nuclear waste.
  - Policy changes must be implemented so that financing alternatives are available for constructing a nuclear power plant in a deregulated market.
- Political leadership and long-term, stable energy policies are needed so Connecticut's residents and businesses can benefit from low-cost, reliable, safe, sustainable, diverse, and environmentally friendly sources of electricity, and from energy efficiency and peak demand reduction programs.
- Uncertainty and changing future regulations and policy (e.g., carbon tax, incentives, and tax policy) will limit future investment in new electricity generation, continuing to put Connecticut at a competitive disadvantage because of high electricity rates.

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