

## **12 Alternatives to Vermont Yankee**

### **12.1 Introduction**

This chapter provides information regarding potential alternatives to the relicensing of Vermont Yankee for continued operation past 2012.

The Vermont Yankee plant is currently rated at 620 MW and produces approximately 4.9 million MWh annually which are sold into the New England power market, about half to Vermont utilities. In 2003, Vermont utilities purchased 35% of Vermont's total electric generation needs and satisfied 28% of its peak load requirements through the Purchase Power Agreement ("PPA") with Vermont Yankee.<sup>1</sup> These purchases from Vermont Yankee are on a unit contingent basis – that is, when the plant operates Vermont utilities receive 48% of that output. This is in contrast to the Hydro Quebec contract under which the capacity and energy are guaranteed, independent of the performance of any particular resource in Canada.

Additionally, there are miles of high voltage transmission lines devoted to transporting the electricity produced at Vermont Yankee both in Vermont and to neighboring states. Through these interconnections, Vermont Yankee also has a role in physically supporting the electric grid in Vermont and neighboring states.

When assessing alternatives, it is important to recognize that the Vermont Yankee plant provides numerous benefits to the state, its utility ratepayers, and the region including: (1) rights to receive 48% of the energy and capacity (after the power up-rate) produced by the plant for each hour in which it operates that are provided to Vermont's utilities under a purchase power arrangement ("PPA") signed at the time the plant was sold to Entergy; (2) certain reliability benefits to Vermont and the region associated with the physical location of the output of the plant; (3) millions of dollars in taxes paid annually; and (4) jobs for over 500 people. The Economic Benefits chapter discusses these impacts more fully. It is therefore

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<sup>1</sup> Vermont Department of Public Service, *Vermont Electric Plan 2005*, January 19, 2005. Retrieved Feb. 19, 2008. pp. 4-7. <<http://publicservice.vermont.gov/pub/state-plans-electric.html>>

crucial to understand the impact of not relicensing the plant and to discuss the alternatives to continued operation of Vermont Yankee. To address this topic, the following items were considered:

Physical Impacts of closing the plant

- Transmission and distribution system implications (local/regional) and associated system stability and reliability implications

Economic Impacts

- Power markets/potential pricing implications (local/regional)
- Vermont utility energy supply and capacity implications (local/regional) and potential replacement power sources (fossil, imports, renewables, energy efficiency, etc.)

Environmental Implications

- Regional emissions impacts
- Vermont electric sector environmental footprint

**12.2 Methodology and Overview of Findings**

This assessment relied on secondary research and review of numerous relevant documents and reports including:

- Vermont Department of Public Service, *Vermont Electric Plan 2005*, January 19, 2005.
- Vermont Electric Power Company (VELCO), *2006 Vermont Transmission System 10 Year Long Range Plan Analysis: A Reliability-Based Electric System Upgrade Schedule for the Vermont Bulk Power Supply System*, June 30, 2006.
- ISO New England, Inc., *2007 Regional System Plan*, October 18, 2007.
- Energy Information Administration, *Renewable Energy Trends, 2005 Edition*.

- Concentric Energy Advisors (CEA), *Vermont Utilities Technical and Cost Issues of Generation Alternatives, Phase One of a Two Phase Report, Draft*, September 14, 2007.
- Vermont Public Interest Research and Education Fund, *A Decade of Change: A Vision for Vermont's Renewable Energy Future*, Summer 2006.
- Howland, Robert E., *Memo to Dave Lamont, Assessment of Hydropower Expansion*, July 16, 2007.

Following is a summary of key findings. The remainder of this section provides more details and sources associated with specific elements.

### **Transmission and Distribution System Implications**

Vermont lies in a fairly robust transmission area, which will not be severely adversely affected by the loss of Vermont Yankee. As long as the Hydro Quebec-Vermont Joint Owners contract is extended beyond its current 2016 expiration date and power continues to flow over the Highgate converter, the minor transmission problems apparent if Vermont Yankee is retired also exist in the case where the facility remains in service. VELCO already has plans to address these concerns. However, there are several more serious implications that could result from non-renewal of the Vermont Yankee license for the regional transmission system, especially in the Monadnock regions of New Hampshire and Massachusetts.

### **Energy and Demand, and Associated Power Markets and Pricing Implications (including Potential Replacement Power Sources)**

The closure of Vermont Yankee would mean that the New England region will have to replace the capacity and energy supplied into the regional grid in some way. Secondly, Vermont utilities will have to replace the contract or price hedge value that is represented by the current contract with Vermont Yankee.

Vermont Yankee is a base load facility, and because of its low variable costs it operates at full output whenever it is available to do so. This is generally 24/7 operation except for scheduled refueling outages lasting about three weeks and occasional unplanned outages and deratings. Should Vermont Yankee be retired, the bid stack of units in New England will shift

down by 620 MW (out of a fleet of 35,000MW). This will result in a slight increase in regional prices throughout the region.

Absent a specific directive to the Vermont utilities mandating a specific power portfolio to replace Vermont Yankee, the regional marketplace will decide what type of power replaces the Vermont portion of the energy which was formerly generated by Vermont Yankee. The other 50%, not currently sold to Vermont utilities, will be replaced by sources developed within the New England market or imports. The nature of these sources will be determined by the market participants and the policies existing in each state.

In the short term, it is likely that replacement energy would be supplied to the grid from existing fossil fueled plants – most likely natural gas combined cycle units. In the long run, it is difficult to predict. Many states have renewable portfolio requirements for power retailers doing business in their states. However, these units can not be considered as replacements for Vermont Yankee since they are “mandated” already.

### **Energy and Demand Implications for Vermont utilities and Potential Replacement Power Sources**

Vermont Yankee currently provides energy at a relatively low and stable cost when compared against its practicable alternatives. Vermont distribution utilities have commitments from Entergy under a 2002 agreement, for electricity at between 3.9 and 4.5 cents/kWh. This agreement (PPA) will expire in 2012. If the Vermont Yankee facility license is renewed, new power supply agreements with the Vermont utilities will need to be negotiated. Entergy will have no obligation, post-2012, to provide power at costs below market price. The only obligation it will have with respect to new power purchase agreements is to negotiate with the Vermont utilities in good faith for 30 days.

Since the current PPA price for Vermont Yankee is substantially below the current and projected market price for power, any new PPA will likely contain higher prices than the current agreement. Because of the permitting requirements to obtain a Certificate of Public Good (“CPG”), Vermont utilities retain significant leverage to negotiate favorable contract terms with Entergy. However, the amount and nature of any discount included in a new contract is at

present uncertain and depends, in some part, on the amount of power Vermont utilities choose to buy from Vermont Yankee.<sup>2</sup>

The current transmission grid could effectively accommodate the import of replacement power into Vermont through the existing network to replace Vermont Yankee's generation. There are many potential partners who could contract with Vermont utilities for power, including renewable energy developers. Terms contained in contracts with power marketers or merchant plant developers, including renewable developers, would be based on prevailing market prices.

It is also possible in the long term for Vermont to develop enough generating capacity in-state to support its electrical energy consumption and peak demand needs. With consideration to cost, generating capacity, and Vermont's commitment to renewable and environmentally friendly resources, the most likely sources are some combination of new wind, wood-fired, and additional small hydroelectric generation. In the foreseeable future, however, these sources will not be available in sufficient quantity as is currently provided through Vermont's share of the Vermont Yankee facility. Additional imports, secured under a market based contract, will be required to help fill the gap. These imports could come from Hydro Quebec, from the remaining regional system mix, which is currently powered by a combination of fuels (primarily natural gas, oil, coal and other nuclear), or from contracts with specific facilities located in the region, some of which could be renewables. The most likely replacement source for the short term is increased operation of natural gas plants currently operating at less than full capacity in New England.

### **Environmental Implications**

Although emissions (NO<sub>x</sub>, SO<sub>2</sub>, CO<sub>2</sub>, etc.) associated with the operation of nuclear power plants are negligible<sup>3</sup>, there remain concerns over reliability and the federal government's

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<sup>2</sup> If one imputes the monies received under the revenue sharing mechanism negotiated in Docket 6545 as a discount to a market based contract, the power cost savings could be substantial, which would translate into direct benefits for Vermont ratepayers. .

<sup>3</sup> While the boiler water reactor at Vermont Yankee has no direct emissions, there are emissions associated with the mining, processing, and transportation of nuclear fuel. Impacts also exist as a result of construction and decommissioning activities that have, or will need to occur at the plant. Although highly debated, recent estimates of lifetime emissions have ranged from 1.4 g/kWh to as much as 288g/kWh. Most analyses place lifetime carbon emissions per kWh from nuclear plants in the same

continuing struggle regarding storage of the nation's nuclear waste. Replacing power from the Vermont Yankee plant through increased output at other existing power plants in the region, or through construction of new fossil-fueled or renewable facilities, will result in increased air emissions or complicated siting and land use commitments. However, these alternatives to continued operation of the Vermont Yankee plant could reduce concerns over reliability and the expanded need for storage of nuclear waste. It is also important to note that the closure of the plant does not necessarily result in the construction of additional renewable sources of power as some might suggest, nor does continued operation preclude increased utility reliance on renewables. The plant's closure similarly would not remove the spent fuel currently stored onsite.

### **12.3 Area-Specific Impacts Assessment**

#### **1. Transmission and Distribution System and Associated Stability and Reliability Implications**

The Vermont Electric Power Company (VELCO) owns nearly all of Vermont's high voltage transmission lines (rated greater than 115kV). This encompasses roughly 540 miles of transmission lines ranging from 115kV to 345kV. The sub-transmission network includes about 950 line miles rated 69kV or below, mostly owned by local distribution utilities.<sup>4</sup>

VELCO submitted a thorough analysis of Vermont's transmission network in June 2006 as part of a 10-year plan for scheduled upgrades and maintenance. The report specifically addressed the possibility that Vermont Yankee does not receive a license renewal past 2012. Removing the Vermont Yankee facility from service will add a certain degree of stress to the local and regional transmission network as Vermont will have to import more power from the regional mix. However, the implications for the local and regional networks will differ only in a few notable ways. Some key findings of this report are:<sup>5</sup>

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range as wind, solar PV, and other renewables - far below those of natural gas, oil and coal fired plants.  
<http://www.nature.com/climate/2008/0810/full/climate.2008.99.html>

<sup>4</sup> Vermont Electric Plan, 2005, pp. 4-12 -- 4-13.

<sup>5</sup> Vermont Electric Power Company (VELCO), *2006 Vermont Transmission System 10 Year Long Range Plan Analysis: A Reliability-Based Electric System Upgrade Schedule for the Vermont Bulk Power Supply System*, June

- Removing Vermont Yankee from service poses no significant reliability or distribution problems to Vermont's transmission network. While there are some minor negative consequences, all of these are addressed by upgrades and maintenance already under consideration by VELCO even if Vermont Yankee remains in service.
- While the local implications are fairly minor, the retirement of Vermont Yankee could cause some problems in the regional transmission system. The Monadnock region of Massachusetts and New Hampshire would see heightened reliability concerns in certain outage scenarios. Of particular note in Massachusetts is that both Pratt Junction – Flagg Pond 115 kV lines overload approximately 25% higher with the retirement of Vermont Yankee, with the worst case scenario being with the loss of the Amherst – Scobie 345 kV line.<sup>6</sup> In New Hampshire, the Comerford –Littleton 230 kV line overload increases from 100% to 106% of its 193 MVA LTE rating with Vermont Yankee retired in a scenario that assumes an outage of a PV20 underground cable and the termination of the Hydro Quebec-Vermont Joint Owners contract. The worst contingency in this scenario is with the loss of the Comerford – Granite 230 kV line.

While this report has not quantified the costs of these out-of-state scenarios, it is important to understand that removing Vermont Yankee from service will result in these types of regional impacts because Vermont ratepayers ultimately pay for 4% of qualified upgrades to the regional transmission system.

## **2. Power Markets and Potential Pricing Implications**

Vermont's current retail electric energy prices are among the lowest in New England, but are quite high by national standards. In November 2007, average electricity prices in Vermont were

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30, 2006. Retrieved Feb. 19, 2008. pp. 35-36.

[http://www.velco.com/Files/Long%20Range%20Planning/Long\\_Range\\_Plan\\_2006\\_Report-final.pdf](http://www.velco.com/Files/Long%20Range%20Planning/Long_Range_Plan_2006_Report-final.pdf)

<sup>6</sup> Even with continued operation of Vermont Yankee past 2012, under certain outage scenarios, these lines may be in overload conditions. Adding removal of the Vermont Yankee plant will cause this overloads to be 25% higher

approximately 12.11 cents/kWh, compared with 14.62 cents/kWh on average for New England but 8.98 cents/kWh for the country as a whole.<sup>7</sup>

In 2006, New England as a whole consumed 132,078,000 MWh of electric energy, with a peak demand of 28,130 megawatts on August 2, 2006.<sup>8</sup> As a result, losing Vermont Yankee's 620 MW and 5 million MWh per year are not significantly consequential to the regional mix, although the pricing and transmission implications are not necessarily negligible. However, those 620 MW of capacity and 4.9 million MWh of energy will need to be replaced by energy and capacity from alternate sources. The loss of Vermont Yankee will result in a small, barely noticeable increase in the wholesale price of electricity. However as a result of the clearing price auction format used to set the hourly price for energy in the New England market, this small increase will be applied to all kWh sold and purchased in New England. Since Vermont ratepayers have committed sources through their utilities, this impact will be felt only for that portion of the Vermont power supply requirements that are "open" or not already committed via a contract or owned facility. For the rest of New England, this increase will be seen in their power bills.

Physically, the energy once generated by Vermont Yankee will have to be replaced in the New England market place. In the short term, this replacement energy will almost certainly come from fossil fuels. Existing nuclear and renewable units are already running as much as their fuel supply will allow and efficiency programs are fully expending their annual budgets, so the shortfall will be made up through increased operation of fossil fuel units. Over the longer term, new units will likely be built and efficiency spending may increase. Predicting what will actually happen is speculation.

Renewables built in response to state mandated RPS programs cannot be assumed to replace Vermont Yankee, since they would be built anyway. Replacement power, if it is to come from renewables will have to be incremental construction within the region. This may be difficult

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<sup>7</sup> Energy Information Administration. *Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, by State*. Retrieved Feb. 20, 2008. <[http://www.eia.doe.gov/cneaf/electricity/epm/table5\\_6\\_a.html](http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html)>

<sup>8</sup> ISO New England, Inc., *2007 Regional System Plan*, October 18, 2007. Retrieved Feb. 19, 2008. pp. 16. <[http://www.iso-ne.com/trans/rsp/2007/rsp07\\_final\\_101907\\_public\\_version.pdf](http://www.iso-ne.com/trans/rsp/2007/rsp07_final_101907_public_version.pdf)>

on a financial basis since incremental development would likely not be supported by REC sales since sufficient quantities will exist to satisfy those requirements. The only thing that is clear is that at present Vermont has little control over what happens in the physical supply situation in New England in the event of a Vermont Yankee retirement.

Even if Vermont were to mandate a specific mix of energy and capacity resources to replace its share of Vermont Yankee, that share represents only 50% of the plant. The remainder would be replaced through market forces. However, because the Northeast has implemented the Regional Greenhouse Gas Initiative (“RGGI”), carbon emissions within the region are capped at 188 million tons.<sup>9</sup> As a result, the removal of Vermont Yankee as a non-emitting resource would not directly increase carbon emissions in the region, but it would make it more difficult and more expensive to meet this goal and, if the cost is too great, could delay any future reductions in the regional cap.

### **3. Energy and Demand, and Associated Power Markets and Pricing Implications (including Potential Replacement Power Sources)**

Nuclear power has represented some of the lowest cost energy available in Vermont today. Under the terms of the PPA negotiated in conjunction with the sale agreement transferring ownership of the Vermont Yankee facility to Entergy in 2002, Vermont’s two largest distribution utilities, Central Vermont Public Service Corporation (CVPS) and Green Mountain Power Corporation (GMP) purchase energy from Vermont Yankee at a cost of between 3.9 and 4.5 cents/kWh through March 2012. Under a Vermont Yankee retirement scenario (post 2012), replacement power would need to be procured and the cost for that power would likely be higher than what would result under a scenario where the Vermont Yankee plant was relicensed.

In thinking about replacing the contract from Vermont Yankee, Vermont utilities have essentially two choices. One option would be to negotiate contracts with Hydro Quebec or any of the power marketing entities selling power in the region, or with a developer of a specific generation resource. Another option would be to own and operate a generator or portfolio of

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<sup>9</sup> [http://www.rggi.org/docs/program\\_summary\\_10\\_07.pdf](http://www.rggi.org/docs/program_summary_10_07.pdf). 188 million short tons of CO<sub>2</sub> per year, which is approximately 4% above annual average regional emissions during the period 2000-2004.

generators and other resources within the New England market area, preferably in Vermont. These are not mutually exclusive options – a replacement power portfolio could include some of each.

Since the advent of wholesale market competition in the ISO-NE region in 1999, market prices have become much more transparent and product offerings and terms much more uniform among power marketers. However, most contracts negotiated in this market are of substantially shorter duration than Vermont's current Hydro Quebec and Vermont Yankee contracts. In the current environment, contracts of longer than five years are uncommon. One reason for the preference among trading partners for shorter duration contracts is the collateral requirements placed on traders. Collateral requirements are obligations on the part of a seller and buyer to provide financial assurances should the pricing terms of a contract deviate too greatly from current market price expectations.<sup>10</sup> As a result, it is likely that, at a minimum, a market contract based portfolio will not have the same price stability which Vermont ratepayers have had with the Vermont Yankee and Hydro Quebec contracts in place.

While Hydro Quebec (HQ) imports stand as one of the most accessible replacements for electricity currently being purchased from Vermont Yankee, such imports will likely be more expensive. Unlike Vermont Yankee, Vermont has limited negotiating leverage with HQ. Any additional power coming from HQ would be procured under a new contract, with terms negotiated by HQ and the Vermont utilities.

Vermont utilities could contract with project developers within the region to fulfill portions of any supply gap. Generally, under a contract, developers or marketers will likely seek a market based price for their output. Renewable projects also generate revenue in the form of Renewable Energy Certificates ("RECs"). These certificates transfer the attributes of the power to the owner of the certificate. As a result, prices for renewable projects will likely be higher than the prevailing market price if one wants to claim the attributes of that power as well.

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<sup>10</sup> For example, if a 10 year contract were negotiated for a fixed price of 9 cents and two years into the contract the forecast market price dropped to 8 cents, the buyer could be obligated to provide financial assurance for the 1 cent difference times the amount of the contract, times the number of years remaining on the contract. The reverse situation would place collateral obligations on the seller.

If Vermont utilities choose to build capacity to replace Vermont Yankee in their portfolios, there are many alternatives to Vermont Yankee that could be built by Vermont utilities within Vermont. However, most alternatives will likely have higher production prices than imports from Quebec, with the exception of some larger coal plant options. It is important to note that Vermont has a general commitment to clean technologies, and has made specific plans to meet growing demand with renewable resources only. For further discussion of alternatives, see Subsection 3 (Energy and Demand Implications and Potential Replacement Power Sources) and Section 12.4 (Potential Replacement Portfolios) below.

In the event that the Vermont Yankee facility's license is renewed for continued operation post 2012, Entergy and the utilities will have 30 days to negotiate in good faith for new contracts. The ultimate cost to Vermont for Vermont Yankee power post 2012 will obviously depend on results from these negotiations. However, a revenue sharing agreement with the Vermont Yankee Nuclear Power Company virtually ensures that, provided market prices remain above \$61.00/MWh, the net power costs from Vermont Yankee will be below market.<sup>11</sup> For a more complete discussion of pricing and the revenue sharing agreement, please see the economics and cost/benefit chapter of the Act 160 report.

Vermont's contracted share of the 620 MW capacity of Vermont Yankee provides approximately 35% of the state's electrical energy needs and meets about 28% of Vermont's summer and winter peak demands (which have been roughly equal over the last ten years in Vermont). Since the 2006 power up-rate, Vermont Yankee has produced approximately 4.9 million MWh per year, representing nearly three fourths of the state's annual electric generation. The facility's retirement would create about a 300 MW gap in Vermont's committed power to be filled. With the Hydro Quebec-Vermont Joint Owners contract to import power from Quebec over the Highgate converter expiring in 2016, this will result in a combined 600 MW reduction in contractually committed electrical energy and capacity for the state.

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<sup>11</sup> There may be other potential benefits from a contract with Entergy that may not be available elsewhere in the market. I understand that additional details on this topic will be discussed in the prefiled testimony of Department witness David Lamont.

In the short-term, Vermont is fully capable of importing more power from Hydro Quebec (HQ). Vermont currently imports about one third of its electricity from HQ. Most of Vermont's HQ power comes through the Highgate converter owned by the Vermont Joint Owners (VJO). This line handles 225 MW of import/transfer capability, with much of the remaining power from HQ being delivered through direct transmission links maintained by the Vermont Electric Cooperative (VEC). Vermont utilities also own 183 MW of power transfer capacity on the 2,000 MW High Voltage DC connection between Des Cantons, Quebec and Sandy Pond, Massachusetts. According to the 2005 Vermont Energy Plan, Vermont's combined entitlements on these lines are more than enough to handle all the HQ power deliveries in the current contract.<sup>12</sup>

If the license to operate Vermont Yankee is not renewed past 2012, a decision will be required regarding how to best reconfigure the energy supply and resource mix in the state. Various parties in Vermont have expressed concern that the state's current dependence on just two sources (Vermont Yankee and HQ) for a high percentage of its electricity needs, poses problems. Despite the reliability and overall low-cost of these sources, it has been argued that a diverse set of power generation resources leaves the state less vulnerable to volatile market swings.<sup>13</sup> As future power supply options are being assessed, it is important to recognize the strengths and issues associated with various alternatives including acknowledgement that Vermont Yankee frequently operates at over 90% capacity factor per year (providing a steady source for base-load capacity) while smaller hydro, solar, and wind plants are often subject to more intermittent operation, and may conflict with other environmental concerns of the State. Recent editions of the Vermont Electric Plan have been clear in their statements regarding the quantity of power in the state's portfolio from a single source. It is likely that Vermont is currently overly dependent on this single source. In the past, Vermont contract owners have pursued swaps with other owners of nuclear units and that remains a possibility. As part of its

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<sup>12</sup> Vermont Electric Plan, 2005, pp. 4-14.

<sup>13</sup> As a move in this direction, Vermont has committed to increase its power generating capacity to meet rising needs only through renewable sources, at least through 2012. This would exclude investment in new coal or gas plants. Energy Information Administration. *Renewable Energy Trends, 2005 Edition*. Retrieved March 12, 2008. <http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/rentrends.html>

contract negotiations with Vermont, Entergy could offer some portion of a contracted amount that would come from its other New England plant – Pilgrim.

Following is a brief listing and discussion of various alternatives to the current Vermont Yankee nuclear power plant. In order to fully capture the benefits of any particular technology discussed below, utilities would need to own these plants. Ownership has its own set of risks and rewards. The capital investment required for this investment would be high. As shown in Figure 3, Vermont utilities would have to invest \$1.2 billion in renewable technologies in order to develop a portfolio of owned renewable resources to replace the current Vermont Yankee contract. Absent an ownership role, merchant plant owners will likely seek a market based price for their product from potential purchasers, regardless of their fuel type or all-in cost for the plant.<sup>14</sup> Further, if retention of any special attributes of the power is desirable for ratepayers, utilities or policy makers, additional costs may have to be included in a contract to obtain ownership of these attributes. The following discussion assumes ownership by Vermont utilities.

**Pulverized/Gasified Coal plants:**

These large central station power plants, while capable of producing some of the cheapest electricity once completed, have environmental implications and entail substantial capital investments that Vermont may not be able to finance alone. Additionally, such large plants could pose environmental and portfolio diversity concerns inconsistent with Vermont's future energy portfolio strategy.

**Natural Gas and Oil:**

Bringing more oil or natural gas into Vermont would require significant infrastructure investments both within and outside the state. Additionally, both oil and natural gas prices have historically been particularly volatile. A natural gas plant could be an attractive alternative since it is a reasonable cost and could extend the reach of natural gas supply to additional areas of the state.

**Solar:**

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<sup>14</sup> Concentric Energy Advisors (CEA), *Vermont Utilities Technical and Cost Issues of Generation Alternatives, Phase One of a Two Phase Report*, January 18, 2008. pp. 11-25.

Increased generation from solar (PV) technology sources will have minimal environmental impacts, compared with fossil fuel generation. Producing any sizeable amount of electricity from this renewable resource may, however, require substantial land commitments resulting in potential visual/aesthetic concerns. The cost for purchase and installation of solar-to electric technologies is currently quite high compared with more traditional and commercially available/utilized technologies and would initially put upward pressure on Vermont's electricity prices. Somewhat offsetting this cost is the fact that solar generation occurs during the higher priced hours of the day.

**Hydroelectric generation:**

Vermont has a substantial base of small hydroelectric generation facilities located and operating within the state. Although there are likely additional, untapped, opportunities for development and expansion of small-to-medium scale hydro resources in Vermont, licensing restrictions and environmental concerns will likely impact the ability to construct new dams or modify the storage capabilities upstream of existing dams. It is estimated that the total contribution of generation from new or repowered hydroelectric power plants in Vermont will range from 12MW to 25MW over the next 10-year period.<sup>15</sup>

**Wind:**

Vermont's ridgelines are the most likely location for wind-based power production. Based on recent studies, it appears that nearly 450 MW could be generated from strategically located wind turbine-generator facilities in Vermont.<sup>16</sup> The demand for purchase and installation of wind turbine/generation equipment has been increasing nationwide and internationally, and is currently driving the price for this technology higher (due to supply vs. demand market dynamics). The cost for engineering and Vermont-specific ridgeline construction projects, if environmentally acceptable, will also impact prices.<sup>17</sup>

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<sup>15</sup> Howland, Robert E., *Memo to Dave Lamont, Assessment of Hydropower Expansion*, July 16, 2007.

<sup>16</sup> Vermont Public Interest Research and Education Fund, *A Decade of Change: A Vision for Vermont's Renewable Energy Future*, Summer 2006.

<sup>17</sup> CEA Report, pp. 22.

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Table 1 provides comparative information regarding various electric generation alternatives to Vermont Yankee.<sup>18</sup> Information from this table has been combined with other data in Section 12.2.4 below to estimate costs associated with potential replacement portfolios.

**Table 1. Summary Information on Various Electric Generation Alternatives**

<b>Alternative</b>	<b>Utility Owned Price/ State Authority Owned Price/ Cooperative Owned Price (\$2008/MWh)<sup>19</sup></b>	<b>Efficient Plant Size</b>	<b>Base/ Intermediate/ Peaking</b>	<b>Environmental Comments</b>
Coal (CFB)	\$63.83/\$59.95/\$59.31	750 MW	Base	Emissions of carbon dioxide ("CO <sub>2</sub> "), SO <sub>2</sub> , nitrogen oxides ("NO <sub>x</sub> "), and mercury emissions. Future more stringent emissions caps may make coal plants uneconomical
Coal (Pulverized)	\$53.69/\$50.60/\$50.09	650 MW	Base	Similar to Coal (CFB). See other table for quantitative emissions differences. Requires cooling water/may damage sources.
Combustion Turbine	\$163.20/\$149.29/\$146.98	50 MW	Peaking	Gas-fired plants emit CO <sub>2</sub> and NO <sub>x</sub> , albeit in significantly smaller quantities than other types of fossil fuel-fired plants. However, CTs can burn diesel fuel. While these units are expected to burn diesel only as a backup fuel source, oil is a more polluting fuel than natural gas.
Combustion Turbine Combined Cycle (CTCC)	\$54.38/\$53.16/\$52.95	560 MW	Intermediate/ Base	Gas-fired plants emit CO <sub>2</sub> and NO <sub>x</sub> , albeit at significantly lower rates than other types of fossil fuel-fired plants. CTCCs emit CO <sub>2</sub> and NO <sub>x</sub> at a lower rate than conventional CTs.

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<sup>18</sup> Data compiled and pasted from CEA Report, pp. 11-25.

<sup>19</sup> Prices indicated are in \$2008 and adjusted for inflation to indicate the annual payments that would need to be made over the plant's estimated lifespan to cover all capital and operating costs, including emission costs. CEA Report, pp. 11.

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Fuel Cells	\$351.23/\$323.73/\$319.17	10 MW	Peaking	Emissions are essentially zero. Small amounts of CO <sub>2</sub> are emitted, but the CO <sub>2</sub> emission rate is small when compared to other fossil fuel technologies.
Integrated Gasification Combined Cycle (IGCC) <sup>20</sup>	\$56.67/\$53.21/\$52.64	640 MW	Base	As with any technology that requires cooling water, increases in source cooling water temperatures may occur, with potential damage to underwater ecosystems.  IGCC plants emit CO <sub>2</sub> , SO <sub>2</sub> , NOx, and Mercury. SO <sub>2</sub> , NOx, and Mercury are reduced by the gasification process. However, more stringent emissions caps than expected may make coal-fired plants uneconomic.
Photovoltaic Solar	\$245.82/\$205.16/\$198.41	5 MW	Not dispatchable, operate around 20% of the time.	No emissions, but land use is extensive. A 5 MW photovoltaic installation would require 30 – 35 acres of cleared land, with good southern-facing sun exposure.
Wind	\$77.61/\$68.86/\$67.41	50 MW	Not dispatchable, capacity factor varies with site.	The best wind regimes in Vermont occur on ridgelines. These locations also have the greatest effect on the viewshed.  Potential to disturb local bird and bat populations.
Wood-Fired Generation, Circulating Fluidized Bed (CFB)	\$70.37/\$66.03/\$65.32	50 MW	Intermediate/Base	While wood-fired (CFB) plants emit carbon monoxide and NOx, they emit no CO <sub>2</sub> , SO <sub>2</sub> or mercury.  Contributes to degradation of New England/New York forests in the event

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<sup>20</sup> IGCC technology is still in its infancy, and there are no commercial sized plants in operation at this time. There is still a fair degree of uncertainty in capital and operating costs, durability, and plant life expectancy (CEA Study, pp. 19). The costs listed here are those used in the CEA analysis, which estimated overnight capital costs to be \$1,998 /kW . In a similar study carried out for the California Public Utility Commission by Energy and Environmental Economics, Inc., the overnight capital cost for IGCC plants was estimated between \$3,100 and \$4,100 per kW to incorporate recent price increases. Therefore the prices per MWh indicated here are tentative, and actual prices may be significantly higher depending on future technology developments, commodity prices and environmental laws.

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				of over-cutting. Fuel transportation via train and/or truck is an additional source of air pollution and highway congestion.
Wood-Fired Generation, Stoker Technology	\$75.03/\$70.92/\$70.24	50 MW	Intermediate/Base	Same as Wood-Fired Generation, Circulating Fluidized Bed (CFB)
New Hydro	No Prices Provided by CEA	Varies with location, 50 MW total	Base/Intermediate	Hydro dams raise many environmental concerns, as they cause a certain degree of disturbance to fish and other wildlife. However, they produce no emissions.
Market Price	\$77.90			Based on the forecasted market price for 2013, translated into 2008\$ with an annual inflation rate of 2.7%.

#### 4. Environmental Implications

Table 2 below quantifies, in a generic manner, environmental impacts associated with various electric generation technologies.<sup>21</sup> This information is used in Section 12.2.5 below to quantify potential environmental impacts associated with Vermont Yankee’s continued operation post 2012 and potential replacement portfolios. As discussed above, total carbon emissions in the Northeast are currently limited by the RGGI protocols. In that context, the CO<sub>2</sub> emissions below could be considered to represent the pressure each source would put on the ability of the region to meet those targets.

**Table 2. Air Emissions Associated with Various Electric Generation Technologies**

	CO <sub>2</sub> (lbs/MWh)	SO <sub>2</sub> (lbs/MWh)	NO <sub>x</sub> (lbs/MWh)	Mercury (lbs/MWh)
Coal, CFB	1,999	1.8	0.7	0.01
Coal, PV	1,825	1.0	0.9	0.02
IGCC	1,755	0.1	0.4	0.01
CT (50MW)	1,269	0.0	0.3	0.0
CT (25MW)	1,269	0.0	0.3	0.0
CTCC	797	0.0	0.1	0.0
Fuel Cell	725	0.0	0.0	0.0
Wood, Stoker	0	0.0	1.0	0.0
Wood, CFBC	0	0.0	0.5	0.0
Nuclear	0	0.0	0.0	0.0
Solar	0	0.0	0.0	0.0
Wind	0	0.0	0.0	0.0

Although emissions (NO<sub>x</sub>, SO<sub>2</sub>, CO<sub>2</sub>, etc.) associated with the operation of nuclear power plants are negligible, there are concerns over reliability and the federal government’s continuing struggle regarding storage of the nation’s nuclear waste. While utilization of replacement power plants would result in increased air emissions or complicate land use commitments, these alternatives to continued operation of the Vermont Yankee plant could reduce Vermont’s future concerns over reliability or the expanded need for storage of nuclear waste.

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<sup>21</sup> CEA Report, pp. 28.

## **12.4 Potential Replacement Portfolios**

In the event that Vermont Yankee is retired in 2012, Vermont will have to decide how to best replace the lost generation. This can be accomplished through building new fossil fuel generation capabilities, building a portfolio of new renewable generators, increasing power imports from neighboring states and/or Canada through market purchases, increasing DSM expenditures, or creating a portfolio combining some elements of all of these. Costs associated with additional power imports would depend on market prices. See Table 4 for electricity price forecasts, as well as predicted emissions from the regional mix. In order to help inform these decisions, GDS has utilized the CEA report and other secondary data sources to develop and summarize pricing and emissions data for four potential portfolios: New Fossil Fuel Generation; New and Expanded Renewable Generation; Continued Operation of Vermont Yankee; and New Imports (see Table 3). One caution regarding price estimates is appropriate. Energy is a worldwide commodity and the world economic structure is changing rapidly. Demand, and therefore price, for fuel to power generators and steel, copper and other commodities necessary to build them is dependent on the level of growth seen worldwide. Forecasting is always difficult, but it is especially so in the current environment.<sup>22</sup> A qualitative discussion and assessment of the pros and cons for each portfolio is presented below.

### **Portfolio 1- New Fossil Fuel Generation**

Building a new 285 MW natural gas fired combustion turbine combined cycle (CTCC) generator could meet the capacity and energy gap for Vermont's share of Vermont Yankee's retired production. While this kind of plant would pose the same types of reliability concerns, it would not present the spent fuel concerns associated with a nuclear plant and would be cheaper and simpler than building a portfolio of various smaller renewable generators.

A plant this size running with an 85% capacity factor would provide over 2,100 GWh of energy, and would cost approximately \$230 million to build. The expected lifetime levelized cost per MWh, adjusted for inflation to indicate the annual payments that would need to be made

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<sup>22</sup> For example, installed costs for wind projects in the CEA report are listed as \$1900/kW. Recent project quotes received by Vermont utilities are in the \$2700-\$2900/kW range. If significant numbers of projects are cancelled or delayed as a result of the economic slowdown, it is possible that bargains on unclaimed turbines could be found.

over the plant's estimated lifespan to cover all capital and operating costs, including emission costs, would be \$54 per MWh.<sup>23</sup> This represents the estimated operating cost for whoever builds, owns and operates the plant. As such, it would need to be escalated somewhat to reflect required rates of return before comparing alongside market prices. The investment to build and operate this plant could pose a slight rate increase to Vermont ratepayers, but would not be as great an impact as what would occur with the renewable portfolio.

While a natural gas plant would be among the cheaper new power plant construction options available to Vermont, it is still a fossil fuel source (with its associated fuel price volatility), and would emit an estimated 850,000 tons of carbon dioxide per year, as well as 106 tons per year of nitrous oxides. One benefit of a CTCC fossil fuel plant is its somewhat flexible siting capability. Unlike wind and hydro plants requiring development only at specific sites (existing dams or remote ridgelines where viable wind resources exist). A CTCC plant can be located closer to available transmission and pipeline facilities and could likely be more easily integrated into the existing transmission infrastructure, cutting down on costly line extensions and interconnection issues. As mentioned above, the costs of a natural gas facility flowing through to ratepayers would vary relative to the market price of natural gas.

### **Portfolio 2- New and Expanded Renewable Generation**

GDS reviewed a published report that identified a portfolio of local, renewable generation resources that Vermont could develop by 2015.<sup>24</sup> This portfolio was used along with information from the CEA report and other publicly available information on renewable facilities being proposed or constructed in the region to come up with a portfolio of renewable resources that could potentially replace the power Vermont currently purchases from Vermont Yankee.

This portfolio is composed of 100% local renewable resources, making it a sustainable source of power produced right in Vermont. The emissions from this portfolio would be minimal when compared with the fossil fuel portfolio, and are similar to the nuclear portfolio while not posing any of the associated concerns over reliability and spent fuel storage. Although siting

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<sup>23</sup> Estimated plant lifetime capital and operating costs/MWH in 2008 dollars.

<sup>24</sup> Vermont Public Interest Research and Education Fund.

and land use concerns will remain. Additionally, the generation from these resources would be insulated from the volatility of gas and oil prices. Future increases in the market prices of fossil fuels and uranium could make a renewable portfolio an even more attractive option.

This portfolio includes 80 MW of new wood biomass production, 25 MW of improvements to existing small hydro facilities, 444 MW of new wind generation, a combination of improvements to existing landfill gas facilities and new plants totaling 7.5 MW, 5 MW of generation from anaerobic digesters (aka “Cow Power”), and 3 MW of customer sited solar/PV systems.

As shown in Table 3, this portfolio of renewable resources would cost approximately \$73 per MWh to develop and operate (excluding permitting, transmission fees, and any profit that would accumulate to the owner) and would be more expensive than the New Fossil Fuel Generation Plant (Portfolio 1).<sup>25</sup> Since building this portfolio of resources would represent additional expenses above what it would cost to continue to run Vermont Yankee, this portfolio would result in some form of increase in the electricity rates seen by Vermont ratepayers. However, the resulting portfolio represents a mix of all local and renewable resources, and is consistent with Vermont’s stated commitment to development and utilization of clean and renewable power production when possible.

It should be noted that for wind in particular, it is possible that significant upgrades to the transmission system may be necessary, since likely generation sites include remote ridgelines not on the current power grid. Siting wind generation along Vermont’s ridgelines may also be problematic due to issues associated with effects on the view shed and the local wildlife. However, a recent state-wide poll found that 81% of Vermonters would find wind turbines along Vermont’s ridgelines acceptable.<sup>26</sup>

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<sup>25</sup> Estimated plant lifetime capital and operating costs per MWh in 2008 dollars. Depending on site-specific circumstances, plant ownership arrangement, and the mix of resources actually installed, these costs will likely be higher or lower.

<sup>26</sup> Vermont Public Interest Research and Education Fund, *A Decade of Change: A Vision for Vermont’s Renewable Energy Future*, Summer 2006, p. 13.

The majority of air emissions resulting from this portfolio (while extremely low) would come from the wood burning biomass facilities, with an estimated 161 tons of nitrous oxide emissions per year. Over the entire life cycle of all these generators, there will be some emissions associated with the construction of the facilities, transportation of fuel for biomass, etc, but the operations of these units produce no carbon dioxide, making them an extremely attractive alternative. It should be noted that sustainable wood generation, as well as landfill gas and aerobic digesters are considered carbon neutral because, although the process does release some carbon into the atmosphere, it would have been released anyway as part of the materials' natural life cycle, unlike carbon releases from fossil fuel generation.

Table 3 provides a summary of the pricing and emissions associated with each of these portfolios and of a comparative control portfolio (continued operation of Vermont Yankee) discussed below. Incorporating aspects of this New and Expanded Renewable Generation portfolio along with the New Fossil Fuel Generation portfolio and increased power imports could greatly reduce the overall cost premium of the individual portfolios when compared with continued operation of Vermont Yankee. However, it should be noted that the average capacity factor of the renewable portfolio is 43%, compared with capacity factors of around 90% for nuclear and large combined cycle natural gas plants. This is due to the intermittent operating nature of some of these technologies associated with their reliance on the natural availability of wind, sun, and river flows to generate electricity as compared to a baseload nuclear or combined cycle plant which can supply full power over 90% of the time. As a result, the total installed capacity of the renewable portfolio needs to be roughly twice that of the other portfolios in order to generate the same amount of energy.

### **Portfolio 3- Continued Operation of VY**

As a comparative control, the continued operation of Vermont Yankee is included as Portfolio 3. For this assessment, it is expected that actual rates would likely be near market price, discounted to reflect the revenue sharing agreement between Entergy and the two large Vermont utilities. See Chapter 11 for extensive discussion of prices and discounts available from Vermont Yankee. Table 4 provides a comparative electricity price forecast.

There would be no direct emissions from the continued operation of Vermont Yankee, excluding emissions associated with the mining and transportation of the nuclear fuel.

However, the continued operation of the Vermont Yankee plant does create the need for additional on site storage of spent fuel, and continued questions as to whether or not the plant can be reliably operated for another 20 years.

#### **Portfolio 4- New Imports**

Vermont also could potentially fill the gap left by retirement of the Vermont Yankee plant beyond 2012, through increased imports from Quebec, New York, and from the New England System Mix. The price impacts associated with this portfolio on Vermont ratepayers would depend on the market price of electricity. See Table 4 for the forecast through 2032.

The environmental impact of this option would depend on the ultimate sources of the power Vermont chose to import. For the purposes of this analysis, it was assumed that the lost production from the retirement of Vermont Yankee would be met by importing one-third of this power from Quebec, one-third from New York, and one-third from the NEPOOL system mix. Power imported from Quebec is by far the cleanest, as it is 94% hydropower. The major components of the system mix from New York are 29% natural gas, 23% nuclear, 18% coal, and 17% hydropower. The NEPOOL system mix's primary components are 36% natural gas, 27% nuclear, and 15% coal.<sup>27</sup> This portfolio would result in approximately 30% less carbon dioxide emissions than the New Fossil Fuel portfolio, but greater sulfur, nitrous oxide, and mercury emissions. All source emissions from this portfolio would be at much higher levels than the Renewable portfolio or the continued operation of Vermont Yankee. The total emissions from this portfolio can be found in Table 3.

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<sup>27</sup> NEPOOL GIS Public Reports.

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**Table 3. Generation, Cost and Emissions data for future energy portfolios<sup>28</sup>**

Combined Cycle Natural Gas Plant				Costs†			Emissions				Source
	GWh	MW	Capacity Factor	Build Costs/ kW (2008 \$)	Total Build Cost (2008\$)	Plant Lifetime Levelized Cost per MWh (2008\$)	CO2 (tons/ year)	SO2 (tons/ year)	NOx (tons/ year)	Mercury (tons/ year)	
Combined Cycle Natural Gas	2122	285	85%	\$853	\$243,183,592	\$54.06	845661	0	106	0	CEA
<b>TOTAL</b>	<b>2122</b>	<b>285</b>	<b>85%</b>	<b>\$853/kW</b>	<b>\$243,183,592</b>	<b>\$54.06</b>	<b>845661</b>	<b>0</b>	<b>106</b>	<b>0</b>	
Renewable Portfolio Additions				Costs†			Emissions				Source
Type	GWh	MW	Capacity Factor	Build Costs/ kW (2008 \$)	Total Build Cost (2008\$)	Plant Lifetime Levelized Cost per MWh (2008\$)	CO2 (tons/ year)	SO2 (tons/ year)	NOx (tons/ year)	Mercury (tons/ year)	
Biomass - Wood	645	80	92%	\$2,579	\$206,320,000	\$70.37	0	0	161	0	CEA Report
Hydro Capacity/Efficiency Improvements	110	25	50%	\$1,300	\$32,500,000	\$39.68	0	0	0	0	Case Studies
Wind	1250	444	32%	\$2,108	\$935,952,000	\$77.61	0	0	0	0	CEA Report
Landfill Gas	62	7.5	95%	\$1,150	\$8,625,000	\$50.00	0	0	0	0	Case Studies
Manure Digesters	37	5	85%	\$4,000	\$20,000,000	\$84.72	0	0	0	0	Case Studies
Customer Sited Solar	5	3	20%	\$9,000	\$27,000,000	\$257.85	0	0	0	0	Case Studies
<b>TOTAL</b>	<b>2109</b>	<b>565</b>	<b>43%</b>	<b>\$2,180/kW</b>	<b>\$1,230,397,000</b>	<b>\$73.19</b>	<b>0</b>	<b>0</b>	<b>161</b>	<b>0</b>	
Vermont's Usage from VY				Costs†			Emissions				Source
	GWh	MW	Capacity Factor	Build Costs/ kW (2008 \$)	Total Build Cost (2008\$)	Plant Lifetime Levelized Cost per MWh (2008\$)	CO2 (tons/ year)	SO2 (tons/ year)	NOx (tons/ year)	Mercury (tons/ year)	
Nuclear	2100	277	87%	-	-	Discount off Market‡	0	0	0	0	EIA
<b>TOTAL</b>	<b>2100</b>	<b>277</b>	<b>87%</b>	<b>-</b>	<b>-</b>	<b>Discount off Market‡</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	
Import Scenario				Costs†			Emissions				Source
	GWh	MW	Capacity Factor*	Build Costs/ kW (2008 \$)	Total Build Cost (2008\$)	Plant Lifetime Levelized Cost per MWh (2008\$)	CO2 (tons/ year)	SO2 (tons/ year)	NOx (tons/ year)	Mercury (tons/ year)	
From NEPOOL System Mix	700	92	87%	-	-	Market	244300	556.5	241.5	0.0105	GIS Reports
From New York System Mix	700	92	87%	-	-	Market	342300	1445.5	511	0.0035	GIS Reports
From Quebec System Mix	700	92	87%	-	-	Market	11200	66.5	28	0	GIS Reports
<b>TOTAL</b>	<b>700</b>	<b>92</b>	<b>87%</b>	<b>-</b>	<b>-</b>	<b>Market</b>	<b>597800</b>	<b>2068.5</b>	<b>780.5</b>	<b>0.014</b>	

\*Capacity Factor for import scenario assumed to be the same as VY since power can be pulled from the grid as needed. Assuming the same capacity factor provides Vermont with the same amount of energy and capacity as was available from VY.

†While these prices were developed with the best information available at the time, it should be kept in mind that energy is a worldwide commodity and the world economic structure is changing rapidly. Demand, and therefore price, for fuel to power generators and steel, copper and other commodities necessary to build them is dependent on the level of growth seen worldwide. These costs therefore may need to be adjusted to reflect changes in these prices. As a result, some values in the CEA report may already be outdated. For example, recent project quotes received by Vermont utilities are in the \$2700-2900/kW range.

‡See Chapter 11 for extensive discussion of prices and discounts available from Vermont Yankee.

<sup>28</sup> It should be noted that prices indicated are in \$2008 and adjusted for inflation to indicate the annual payments that would need to be made over the plant's estimated lifespan to cover all capital and operating costs, including emission costs. They do not include pre-construction, permitting and design costs, and do not include any profit to the owner or transmission fees. CEA Report, pp. 11.

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**Table 4. 2007 AESC Price Forecast Through 2032**

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
AESC 2007 Forecast - Energy (w/forwards) (\$/MWh Nominal)	\$79.44	\$77.82	\$80.61	\$82.26	\$86.70	\$91.92	\$92.74	\$94.14	\$99.63	\$103.82	\$108.51	\$112.84	\$117.34	\$122.01	\$126.88	\$131.93	\$137.19	\$142.66	\$148.35	\$154.26	\$160.41
AESC 2007 Forecast - Capacity (adjusted) (\$/kW-yr Nominal)	\$68.71	\$92.41	\$116.12	\$139.83	\$163.54	\$167.62	\$171.82	\$176.11	\$180.51	\$185.03	\$189.65	\$194.39	\$199.25	\$204.23	\$209.34	\$214.57	\$219.94	\$225.44	\$231.07	\$231.07	\$231.07
<b>Total Price (including Energy and Capacity)</b>	<b>\$87.28</b>	<b>\$88.37</b>	<b>\$93.86</b>	<b>\$98.22</b>	<b>\$105.37</b>	<b>\$111.06</b>	<b>\$112.36</b>	<b>\$114.24</b>	<b>\$120.24</b>	<b>\$124.95</b>	<b>\$130.16</b>	<b>\$135.03</b>	<b>\$140.08</b>	<b>\$145.33</b>	<b>\$150.77</b>	<b>\$156.43</b>	<b>\$162.30</b>	<b>\$168.40</b>	<b>\$174.73</b>	<b>\$180.64</b>	<b>\$186.79</b>

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