Chapter 5 - Generation & Supply Alternatives

To ensure that it continues to provide safe, reliable energy at the lowest present value life cycle cost, including environmental costs, BED evaluated its future energy and capacity needs and compared them to its current resources and planned resource additions. Future energy and capacity needs are rooted in the 20-year load forecast and reflects various scenarios; some of which consider the impacts of strategic electrification initiatives and distributed generation resources. Like previous IRPs, the forecast reflects BED's anticipated energy requirements, including losses, as well as its annual peak demand or annual capacity obligation (demand at ISO-NE peak hour plus reserves). In this chapter, BED provides an overview of its existing energy and capacity resources, as well as a description of the renewable energy credits generated from such resources. This chapter also includes an assessment of the resources that may be available to BED and that BED considered, with its IRP committee members, to meet its future obligations. Lastly, this chapter provides a summary of BED's processes for evaluating future supply options.

Current Resources

Over the 2016 – 2036 IRP planning period, BED's existing resource mix is comprised of owned and contracted resources. Table 5.1, below, provides on overview of the basic characteristics of BED's existing resources and indicates that some of BED's contracted resources grow in magnitude during the IRP period, while other contracts expire.

Table 5.1: 2016-2036 BED Current Power Supply Resources

Resource	Description	Fuel	Location	Expiration
BED Owned Resources				
McNeil	Dispatchable Unit	Wood	VT Node 474	Owned
BED GT	Peaking unit	Oil	VT Node 363	Owned
Winooski One	Run of River Hydro	Hydro	VT Node 622	Owned
Airport	Fixed array	Solar	Internal to BED	Owned

Resource	Description	Fuel	Location	Expiration
Solar	rooftop solar		System	
BED (585 Pine St) Solar	Fixed array rooftop solar	Solar	Internal to BED System	Owned
BED Contracted Resources				
NYPA	Preference Power	Hydro	Roseton Interface 4011	Niagara-2025 St. Lawrence -2017
Hydro Quebec	7x16 Firm Energy Only	HQ System Mix	Highgate Interface 4013 (via market bilateral)	2035 and 2038
VEPPI	PURPA Units	Hydro	Various VT Nodes	2015 - 2020
VT Wind	Intermittent wind	Wind	VT Node 12530	2021
Georgia Mountain Community Wind	Intermittent Wind	Wind	VT Node 35555	2037
NextEra Hydro	Small Hydro Portfolio	Hydro	Maine Zone 4001	2017
Hancock Wind	Intermittent Wind	Wind	Contract delivers to Vermont Zone 4003	2027, with option for an additional 15 years.
Market	ISO-NE or bilateral energy	System mix	Various NE Nodes	No market energy contracts currently

Resource	Description	Fuel	Location	Expiration
Solar	Long Term Contract	Solar	Internal to BED System	2032
Solar	Net Metering	Solar	Internal to BED System	N/A
Standard Offer	VT Standard Offer	Various	VT Zone 4003 and Various VT Nodes	BED has received an exemption for 2017 from Standard Offer purchases and anticipates receiving such an exemption again for 2018.

- **McNeil Station:** BED is a 50% owner of the McNeil Station, of which BED's entitlement provides 25 MW of nameplate capacity (though peak capability is higher). The plant is projected to operate approximately 60-70% of the total available annual hours. The selective catalytic reduction unit installed in 2008 has allowed for the reduction of NOx emissions as well as the ability to improve the economics of plant operations through the sale of Connecticut Class I Renewable Energy Credits (REC). BED bids the unit partially based on variable costs but recognizes that REC revenues will be received in addition to energy revenues.

- **Burlington Gas Turbine**: BED is the sole owner of this oil-fired peaking unit with a 25.5 MW nameplate rating. BED's GT is assumed to be available to provide peaking energy, capacity, and reserves.

- **Winooski One:** BED took ownership of the Winooski One facility effective September 1, 2014. This is a Low Impact Hydropower Institute (LIHI) certified hydro facility electrically connected to BED's distribution system. LIHI certification is a voluntary program designed to help identify and reward hydropower dams that are minimizing their environmental impacts and enables low impact projects to access renewable energy markets. Winooski One currently produces MA Class II (non-waste) RECs in addition to the energy and capacity normally associated with such a unit. The unit is qualified in the Forward Capacity Market (as an intermittent resource) and operates at an approximate 50% annual capacity factor.

- **Airport Solar:** BED has a 20 year lease for space on the Burlington International Airport Parking Garage roof and has constructed a 576.5 kW DC (499 kW AC) solar facility that BED owns and operates. The project was energized on January 26, 2015 and connected to the BED distribution system. With this project, the airport has reduced the need to buy energy from outside sources.

- **BED Rooftop Solar:** In October 2015, a 124 kW DC (107 kW AC) solar array at BED's Pine Street headquarters came online. This new solar array is a BED-owned asset and reduces the need to buy energy from outside sources.

- **NYPA**: BED receives approximately 2.616 MWs of New York Power Authority (NYPA) power through two separate contracts. The contracts, Niagara and St. Lawrence, expire in 2025 and 2017, respectively. Negotiations by the State of Vermont, regarding the renewal of the St. Lawrence contract are underway and renewal is expected. Energy under these contracts is favorably priced but NYISO ancillary charges are incurred to deliver the energy to New England.

- **Hydro Quebec**: Along with many of the other Vermont utilities, in 2010 BED executed a contract for firm energy deliveries from Hydro Quebec. For BED, this contract started in November 2015 at 5 MW and will increase to 9 MW beginning November, 2020. The current contract expires in 2038. Energy deliveries are by market transfer and are delivered during the "7x16" market period (i.e. hour ending 8 to hour ending 23, all days including holidays). This contract does not provide any corresponding market capacity.

- **VEPP Inc.**: BED currently receives a share (approximately 2.4 MW of nameplate rating) of the output from generators under a contract with VEPP Inc. BED modeled the VEPP Inc. units assuming normal weather conditions with individual unit contracts (and respective output) retiring according to their contract terms. Effective 6/1/2010, VEPP Inc. generators are considered intermittent resources and have a much lower capacity rating than in previous years. Beginning in November 2012, BED only receives an assignment of Ryegate energy in years where McNeil provides less than 1/3 of BED's energy needs (this has not happened and is not expected). Also in 2015, BED began to receive an entitlement from Bolton Falls and Newport Hydro, but these are short duration contracts that are not anticipated to materially affect BED's market position. During the first half of the IRP period, all of VEPP Inc. contracts will expire, but the impact on total energy supply will be quite small.

- **Vermont Wind:** BED receives 16 MW (40%) of the output (energy, capacity, RECs, and ancillary products) from the 40 MW Wind project located in Sheffield, Vermont. The project is assumed to provide energy, capacity and other credits throughout the lifetime of the ten year contract, which will expire in 2021.

- **Georgia Mountain Community Wind**: BED has 100% entitlement to the output from the 10 MW facility for a twenty-five year period that began in 2012. The contract includes energy, capacity and other credits.

- **NextEra Hydro:** BED has a five year agreement (covering the period 2013-2017) with NextEra for output from a portfolio of small hydro resources located in Maine. The contract is unit-contingent based on the combined output of the three facilities specified and includes the renewable attributes associated with the actual output delivered to BED. Volume was 10 MW for 2013 and 2014, and 5 MW for the balance of the contract.

- **Bilateral Market Contracts:** BED adheres to a long-standing strategy to hedge its exposure to spot market price variability that is not covered by other supply resources. Based on its energy position, BED may purchase 1/3 of its remaining energy requirements for the future 7 - 15 month period at the end of each calendar quarter, if necessary. Such purchases effectively hedge the majority of BED's energy requirements for the following 12 month period. This strategy has been approved by BED's Board of Electric Commissioners and the City of Burlington Transportation and Energy Committee. Additionally, BED's strategy allows for additional purchases if and when spot energy market prices are at a level that allows some measure of rate stability. Currently, BED does not have significant annual market exposure.

- **Solar (Contracted):** BED has obtained the rights to the output of relatively small PV arrays located on several of the City's schools as well as on some non-profit housing properties. These projects are under long term purchase power agreements that expire in 2032.

- **Solar (Net Metered):** Burlington customers can install net metered projects (with solar being the predominant technology in BED's territory) and, if generation is separately metered, solar projects can receive an additional incentive payment. Net-metered projects reduce Burlington's load, which can have a positive impact on BED's capacity position. As of June 2016, Burlington had 117 net-metered customers.

- **Vermont Standard Offer Contracts:** BED receives its pro-rata share of Vermont Standard Offer contracts for renewable resources, which includes a range of farm methane, landfill methane, hydro, and solar projects. It is anticipated that the Standard Offer output will increase slightly during the 2016-2036 time period. Effective January 1, 2017, pursuant to PSB Order of January 13, 2017, BED is exempt from purchasing Standard Offer energy for 2017. BED expects that, even absent any additional resource acquisitions, this exemption will continue for at least 2018.

Renewable Energy Credits (RECs)

As shown in the table below, BED obtains RECs from a variety of generation resources. BED is actively selling some of high value RECs to generate additional revenues, while other RECs may be sold in the future once the generation resources are constructed and/or fully registered with ISO – NE. RECs generated from BED's resources could also be retired against load in the future if such sales help BED to achieve a balanced public policy directive.

Table 5.2: BED REC Resources

Resource	Description	Fuel	REC Classification	Status
BED Owned Resources				
McNeil	Dispatchable Unit	Wood	Connecticut Class 1	Active Sales
Winooski One	Run of River Hydro	Hydro	Massachusetts Class 2 (non-waste)	Active Sales
Airport Solar	Fixed array rooftop solar	Solar	Not yet registered	Pending
BED (585 Pine St) Solar	Fixed array rooftop solar	Solar	Not yet registered	Pending
BED Contracted Resources				
Standard Offer	VT Standard Offer	Various	Massachusetts Class 1	Active Sales

Resource	Description	Fuel	REC Classification	Status
VT Wind	Intermittent wind	Wind	Tri-Qualified (Connecticut, Massachusetts, and Rhode Island Class 1)	Active Sales
Georgia Mountain Community Wind	Intermittent Wind	Wind	Tri-Qualified (Connecticut, Massachusetts, and Rhode Island Class 1)	Active Sales
In-City Solar (6 sites)	Long-term contract (PPA)	Solar	Massachusetts Class 1 (only 2 of 6 are registered)	Active Sales
Hancock Wind	Intermittent Wind	Wind	Tri-Qualified anticipated (Connecticut, Massachusetts, and Rhode Island Class 1)	Pending
South Forty Solar	Long Term Contract	Solar	Not yet registered	Pending

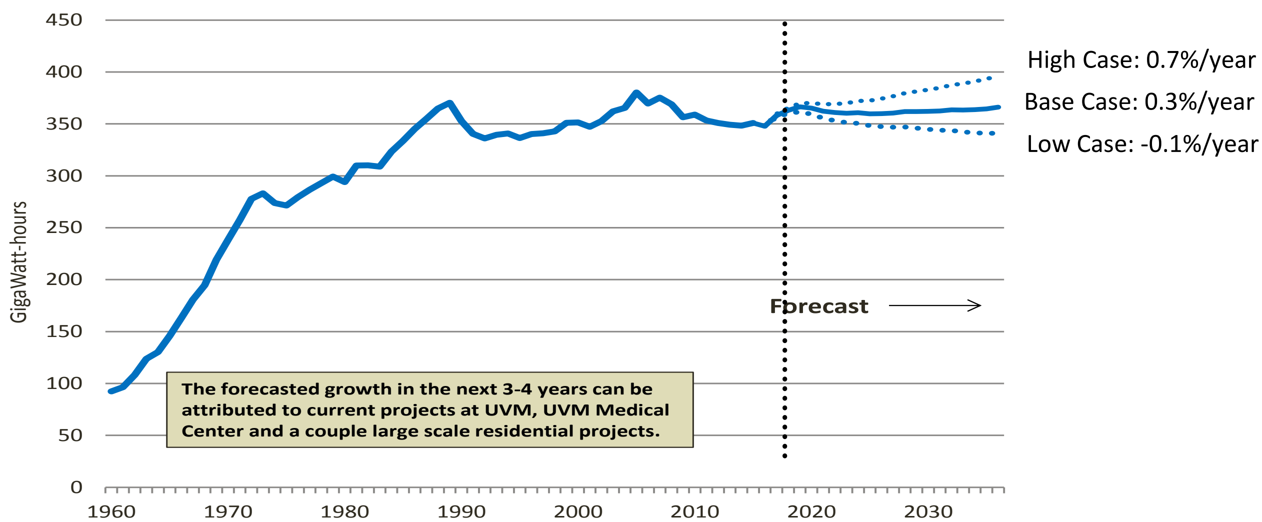
Gap Analysis

Between 2017 and 2020, energy load in the City is expected to increase from 350 GWh to 365 GWh upon the completion of a few major construction projects on the campuses of UVM and the UVMMC.[1] Thereafter, energy loads, in the aggregate, will likely increase around 0.3 percent annually. Flat load growth during the outer years is generally perceived to be a function of aggressive energy efficiency programs, rising building codes and appliance standards, flat population growth and a continuation of a less energy-intensive, service-oriented economy; which is a long-term historical trend that is expected to continue.

There is, however, the potential that energy loads could increase at a faster pace (0.7%/year). Factors that could drive electric energy loads up include but are not limited to a population grow rate that is faster than originally anticipated, a more robust economy that increases the pace of hiring and/or business formation, and greater acceptance of energy transformation projects than projected.

Energy loads could also decrease relative to the base case scenario. Lower than expected energy demand would likely be due to increased levels of net-metered PV installations, economic recession and/or population migration out of the city and/or Vermont.

Figure 5.1
System Energy Forecast: 2016 – 2036



[1] This forecast does not include the forecasted effects, if any, from energy transformation projects created and implemented under the Renewable energy standard discussed in Chapter 3.

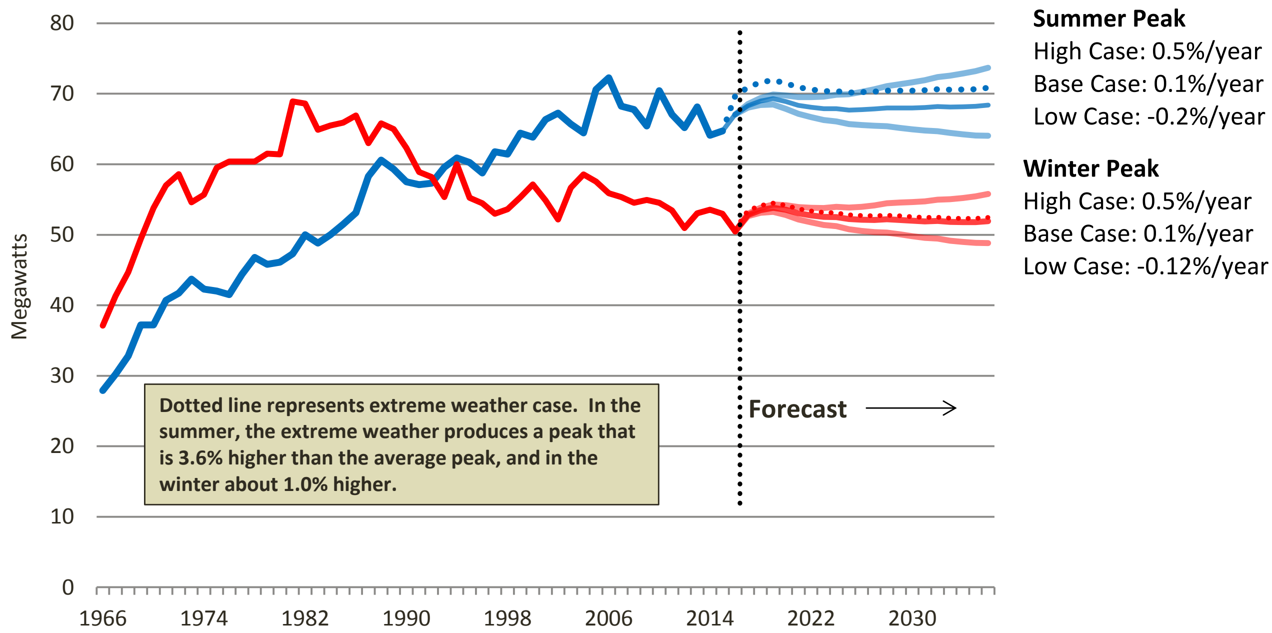
Similar to energy, system peak demand is also expected to remain flat over the planning period. Flat growth is contigent primarily on "normal" weather patterns continuing into the future; meaning, summer tempertures do not vary dramatically from historical trends. Under this base case scenario, BED also assumes that the duration of summer hot spells is not materially different than past experiences.

Higher than expected peak demand growth (0.5%/year) may, however, be driven by a variety of causes. The most likely reason would be hotter than expected summer tempertures. Demand could also rise due to: increased population growth, employment and/or business formation as well as additional cooling demand in building areas that were not previousily conditioned. Such additional cooling load increases, if they occur, would be a consquence of increased adoption in "cold climate" heat pumps, which also serve as efficient cooling systems during the summer.

Additionally, winter peak demand could increase relative to expectations due to higher than expected penetration of cold climate heat pumps used for space heating. Since current peak winter demand is considerably lower than summer peak demand, increased use of cold climate heat pumps is not viewed as a potential reliability problem during the winter, especially since cold climate heat pumps are known to shut down at tempertures below -15F, when winter demand typically spikes.

Summer peak demand may also decrease relative to expectations. Reasons that may lead to lower peak demand include higher penetration of net metered PV and/or renewed focus on active demand resources. Decreases in population growth and economic maliase could also diminish both summer and winter peak demand.

Figure 5.2
System Peak Demand Forecast: 2016 - 2036



As noted above, customer adoption of energy transformation technologies may impact BED's energy and capacity needs in the future. A faster than anticipated rate of adoption of cold climate heat pumps, electric buses and electric vehicles, for example, could increase BED's need for new energy resources. Also, if more net metered solar arrays are installed, BED's energy requirements could be lower than anticipated. With regard to BED's capacity needs, active demand response, solar and battery storage could reduce peak demand relative to expectations. But whether such technologies can actually offset one another as they are deployed is unknown at this time. However, at the current anticipated rates of deployment, BED does not envision a realistic scenario in which such technologies could have a material impact on system reliability. Nevertheless, BED will be monitoring when energy transformation projects are being deployed and the location of such projects in order to evaluate their impacts, if any, on BED's future energy and capacity needs.

Energy Needs & Resources

BED anticipates that its energy needs will exceed its production resources (from owned and contracted sources) in 2018. Thus, BED will need to acquire additional resources under contract or purchase spot market energy to close the small gap, as illustrated in

Figure 5.3, below. The energy supply gap results from the expiration of two contracts: the Nextera Hydro Contract, which expires at the end of 2017 and a Vermont Wind contract, which expires in 2021.

The forecasted energy shortfalls are largely a function of BED's modelling procedures. As shown in Table 5.3, BED's anticipated energy deficits take into account three capacity factors for all resources (30%, 60%, and 90%). As capacity factors are reduced, the less energy BED's generators produce and, thus, the increase in the supply gap. While the need for additional energy resources is projected to be small and manageable, it is clear that BED will need additional energy resource(s) to maintain its 100% renewable position. Assuming no other changes materially impact BED's forecasted energy supply imbalance, BED will likely be able to fill the expected gaps with so - called replacement contracts.

It should be noted that the McNeil biomass facility provides approximately 40% of BED's energy supply at this time. Loss of this output would significantly alter BED's energy position. The economics of the McNeil facility, however, depend on four key inputs: plant costs, capacity factor, the price of energy, and the price of RECs (Connecticut Class 1 at this time). Due to the currently extra low wholesale energy prices, the operations of the McNeil plant have been deteriorating relative to past years and its ability to recover its full costs has been undermined.

Compared to other generating facilities, McNeil has relatively high non-fuel variable costs, which suggests, all other things being equal, that operating the plant at a higher capacity factor could help to improve McNeil's economics. Additionally, declining REC prices, as well as increasing operating and maintenance costs could exacerbate cost recovery efforts for the McNeil power plant. Despite these challenges, the McNeil plant has been a useful hedge against high and volatile natural gas prices in the past and will likely remain so in the future.

Figure 5.3

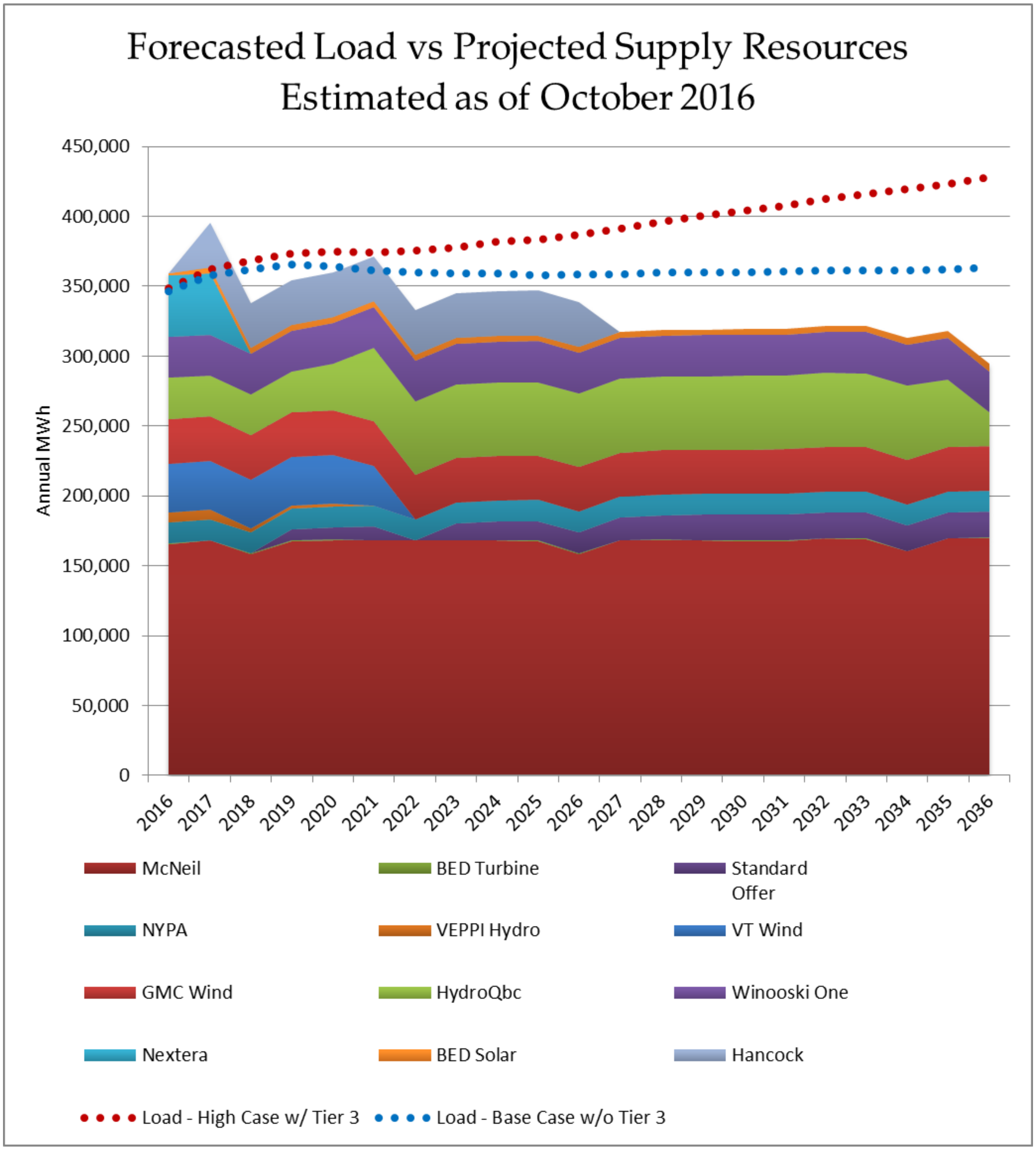

Forecasted Load vs Projected Supply Resources
Estimated as of October 2016
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Annual MWh
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
McNeil
BED Turbine
Standard Offer
NYPA
VEPPI Hydro
VT Wind
GMC Wind
HydroQbc
Winooski One
Nextera
BED Solar
Hancock
Load - High Case w/ Tier 3
Load - Base Case w/o Tier 3

Table 5.3

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Projected Annual Energy (Shortfall) (MW)	19,211	36,906	(24,404)	(19,103)	(11,396)	2,676	(23,528)	(21,768)	(20,488)	(18,897)	(26,983)
	Resource Size (MW) to Meet Projected Energy Shortfall Based on Capacity Factor										
30% Capacity Factor	NA	NA	9.29	7.27	4.34	NA	8.95	8.28	7.80	7.19	10.27
60% Capacity Factor	NA	NA	4.64	3.63	2.17	NA	4.48	4.14	3.90	3.60	5.13
90% Capacity Factor	NA	NA	3.10	2.42	1.45	NA	2.98	2.76	2.60	2.40	3.42
	2027	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**
Projected Annual Energy (Shortfall) (MW)	(17,152)	(16,710)	(16,749)	(16,739)	(16,782)	(15,014)	(14,860)	(23,704)	(19,770)	(44,536)	(46,580)
	Resource Size (MW) to Meet Projected Energy Shortfall Based on Capacity Factor										
30% Capacity Factor	6.53	6.36	6.37	6.37	6.39	5.71	5.65	9.02	7.52	16.95	17.72
60% Capacity Factor	3.26	3.18	3.19	3.18	3.19	2.86	2.83	4.51	3.76	8.47	8.86
90% Capacity Factor	2.18	2.12	2.12	2.12	2.13	1.90	1.88	3.01	2.51	5.65	5.91

Renewability Needs & Resources

In addition to BED's own commitment to meeting 100% of its energy needs with renewable resources, BED is also subject to Vermont's Renewable Energy Standard (RES). The RES will impact BED's need for specific types of energy resources over the IRP time horizon. Due to its current 100% renewability position, BED is in a strong position to satisfy its Tier 1 obligation, which requires 55% of retail sales in 2017 (increasing annually to 75% by 2032) to be met with renewable resources, as shown in Figure 5.4.[2] Because of its renewability, BED has also been able to modify its RES Tier 2 requirement. Without such modification, the RES would have required 1% of BED's retail sales (increasing annually to 10% by 2032) to be met with distributed renewable generation. However, as a result of the Tier 2 modification, BED will be able to apply non-net-metering Tier 2 resources to its Tier 3 requirements. To comply with Tier 2, BED will still need to accept net-metering installations and retire any and all associated RECs it receives. As Figure 5.5 shows, if BED does not maintain its 100% renewability, there may be a large gap between its Tier 2 requirement and Tier 2 eligible resources. In that situation, BED does not anticipate that excess net-metering credits would be available to apply to its Tier 3 requirement. Tier 3, which begins at 2% of retail sales in 2017 and increases annually to 12% by

[2] Figure 5.4 through 5- 6 do not reflect forecasted impacts that may result from energy transformation projects.

2032, can be satisfied with non-net-metered Tier 2 distributed renewable energy, additional distributed renewable resources, or with "energy transformation" projects that reduce fossil fuel consumption. As Figure 5.6 shows, even when Tier 2 resources are applied to Tier 3, there is a large gap between BED's Tier 3 requirement and its eligible resources. BED has a statutory right to pursue reductions in its Tier III requirement (based on its renewable status and status as an Energy Efficiency Utility). However, as a result of the analyses contained in the Technology chapter of this IRP, BED has concluded that sufficient Tier III potential in Burlington exists. Thus, the organization is advancing a number of energy transformation projects and has decided to forego its option to request modifications of its RES requirements at this time.

Figure 5.4

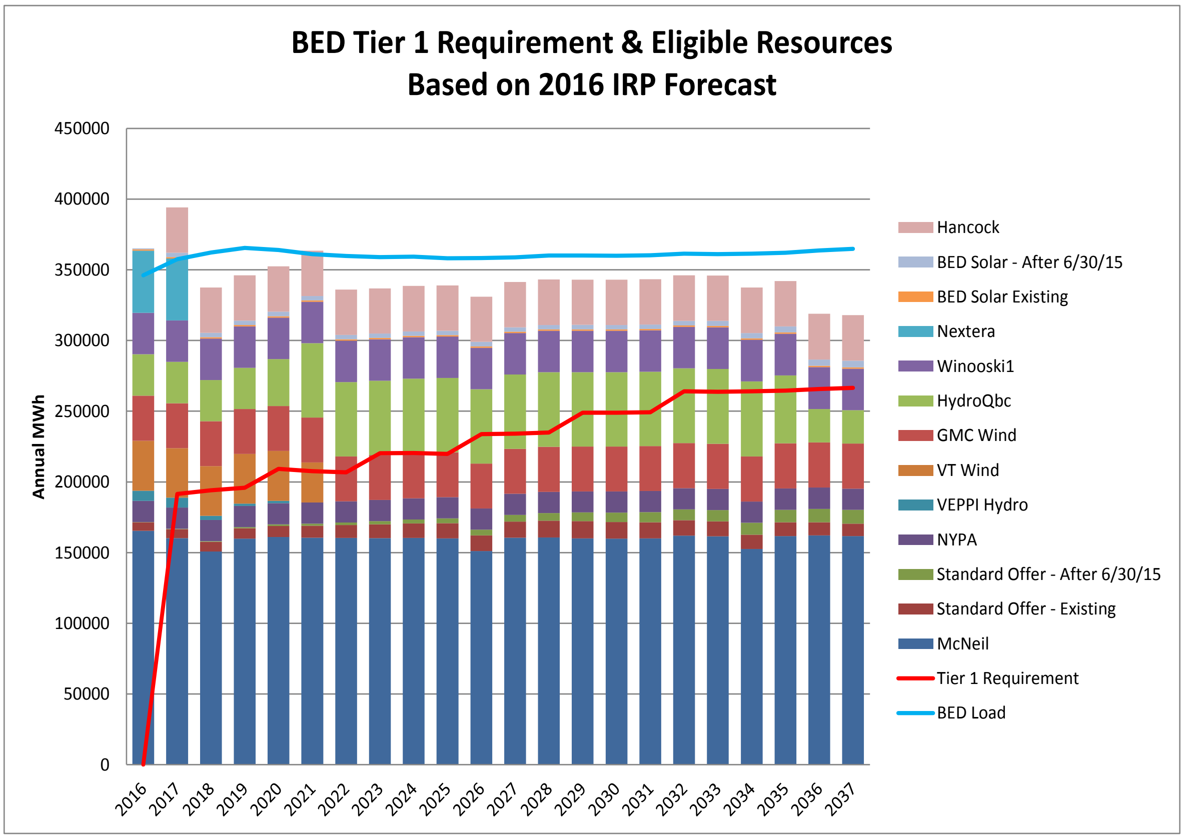


Figure 5.5

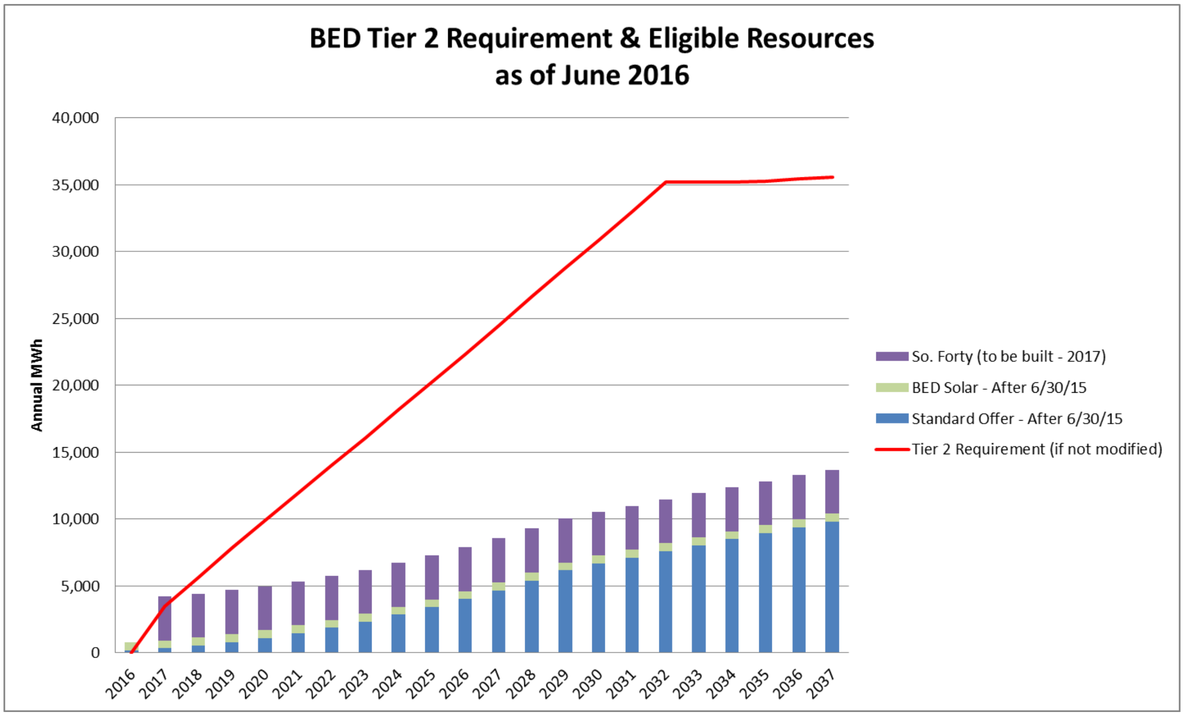
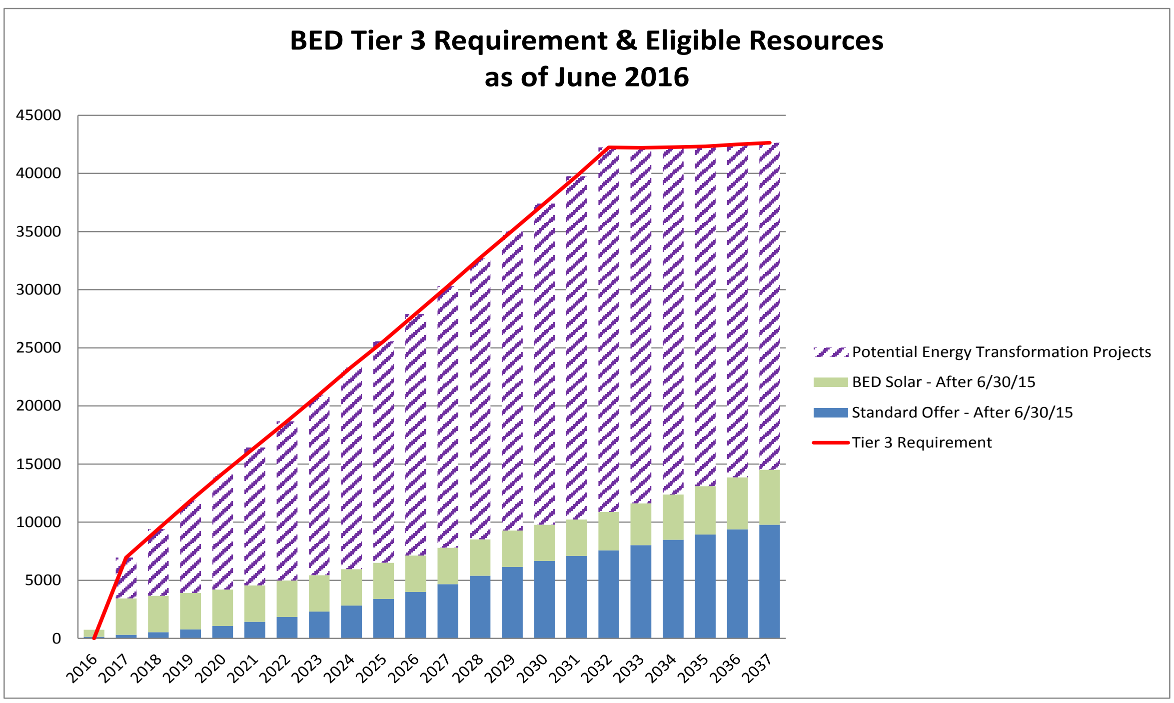


Figure 5.6

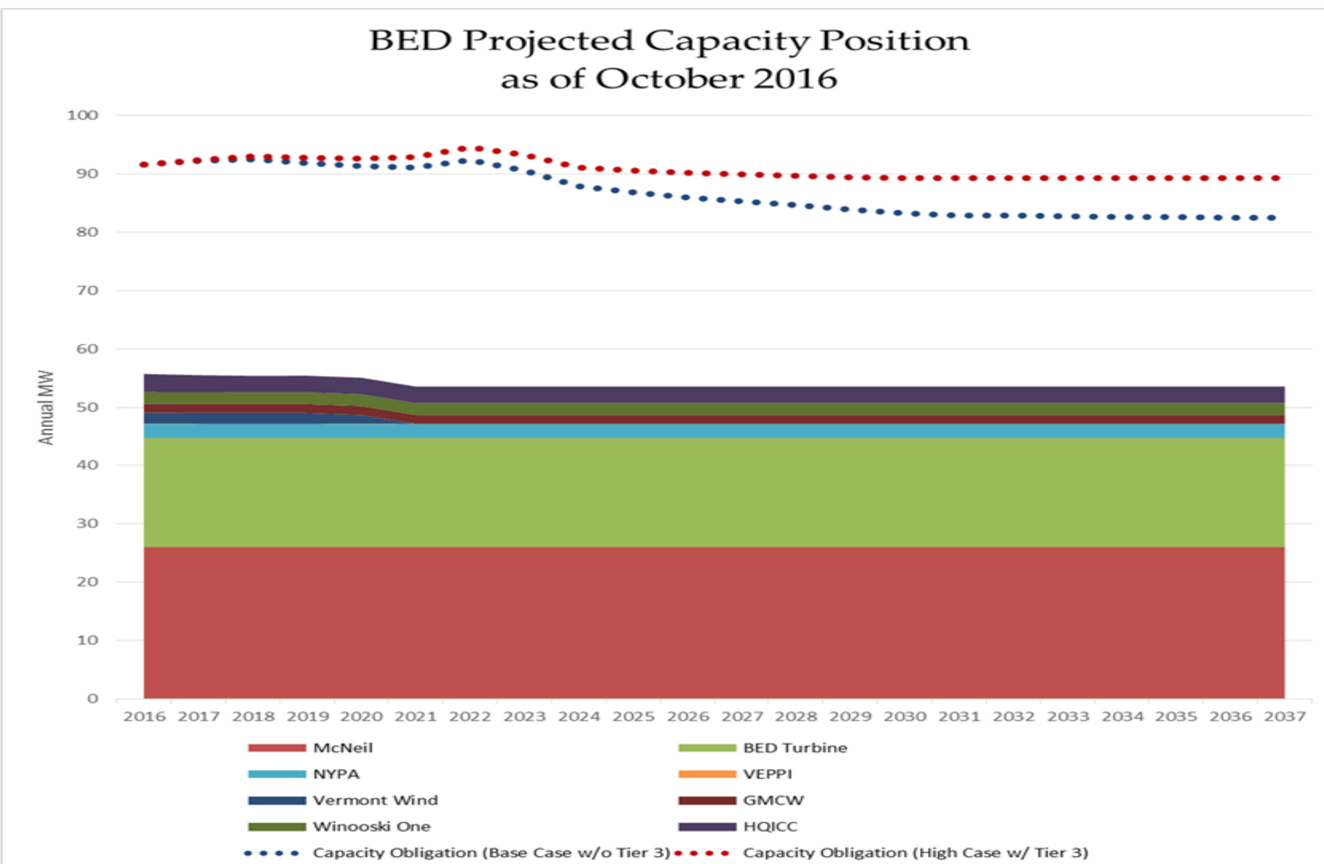


Resource Capacity

BED has control over, or contracts for, generation resources sufficient to satisfy roughly two-thirds of its capacity obligation, inclusive of the 15 percent reliability margin imposed on all distribution utilities by ISO – NE. Of the resources that BED controls, two facilities provide the vast majority of the capacity available to comply with regional requirements. These resources are the 50 MW McNeil Biomass facility and the 25 MW gas – turbine.[3]

To make up the capacity shortfall, BED is required to purchase additional capacity on a monthly basis. Such payments are necessary to ensure generators in New England are able earn revenues during all times of the year even though they may only be needed during the hottest days of the year. This capacity shortfall position is not unique to BED. In fact, many distribution utilities in New England are in a similar position as BED and are also required to pay generators for their capacity should it be needed. BED anticipates, as do most other Vermont distribution utilities, that this capacity shortfall situation will persist into the future. Accordingly, BED has undertaken additional evaluations of alternative resources as a means to identify a cost effective path forward. As discussed in more detail below, these additional evaluations might include building additional capacity resources, contracting with another generator, or pursuing active demand response initiatives, including energy storage.

Figure 5.7



[3] BED owns a 50 percent share of the McNeil Plant.

Gap Analysis Findings

Based on a comparison of its projected energy and capacity requirements against its available supply resources, BED has identified several key issues:

- Although flat load growth is anticipated to continue well into the future, BED expects that it will need to continue making monthly capacity payments in order to comply with regional reliability requirements. And, the price of wholesale capacity could increase substantially, if not hedged or actively managed.
- Loss of McNeil, the Gas turbine or both represents a significant financial risk, as BED would be required to make up additional energy and capacity deficits by purchasing resources at wholesale market prices. Although wholesale energy prices are expected to remain low, wholesale capacity prices will likely increase over the intermediate term.
- Continued reliance on REC revenue exposes BED to market volatility as REC prices have been depressed and will likely remain so over the planning the horizon.
- Maintaining BED's status as a 100% renewable provider is an important organizational goal but maintaining this status comes at a price since wholesale energy prices are at historic lows.
- As a 100% renewable provider, BED is able to comply with Tiers 1 and 2 of the state's renewable energy standard. However, the potential loss of McNeil, which generates up to 40 percent of BEDs renewable energy, could undermine BED's capabilities to comply with the RES.
- Even if BED maintains its 100% renewability status, Tier 2 resources can only meet about one - third of its Tier 3 requirements in the later years of the RES. Thus, BED will need to pursue a number of energy transformation projects at a cost of $60/MWh equivalent.
- If BED is unable to maintain its 100% renewability status and cannot modify its Tier 2 requirement, then it will need significantly more Tier 2 eligible distributed renewable generation resources.

Tier III Activities Impact on Energy and Capacity Needs

As described in the technologies options chapter, BED intends to pursue multiple energy transformation projects to comply with Tier III of the RES. Many of these projects will add energy loads (and to a lesser extent peak demands) to the system over time. However, BED expects that annual electric energy consumption by these projects will be minimal relative to current loads, the total resources on hand, at least in the initial years of the IRP planning period.

Additionally, energy efficiency resources will continue to help offset increases in load from such energy transformation projects, as will active demand resources and new net metered PV arrays. In general, the inclusion of Tier III anticipated loads does not change BED's resource questions substantially, but the modeling in the Decision Tree chapter was based on the post Tier III energy and capacity needs.

Alternatives Analysis Methodology

The gap analysis highlighted three major issues that needed additional consideration and analysis. These included:

- Effectiveness;
- Accessibility; and
- Costs

The section immediately below provides an overview of BED's methodology and processes for assimilating data as they pertain to its assessment of a potential resource's overall effectiveness, accessibility and cost. In general, a resource is deemed effective based on its ability to reliably produce energy and capacity when needed, and if it is renewable. In terms of accessibility, BED considered whether the alternative resource would actually be available for acquisition during the IRP horizon and, if so, at what cost. As an example, BED's efforts did not consider coal as a resource since pursuing a coal strategy would have been incongruent with BED's overall objectives and Vermont' values. Thus, BED never considered coal as an accessible resource alternative, even though it could be viewed as a least cost resource under a strict interpretation of the utility cost test.

Resource Effectiveness

The extent to which a specific resource can meet BED's projected energy, capacity, or renewability needs is a critical evaluation component. As noted in the gap analysis, BED has unmet need for both energy and capacity supply and has ongoing renewability targets. As a general rule, the ability for a single resource to meet multiple supply needs is advantageous. However, the difference in magnitude between BED's energy and capacity supply needs suggests identifying a single resource to meet both in a cost-effective manner could be challenging. Additionally, the traditional poor performance of renewable resources as capacity providers further suggests that it will be difficult to meet renewable energy goals and capacity needs with the same resource.

Energy

There are many types of energy supply resources ranging from highly controllable and dispatchable generators (such as biomass and combined cycle natural gas) to intermittent and uncontrollable renewable resources like wind turbines and run of the river hydro units. Those resources that are controllable and dispatchable generally have a higher capacity factor and are viewed as more reliable energy resources.

Capacity

Traditional "peaker" resources such as fossil fuel fired generators may be cost-effective capacity supply resources, but are rarely a cost-effective energy supply resource. Some energy producing resources (typically dispatchable resources) also provide significant capacity, but if the full energy output is not needed or desired, the energy would have to be sold, which leaves a utility vulnerable to wholesale energy market forces (risk of low prices rather than high prices). For the purposes of the alternatives analysis, a resource that effectively meets both BED's energy and capacity needs (without significant excess energy) would be viewed more favorably than resources that only meet energy or capacity needs. However, renewable resource capacity supply is typically not robust and is further exacerbated by wholesale capacity market structures that can leave a utility that relies on renewable resources open to capacity price fluctuations.

Renewable Energy Standard – Tier 1

In addition to meeting locally developed goals, BED's current 100% renewable position provides important benefits with respect to meeting Vermont's RES and avoiding costly alternative compliance payments (ACP). Under RES Tier 1, beginning in 2017, utilities must source 55% of their energy from renewable resources, increasing annually to 75% by 2032. If a utility is unable to achieve the required level of renewability, it is subject to an ACP for each kWh it is short of the requirement. Therefore, the ability of a resource to produce energy that meets the definition of renewability under Tier 1 of the RES provides additional value as compared to non-renewable resources.

Renewable Energy Standard – Tiers 2 & 3

Tier 2 of the RES requires utilities to meet 1% of their retail sales with distributed renewable generation beginning in 2017, increasing annually to 10% by 2032. Tier 3 of the RES requires utilities to reduce fossil fuel consumption by an amount equal to 2% of their retail sales in 2017, increasing annually to 12% by 2032. If BED maintains its 100% renewable position, its Tier 2 requirement is waived and BED may apply any non-net-metered Tier 2 resources to its Tier 3 requirement provided BED accepts all new net-metering systems and retires the associated net-metering RECs. For both Tiers 2 and 3, any failure to meet the requirements leaves utilities vulnerable to an ACP six times higher than the Tier 1 ACP. Therefore, resources that meet the Tier 2 definition of distributed renewable generation and can be used to meet either the Tier 2 or, in the case of a 100% renewable utility, Tier 3 requirements offer significant benefits.

Resource Access

BED's ability to access a particular resource affects its attractiveness and effectiveness with respect to other resource alternatives. Each resource alternative is assessed for its availability, meaning that BED could access it through typical utility mechanisms and without extraordinary measures or unusual circumstances. Each resource is also evaluated based on whether BED could reasonably expect to have the opportunity to own it (or a portion of it) or conversely, whether BED would have to own it in order to have access to it. In all cases, greater availability is viewed positively.

Resource Cost

The resource alternatives cost analysis is composed of initial costs (if applicable), ongoing costs, as well as an assessment of whether the resource is consistent with BED's internally developed goals. In all cases, lower initial costs and ongoing costs are viewed favorably in the alternatives analysis.

Initial Cost

In most cases, the initial cost is the upfront capital cost associated with purchasing or constructing a resource. These costs are typically financed over a long period of time and are fixed, not varying based on resource output.

Ongoing Costs

The ongoing cost category includes such items as standard operating and maintenance costs regardless of whether BED owns the resource or whether those costs are paid through a purchased power agreement. Ongoing costs can also include related transmission/wheeling fees or administrative fees that are directly attributable to a particular resource. These costs can be variable in nature, as output can drive costs up or down. Some ongoing costs are also fixed and unavoidable, such as property taxes.

Consistency with BED Goals

BED and the City of Burlington have long-standing commitments to innovation and the protection of the environment. Prime examples of this commitment are BED's achievement of 100% renewability and BED's recently proposed strategic goal to make Burlington a net zero city. To ensure the ongoing achievement of these goals and future goals, BED must consider whether resource alternatives are consistent with and will advance the goals. While it is not feasible to place a financial or numeric value on this concept, consistency with BED's goals may make an otherwise more expensive resource based on initial and ongoing costs more attractive than a lower cost resource. While non-renewable resources will not advance BED's renewability goals, consideration of such resources does, at a minimum, provide a useful benchmark to compare renewable resources against. Additionally, non-renewable resources might remain as viable capacity providers as filling that function does not impact energy source renewability in a substantial way.

Resource Risk

There are risks associated with every generation and supply resource alternative. Some risks, such as fuel, maintenance, or capital cost increases, are easy to quantify while others are more subjective and difficult to quantify, such as potential regulatory changes. To evaluate each resource as completely as possible and to arrive at a thorough understanding of likely financial and societal costs, a review of known and anticipated risks is included.

Resource Conclusion

Each resource analysis ends with a brief conclusion that summarizes its effectiveness, access, costs and risks. These summaries are used to fill in the Generation & Supply Alternatives Matrix labeled as Figure 5.11 at the conclusion of this chapter as well as Figure X.XX in Chapter X, which identifies generation and supply options to meet particular courses of action that emerge from the decision tree analysis.

Resource Environmental Considerations

With regard to fossil fuel capacity resources, it should be noted that they could serve as a useful interim capacity solution until storage technologies become economically viable.

Alternatives Analysis

In the section below, a description of each resource is provided as well as a summary of the resources overall effectiveness, accessibility and cost. Later on, the report provides an overview of how the selected resources compare to one another. This comparative analysis helped to determine which resource options have the greatest potential for meeting the public's need for energy services at the lowest present value costs, including environmental and economic costs. The analyses contained herein also served as a guide for evaluating resource options that were evaluated in the decision tree for this IRP.

The following list of potential resource alternatives was developed with the 2016 IRP Committee. To help the committee to evaluate and compare resource options, BED assembled the capital cost, fixed and variable O&M cost and levelized costs. Risk assessment information for each identified alternative was also provided, as shown below.

Plant Type	Fixed O&M Cost (2017 $/kW-year) (1)	Variable O&M Cost (2017 $/MWh) (1)	Capital Cost (2017 $/kW) (1)	Levelized Cost (2017 $/MWh) (2)	Initial Cost Risk (3)	Fuel Cost Risk (3)
Natural Gas						
Combined Cycle (620 MW)	$14.30	$3.91	$1,037	$58 - $86	Medium	High
Fuel Cell (10 MW) (4)	$0.00	$46.68	$8,038	$117 - $185	NA	NA
"Peaker" Unit (85 MW)(5)	$7.97	$16.77	$1,100	$183 - $242	NA	NA
Other Non-Renewable						
Nuclear (2,234 MW) (6)	$101.27	$2.32	$8,595 (2)	$107 - $151	Very High	Medium
Renewable						
Biomass (50 MW)	$114.68	$5.71	$4,523 (2)	$91 - $122	Medium	Medium
Wind - Onshore (100 MW)	$42.94	$0.00	$2,503	$35 - $85	Low	None
Hydroelectric (500 MW)	$15.34	$0.00	$3,320	$95.52 (7)	NA	NA
Solar PV (20-30 MW)	$30.13	$0.00	$2,050 (8)	$91 - $268 (9)	Low	None
Solar PV (DG < 5 MW)	$11.94 (2)	$0.00	$2,880 (8)	$158 - $289 (10)	Low	None
Battery Storage (25 MW) (11)	$6.45	Cost of Energy	$3,407 (12)	$348 -$714 (13)	NA	NA

Note: All prices have been adjusted from their original year (either 2012 or 2013) to 2017 dollars using the average annual 2010-2015 Consumer Price Index (CPI) inflation rate (1.657%) for O&M costs or the average annual 2010-2015 Construction Cost Index (CCI) inflation rate (2.49%) for capital costs. A blend of the CPI and CCI average rates (2.0735%) was used to adjust the levelized costs.

(1) Unless otherwise noted, source: “Updated Capital Cost Estimates for Utility Scale Generating Plants”, US Energy Information Agency, April 2013. Fixed O&M costs are inclusive of such things as property taxes, insurance, and standard staffing and plant maintenance costs. Variable O&M expenses are production-related costs which vary with generation levels, such as water and consumable supplies, but not fuel costs.

(2) Source: “Levelized Cost of Energy Analysis – Version 9.0”, Lazard, November 2015. Levelized costs are inclusive of initial capital costs, ongoing O&M costs (fixed and variable), fuel costs, and applicable federal subsidies.

(3) Source: "Practicing Risk Aware Utility Regulation: 2014 Update", Ceres, November 2014

(4) AEO2015 report indicates that most fuel cell operators consider all O&M expenses as variable, therefore fixed O&M expenses are set at $0.

(5) Proxy for a "Traditional Peaker" alterantive.

(6) Proxy for "Long Term Non-Renewable Contract" alternative.

(7) Source: "2020 Leveliized Costs AEO 2015", Energy Information Agency, April 2015

(8) Based on $2.05 per watt in 2017 for systems over 10 MW and $2.88/watt for systems under 10 MW, which is cost used in BED's load forecast prepared by Itron

(9) These values reflect higher costs related to lower capacity factors in the Northeast.

(10) Calculated by averaging the costs for residential rooftop, commercial rooftop, and community solar.

(11) All Battery Storage cost figures come from: "Levelized Cost of Storage Analysis - Version 1.0", Lazard, November 2015.

(12) Based on an average of the low and high case capital cost projections.

(13) The levelized cost of storage does not include any federal or state subsidies.

The data in the above tables was assembled from several sources; most notably from the Energy Information Agency’s (EIA) 2015 Annual Energy Outlook report (AEO2015). The levelized cost of energy data was performed by Lazard in 2015, and a 2014 electricity industry risk assessment report was sponsored by Ceres, a non-profit organization advocating for sustainable energy leadership. The Ceres report is intended to look beyond cost data to provide a broader, more qualitative analysis of the risks associated with each resource option. Resources are rated according to various types of risk, including such things as initial cost risk (includes risk of unplanned cost increases and delays) and fuel cost risk (includes risk of fuel availability changes and cost increases).

In order to evaluate the value of capacity supply options on a consistent basis across all types of resources, the 2017 capital cost per kW of each resource was converted into a cost per kWh – month value, as shown below. This analysis suggests that the lowest cost resource is a 620 MW combined cycle Natural gas plant located somewhere in New England. By way of comparison, ISO-NE's forward capacity planning process estimated that the cost to construct a new natural gas fired power plant would be approximately $10.81/kW-month. This is referred to as the "cost of new entry" or CONE value. However, in the most recent forward capacity auction, FCA 10, generation cleared at $7.03/kW - month, well below the CONE. The low price of generation in FCA 10 indicates that the New England market for capacity is robust and that new generators may be able to enter the market economically below the CONE values. Although wholesale capacity costs may be relatively low today, BED is concerned that these low prices may not continue. As noted elsewhere, capacity costs could increase in the not-too-distant future to between $9 and $12 kW – month.

Table 5.13 – Alternative Resource – Capacity Cost Evaluation

Plant Type	Capital Cost (2017 $/kW) (1)	Cost $/kW-month (*)
Natural Gas		
Combined Cycle (620 MW)	$1,037	$6.36
Fuel Cell (10 MW)	$8,038	$49.29
"Peaker" Unit (85 MW)	$1,100	$6.75
Other Non-Renewable		
Nuclear (2,234 MW)	$8,595	$52.70
Renewable		
Biomass (50 MW)	$4,523	$27.73
Wind - Onshore (100 MW)	$2,503	$15.35
Hydroelectric (500 MW)	$3,320	$20.36
Solar PV (20-30 MW)	$2,050	$12.57
Solar PV (DG < 5 MW)	$2,880	$17.66
Battery Storage (25 MW)	$3,409	$20.90

(*) Assumes 20-year debt at 4%

In addition to the resources listed below, BED has access to energy and capacity resources through the wholesale markets operated by ISO-New England. Wholesale energy and wholesale capacity, which can be viewed simply as a "do nothing" alternatives are also included in the alternatives matrix at the end of this chapter.

Biomass - New

Resource Description

In this analysis, biomass refers to the use of waste or sustainably-sourced plant-based products to generate energy. BED is currently a 50% owner as well as the operator of the McNeil biomass facility in Burlington, Vermont. For the purposes of the alternatives analysis, BED's current share of McNeil is classified as "existing biomass." The term "new biomass" refers to an entirely new generating facility separate from McNeil, whether it is already in existence or yet to be built.

Resource Analysis

Resource Effectiveness

Energy

Biomass generators are generally viewed as relatively flexible energy producers. Biomass generators are controllable and dispatchable and can participate in both the day ahead and real time wholesale energy markets. They can operate around the clock as baseload generators or cycle daily and operate as intermediate generators. This operational flexibility does offer utilities some ability to manage generation levels and their exposure to wholesale energy market forces. However, biomass generation is not as efficient as other generating processes, as indicated by its heat rate being typically in excess of natural gas, coal, oil, and nuclear generation.

Capacity

Biomass generators are generally viewed as excellent capacity supply resources because they are controllable and dispatchable, or else run as baseload. They are often able to offer their full nameplate capacity as a capacity supply resource, either as a utility self-supply resource or through participation in the wholesale capacity market.

Renewability

The use of either waste or sustainably harvested plant material allows biomass to be considered renewable generation in many jurisdictions. The installation of air quality control devices at generating plants to reduce particulate emissions further improves the environmental sustainability of biomass. Therefore, the alternatives analysis considers new biomass as an eligible VT RES Tier 1 resource. Additionally, current standards allow sustainably harvested biomass to qualify for high value Class 1 RECs in Connecticut. These RECs could serve as an significant revenue source if BED were to acquire new biomass as a supply resource.

Resource Access

Availability

The likelihood of a new (to BED) biomass facility being available is relatively low. There is one other existing biomass plant in Vermont, Ryegate, but it currently is operating under a Standard Offer contract (with the State of Vermont) with terms favorable to its owner. The potential to construct an entirely new biomass plant in Vermont also seems unlikely given amount of land

and capital investment it would require (see Initial Cost section below). It is possible BED could enter a contract to purchase the output of one of the other 17 biomass plants located within the ISO-NE territory. According to EIA's AEO2015, the construction of a new 50 MW biomass plant would take four years from the date it is ordered.

Ownership

As noted, there is only one other biomass plant in existence in Vermont and it currently has a contract with the State of Vermont (Standard Offer).

Resource Cost

Initial Cost

The initial cost for BED to purchase or construct a new biomass facility would be significant. In 2013, the EIA published estimated capital costs for power generators and found a 50 MW biomass plant to have capital cost of approximately $205,700,000 and the Lazard report of 2015 estimated the cost for a similar plant to be in the $200,000,000 range. Therefore, the capital cost per kW for a utility scale biomass plant is approximately $4,500 when adjusted to 2017 dollars. When compared to the other alternative resources, biomass capital costs per kW are in the mid-range.

Ongoing Costs

The estimates of non-fuel fixed and variable operating and maintenance (O&M) costs in Figure 5.12 indicate high costs relative to the other generating plant types evaluated. Additionally, when compared to other renewable resources, biomass is the only alternative that incurs variable O&M costs. The levelized cost of energy is moderate and ranges from $91 - $122 per MWh.

Consistency with BED Goals

Assuming the use of a sustainably sourced fuel, biomass meets BED's renewability goals. However, new biomass outside Burlington and, to a greater extent, outside Vermont would be less desirable in terms of BED's proposed net zero strategic target, which aims to source renewable energy as close geographically to Burlington as possible.

Resource Risk

Biomass plants running on sustainably harvested fuel are considered renewable and can therefore generate high value RECs in Connecticut and likely qualify as an eligible Tier 1 resource under the Vermont RES. However, regulatory changes in Connecticut and/or Vermont could dramatically shift the financial and renewability benefits of biomass. If either state were to alter its view of biomass renewability, BED could lose a significant revenue source or face challenges with respect to meeting its RES Tier 1 requirements, which would expose BED to an alternative compliance payment.

Resource Conclusion

New biomass would offer BED a reliable and flexible energy supply resource, an excellent capacity supply resource, and would also assist in meeting BED's Tier 1 requirements. Access to new biomass would be significantly challenging, as there is only one other biomass plant in Vermont and a relatively small number in the ISO-New England region. From a cost perspective, initial costs to purchase or construct a facility would be significant and ongoing costs tend to be moderately high compared to other generating technologies.

Biomass - Additional

Resource Description

As with new biomass, "additional biomass" refers to the same technology using waste or sustainably sourced plant-based materials to generate energy. For the purposes of the alternatives analysis, BED's current share of McNeil is classified as "existing biomass" while term "additional biomass" refers to the procurement of some portion of the 50% share of McNeil not currently owned by BED.

Resource Analysis

Resource Effectiveness

Energy

For this resource, BED has direct experience with its effectiveness as a provider of energy supply. Relative to its age, McNeil is a reliable and flexible energy supply resource and participates in the day ahead and real time wholesale energy markets. McNeil's capacity factor ranges from 65-70%, allowing BED to meet approximately 40% of its energy needs with McNeil. It is anticipated that the share of BED's energy needs covered by McNeil would increase proportionally to the additional share of McNeil ownership procured.

Capacity

McNeil's qualified capacity rating according to ISO-New England's Forward Capacity Market ranges from 52 to 54 MW, which is up to its full nameplate capacity. McNeil is scheduled as a self-supply resource for BED; providing 26 MW of capacity supply that BED can consistently rely on to meet its capacity requirement.

Renewability

McNeil is equipped with a series of air quality control devices that limit the particulate stack emissions to one-tenth the level allowed by Vermont state regulation. McNeil's emissions are one one-hundredth of the allowable federal level. The only visible emission from the plant is water vapor during the cooler months of the year. In 2008, McNeil voluntarily installed a $12 million Regenerative Selective Catalytic Reduction system, which reduced the Nitrogen Oxide emissions to 1/3 of the state requirement. Due to these measures, McNeil energy qualifies under the Connecticut Renewable Portfolio Standard and each MWh of energy generated creates a Connecticut Class 1 REC. Additionally, McNeil's energy qualifies as renewable under Tier 1 of the Vermont RES.

Resource Access

Availability

While BED has a 50% ownership share of McNeil, the other 50% is shared among two entities; Green Mountain Power (31%) and Vermont Public Power Supply Authority (19%). The three owners meet quarterly and maintain open lines of communication regarding the facility's operations and finances. In that regard, BED has direct and frequent access to the parties who could make additional biomass resources available. BED could discuss with the joint owners options to access a greater share of McNeil's energy, capacity, or both.

Ownership

As noted above, BED has an existing ownership share and a direct relationship with the other joint owners, making ownership of additional biomass possible from an access standpoint.

Resource Cost

Initial Cost

If BED pursued a greater ownership share, there is the potential for significant initial costs related to "buying out" current joint owner shares. If instead BED were to enter into a contract to purchase a joint owner's share of energy or capacity, but not full ownership rights, the initial cost could be less. However, the price of a buy-out is very dependent on the potential seller's market view.

Ongoing Cost

BED has firsthand knowledge of McNeil's current operating and maintenance costs and the elements that drive its economics. When compared to other controllable and dispatchable energy supply resources, McNeil's variable costs are relatively high. BED also manages the sale of McNeil's Connecticut Class 1 RECs for both BED and GMP and is aware of the importance of REC revenue in helping McNeil remain a cost-effective energy supply resource as they serve to reduce the net cost of production. Falling REC prices would essentially make McNeil more expensive to operate. McNeil is also an aging plant and increased maintenance costs and additional capital expenses are anticipated in the coming years.

Consistent with BED Goals

Additional biomass would be very supportive of BED's renewability and sustainability goals. Greater energy supply from McNeil would assist with maintaining 100% renewability, meeting RES Tier 1 requirements, and would help achieve the net zero goal for the City of Burlington.

Resource Risk

Unlike other renewable resources that do not use fuel and are completely emission-free, biomass requires fuel and does generate emissions, albeit limited. As noted under "New Biomass," the renewability classification of biomass is tied in large part to the sustainability of its fuel as well as its level of emissions. More stringent regulations with respect to fuel and emissions could alter its renewability classification and potentially impact the availability of high value RECs and RES compliance eligibility. With BED already relying on McNeil for 40% of its energy supply, greater reliance on McNeil would increase BED's exposure to market forces on McNeil's economics.

Resource Conclusion

Additional biomass resources from McNeil would serve as a reliable energy supply, an excellent capacity supply, and as a renewable resource consistent with BED's goals and RES requirements (assuming no regulatory changes impact its renewability classification). In terms of cost, McNeil already has relatively high operating costs, with the potential for its net expenses to increase due to REC revenue declining in the future. However, BED does have a reasonable high level of access to the resource and could investigate shorter term non-ownership options as a means to avoid high initial costs or a higher share of future capital expenditures. However, increased reliance on McNeil in any form would expose BED to greater risk of market forces on McNeil's economics. BED could also consider increasing its ownership share of McNeil, if one of the other Joint Owners sought to reduce their ownership share.

Combined Cycle Natural Gas

Resource Description

According to ISO-NE, the late 1990s ushered in a steady shift to natural-gas-fired generation in New England. These resources are easier to site, cheaper to build, and generally more efficient to operate than oil-fired, coal-fired, and nuclear power plants.[4] A combined cycle natural gas facility uses both gas and steam powered turbines to produce electricity. The waste heat from the gas turbine is used to generate steam, which then powers the steam turbine. The use of waste heat from the gas turbine increases electricity output without additional fuel use, and therefore increases the efficiency of the facility as compared to simple cycle plants.

Resource Analysis

Resource Effectiveness

Energy

Combined cycle natural gas facilities are viewed as strong energy supply resources due in large part to their efficiency from the use of waste heat. They are controllable and dispatchable facilities and can participate in both the day ahead and real time wholesale energy markets. While historically natural gas generators operated as intermediate resources, advances in equipment allow them to now operate as baseload generators while maintaining the flexibility to ramp up and down to balance intermittent renewable resources.

Capacity

Combined cycle natural gas plants are generally excellent capacity supply resources. As a non-intermittent generator, these units generally operate at a high capacity factor (85-90%) and their qualified capacity values are not de-rated, as would be the case with an intermittent generator. In 2015, 27% of the summer capacity and 26% of the winter capacity in the ISO-NE region was provided by combined cycle natural gas generators[5] and since 1997, about 80% of all the new capacity built in the region runs on natural gas[6].

Renewability

The overwhelming majority of natural gas used in energy production in the United States is non-renewable and comes from conventional drilling or hydraulic fracturing (fracking). To a much smaller degree, renewable natural gas

[4] "2016 Regional Electricity Outlook," page 8, ISO-New England, January 2016.
[5] "CELT Report: 2016-2025 Forecast Report of Capacity, Energy, Loads, and Transmission," ISO-New England, May 2016.
[6] "2016 Regional Electricity Outlook," page 8, ISO-New England, January 2016.

(also known as sustainable natural gas) is available. Renewable natural gas is a biogas (biomethane) that is purified to a level where it is essentially interchangeable with standard natural gas. Sources of renewable natural gas include landfills, wastewater treatment plants, and livestock. While Vermont Gas Systems recently began offering a renewable natural gas option to its customers, utility scale quantities sufficient to meet major power plant demands do not appear feasible at this time. Additionally, renewable natural gas is significantly more expensive than standard natural gas at this time, which would impact the cost competitiveness of a combined cycle natural gas facility compared to other resource options. The cost analysis below assumes the use of standard, non-renewable natural gas. As such, a combined cycle natural gas facility would not assist BED with meeting its Tier 1 RES requirement.

Resource Access

Availability

In 2015, natural gas powered facilities provided 49% of the power in the ISO-NE region and over 60% of the resources in the ISO-NE generator interconnection queue are fired by natural gas.[7] Clearly, natural gas resources are present and growing in number in the region. While there are no natural gas generators in Vermont, given the number of existing facilities and the number coming online in future years, it is likely that BED could have access to an existing or new combined cycle natural gas generator through a contract. Natural gas is not widely available within Vermont, but Burlington and most residents of Chittenden County are within the Vermont Gas' service territory and have access to a natural gas pipeline that might power a natural gas generator. In fact, natural gas is already available via pipeline at the McNeil biomass facility. Additionally, Vermont Gas is currently extending its pipeline approximately 40 miles farther south to Middlebury, Vermont, with the pipeline running generally parallel to routes 2A, 116, and 7. While this expansion will increase geographic availability of natural gas, it could constrain availability during the winter months for generation due to heating demand.

Ownership

As noted above, many developers are proposing to construct natural gas generators throughout the ISO-NE territory, although none are proposed for Vermont. Even though the construction of a natural gas generator has been categorized as cheaper and easier than other large-scale non-renewable

[7] "2016 Regional Electricity Outlook," page 8, ISO-New England, January 2016.

generators, it still would require significant land and financial resources. While Burlington and the core of Chittenden County has access to pipeline natural gas, as will several Addison County communities by the end of 2016, the Vermont Gas service territory tends to correspond with densely populated areas. Siting a new combined cycle natural gas generator in Vermont in population centers where there is existing natural gas service would be challenging. Therefore, if BED sought to own a portion of a combined cycle natural gas generator, it would face the prospect of either constructing one along the existing pipeline, seeking an extension of the pipeline to the generator, or acquiring ownership of a plant elsewhere. Vermont Gas' recent pipeline expansion project has faced highly vocal opposition from environmental organizations and local residents along the pipeline route, making the prospect of further expansion to supply a power generator questionable. Three new dual-fuel generators, which will use natural gas as their primary fuel, cleared in the most recent Forward Capacity auction. The size of the three units is indicative of the magnitude of most natural gas generators, 485 MW, 484 MW, and 333 MW. Based on the energy position shown in Figure 5.3 and Table 5.3, a unit of this size is significantly larger than BED's projected energy and capacity needs.

Resource Cost

Initial Cost

Of the resources summarized in Figure 5.12, a combined cycle natural gas generator has the lowest initial cost per kW, at $1,037. Despites its low construction costs relative to other resources, combined cycle natural gas generators were rated as having a medium initial cost risk, indicating some risk of unplanned costs or delays during the project's estimated three year development process[8].

Ongoing Cost

Similar to its initial cost profile, the ongoing costs of a combined cycle natural gas generator are also quite moderate compared to other resource options. The fixed O&M costs are in line with some of the lowest cost renewable resources and while there are variable O&M costs, the currently low natural gas prices keep those costs low as well. In terms of its ongoing cost risk profile, combined cycle natural gas was rated as having a high fuel cost risk due to the potential for natural gas prices to spike or to be unavailable due to pipeline constraints in the northeast, particularly in the winter months. It should be noted, however, that

[8] "Annual Energy Outlook 2016- Electricity Market Module', Energy Information Agency, Table 8.2.

the 2016 IRP Committee weighed in on potential future natural gas prices while developing the energy price forecast, as described in Chapter 2. As Figure 2.2 indicates, BED's base case energy price forecast assumes the levelized natural gas prices over the 20 year IRP time horizon will remain below the levelized price from 1990-2015.

Consistent with BED Goals

As noted above, combined cycle generators using standard natural gas are non-renewable resources, and as such do not meet BED's renewability goals. At this time, utility-scale supply of renewable natural gas would likely be challenging from both a supply and cost standpoint.

Resource Risk

The high proportion of natural gas fired generators in ISO-NE's interconnection queue has raised concerns about the availability of natural gas in New England. In its 2016 Regional Electricity Outlook, ISO-NE indicated "Inadequate natural gas pipeline infrastructure is at times limiting the availability of gas-fired resources or causing them to switch to oil, which is creating reliability concerns and price volatility, and contributing to air emission increases in winter."[9] Therefore, reliance on a combined cycle natural gas generator would expose BED to risks of higher costs (spiking natural gas prices, oil prices, or high wholesale energy prices) and higher emissions. Additionally, all the New England states have passed their own renewable portfolio standard, which provides utilities with an economic incentive to increase or maintain their use of renewable resources. It is likely that increased renewability targets will make non-renewable resources such as a combined cycle natural gas generator less desirable over time.

Resource Conclusion

Combined cycle natural gas plants function as strong energy and supply resources and offer utilities high efficiency and relatively low projected initial and ongoing costs (assuming the fuel is non-renewable natural gas). However, BED's access to this type of resource is limited by the absence of any combined cycle natural gas plants in Vermont and the general alignment between population centers and pipeline natural gas availability, which limits suitable areas for siting a generating facility. Additionally, because standard natural gas is non-renewable and renewable natural gas is likely not to be a viable option at this time, a combined cycle natural gas facility would not be consistent with BED's renewability goals and was not included as a decision tree option.

[9] "2016 Regional Electricity Outlook," page 11, ISO-New England, January 2016.

Traditional "Peaker" Unit

Resource Description

Facilities referred to as traditional "peaker" units are fossil fuel-fired simple-cycle generators. The primary fuels used in their operation are oil and natural gas, but other fossil fuels can also be used. Many units are capable of running on multiple fuels to adjust to fuel availability and take advantage of cost differences. Additionally, the potential for these generators to run on biodiesel or renewable natural gas may offer other opportunities. For the purposes of this analysis, an 85 MW natural gas conventional combustion turbine has been used to determine the benefits, costs, and risks of a "peaker" unit.

Resource Analysis

Resource Effectiveness

Energy

Traditional peaker units are rarely a cost-effective energy supply resources, except perhaps if the waste heat can be used. The equipment and design of these facilities is not intended for baseload or even intermediate resource operations. Rather, these facilities are intended to only operate during peak hours or as occasional back-up resources. Therefore, because of their limited operation, fixed costs must be recovered over a small number of hours, which drives the levelized price per MWh higher than generators designed for frequent and consistent energy production. The main source of revenue for these units is the capacity and reliability markets, not the energy market.

Capacity

Peaker units are designed and constructed to serve as capacity resources. ISO-NE's Forward Capacity Market uses this type of unit as the basis for the Cost of New Entry in the region-wide new capacity costs, and as a result, the market capacity costs paid by utilities are impacted by the cost of constructing this sort of facility.

Renewability

These are fossil fuel-fired units and therefore are not renewable resources. As noted above, renewable gas is now available in Vermont, but utility scale quantities sufficient to meet power plant demands do not appear feasible at this time. Additionally, renewable natural gas is currently significantly more expensive than standard natural gas, which would impact the cost to operate a peaker unit by increasing its variable costs. As the cost to operate increases, the unit becomes less competitive with other resources and will run less, which would make it an ineffective Tier 1 resource. However, the use of renewable gas for a peaker, due to the relatively low energy production, would be less of a problem than for a combined cycle plant. The cost analysis below assumes the use of standard, non-renewable natural gas. For these reasons, a peaker unit would not assist BED with meeting its Tier1 RES requirement.

Resource Access

Availability

BED currently owns a 25 MW peaker generator, known as the Burlington Gas Turbine (though in fact it can only sue oil fuel at this time), which is located at the Burlington waterfront in downtown Burlington. Due to their infrequent operation and moderate size compared to other generating resources, siting a peaker unit is generally not as challenging as other types of resources. In addition to the Burlington Gas Turbine, several other peaker units owned by other Vermont utilities are located throughout Vermont and there are many such generators throughout the ISO-NE region. For these reasons, BED views a peaker generator as reasonably available.

Ownership

Multiple "peaker" units are located in Vermont; all are serving as important capacity resources for the utilities that own them. BED is not presently aware of any plans by Vermont utilities to sell existing peaker units in the state. Therefore, BED's ownership of another peaker unit would likely be tied to the construction of a new facility. The most recent peaker unit built in Vermont was a facility in Swanton, constructed by the Vermont Public Power Supply Authority in 2008.

Resource Cost

Initial Cost

Compared to the other resource alternatives reviewed, a peaker unit has a relatively low initial cost on a per KW basis. At $1,100 per kW, only the larger combined cycle natural gas generator have lower capital cost per kW than a peaker unit. A simple-cycle natural gas turbine was not part of the risk evaluation completed in the Lazard report cited in Figure 5.12, but the AEO2015 Electricity Market Module assigned the technology a 2-year construction timeline and noted that it could be constructed more quickly. This suggests a relatively low capital cost risk related to project length or delay.

Ongoing Cost

The fixed O&M costs for a peaker are the lowest among the resources reviewed while the variable O&M costs are relatively high. Because capital costs must be recovered over a small number of generation hours, the levelized energy costs of a peaker unit are quite high, and are by the far the highest among the non-renewable resources considered. Although, it is important to remember that a peaker unit is not intended to serve as a primary energy supply resource. Rather, the ongoing economics of a peaker unit are tied to whether its cost of operation is less than the cost to purchase market capacity or capacity from another resource.

Consistent with BED Goals

As a fossil-fuel powered generator, a peaker unit is not consistent with BED's renewability goals. However, unlike baseload or intermediate non-renewable resources that produce significant amounts of energy, the magnitude of non-renewable energy generated by a peaker unit is quite small. The potential exists to use renewable natural gas for peaking purposes, or the output from a peaker could be "greened" using replacement or excess RECs (or other emission offset tools) equal to the unit's annual MWh output, as is currently done with BED's Gas Turbine.

Resource Risk

Because peaker units derive their financial value from the capacity and reserve markets and do not generally generate revenue from energy production, their economics are vulnerable to clearing prices of just one or two market auctions each year. A low clearing price could dramatically reduce important revenue for a peaker unit for an entire year with little opportunity or ability for a utility to improve it. Past history has seen extended periods where the capacity market revenues would not support peaking generation, though the revised FCM structure may help somewhat.

Resource Conclusion

Peaker units are intended to serve a narrow yet important primary function; the provision of capacity supply to a utility. In terms of this specific function, peaker units are highly efficient and cost-effective. As expected, when compared to resources intended to serve as energy-producers, they do not appear economically attractive.

Utility Scale Wind

Resource Description

For the purposes of this analysis, utility scale wind refers to an onshore wind farm consisting of multiple large wind turbines that have a combined nameplate capacity of as much as 100 MW or more. According to ISO-NE, in 2015 there are over 800 MW of grid connected wind resources currently installed in the ISO-NE region with an additional 4,200 MW in its interconnection queue.[10]

Resource Analysis

Resource Effectiveness

Energy

Wind generators are intermittent resources that experience rapid changes in their production due to weather forces. In New England, utility scale onshore wind has a capacity factor of approximately 25-35%, which positions wind as a moderately effective energy resource.

Capacity

Due to their intermittent nature, wind is not viewed by ISO – NE as an effective capacity supply resource. Indeed, a key feature of an effective capacity resource is its capacity to perform on demand when needed the most. Because wind resources are not controllable and, thus, cannot be assumed to be available at times when energy demand is highest, ISO – NE "de-rates" wind generators nameplate capacity when it assigns its qualified capacity (QC) rating. According to ISO-NE, wind resources only make up 0.3% of the installed capacity in the region despite providing 1.8% of the region's energy.[11] A review of the Vermont wind generator's QC ratings as a percent of their nameplate capacity in FCA 10 demonstrates this trend.

Vermont Wind Generator Capacity Values in FCA 10

	Nameplate Capacity	FCA 10 Winter QC	% of Nameplate in FCM
Vermont Wind	40 MW	8.235 MW	21%
Georgia Mountain Community Wind	10 MW	2.28 MW	23%
Kingdom Community Wind	63 MW	15.695 MW	25%

[10] "2016 Regional Electricity Outlook," page 10, ISO-New England, January 2016.
[11] "New England 2015 Regional System Plan (RSP15) Load, Energy and Capacity Resource Overview", Maria Scibelli, April 2015.

Renewability

Wind is a fuel and emission free renewable resource. Wind resources qualify for high value RECs in multiple markets throughout New England and nationally. Wind therefore qualifies as an eligible resource to meet BED's RES Tier 1 requirement (though due to size restrictions large scale wind is not available for Tier II/III purposes).

Resource Access

Availability

There are currently four utility-scale wind farms in Vermont; Searsburg Wind Facility (6 MW), Georgia Mountain Community Wind (10 MW), Sheffield/Vermont Wind (40 MW), and Kingdom Community Wind (63 MW). BED currently purchases energy from Georgia Mountain Community Wind (100%) and Vermont Wind (40%) through a contract and is also under contract to purchase energy from Hancock Wind, a facility which began commercial operations in December 2016. As noted above, throughout the ISO-NE region, 4,200 MW of wind resources have been proposed and are in the interconnection queue, which is over five times the amount of wind resources currently installed in the region. Wind is therefore considered a resource with ample availability to BED.

Ownership

While BED has three existing wind contracts, it does not currently own any utility scale wind facilities. With the anticipated significant growth of wind resources in the ISO-NE region over the next few years, it seems reasonable that BED could acquire an ownership share in a wind resource in the future.

Resource Cost

Initial Cost

Of the renewable resources evaluated, wind has the lowest per kW capital cost, at approximately $2,503/kW. The cost of wind turbines has decreased in recent years and is anticipated to continue to fall. The resource risk assessment found that onshore wind resources have a low capital cost risk.

Ongoing Cost

Most onshore wind operators do not treat O&M on a variable basis, and consequently, all O&M expenses are shown on a fixed basis.[12] Obviously, without fuel needed for operation, the fuel cost risk is zero. Compared to other fuel-free renewable resources, the fixed O&M costs are relatively high. However, levelized energy costs for onshore wind are the lowest among the renewable resources and are becoming more comparable to combined cycle natural gas generator costs.

Consistent with BED Goals

As a renewable and zero emission resource, onshore wind is consistent and supportive of BED's goals. The existence of wind resources in Vermont and throughout New England also suggests that additional wind resources could be consistent with BED's net zero target for the City of Burlington.

Resource Risk

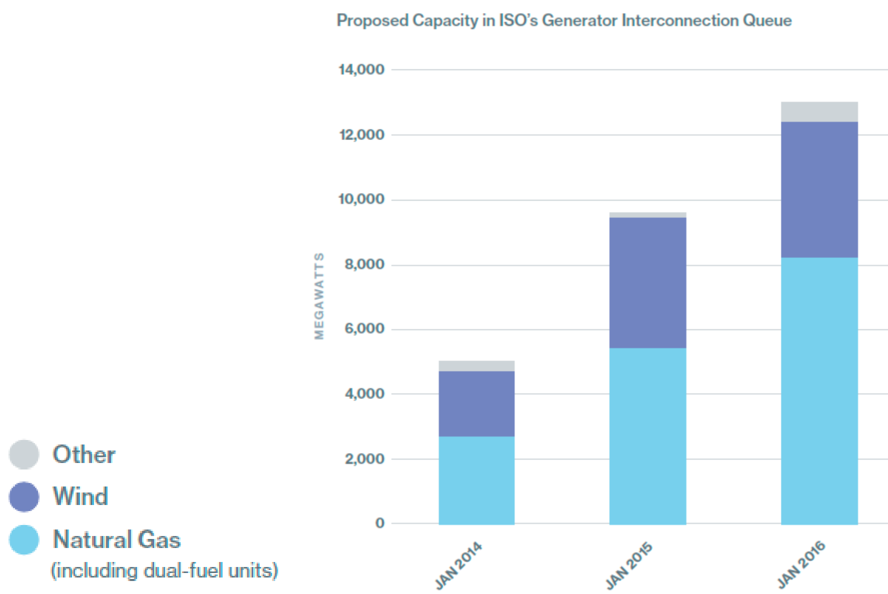
Like most renewable resources, wind generators are subject to weather forces outside a utility's control. As a utility increases the proportion of its load met with intermittent/uncontrollable resources increases, it must consider methods to smooth the intermittency. Increasingly affordable storage technologies could help address the issue in the future, but more immediately, greater reliance intermittent resources like wind could increase BED's exposure to wholesale energy prices when wind generation is not available and to costs related to the bidding of these resources in constrained export areas. Wind has also faced public opposition in Vermont, so for new resources proposed in Vermont, there would be a risk of permitting and construction delay.

Resource Conclusion

Despite its intermittency, wind generation is a moderately strong energy resource, but is not an effective capacity supply resource. Levelized energy costs for onshore wind are becoming more comparable to combined cycle natural gas generators, so it is not surprising that these two resources make up the vast majority of proposed projects in ISO-NE's interconnection queue (see Figure 5.13). In addition to being a cost-competitive resource, wind also generates high value RECs that can serve as a utility revenue source or alternatively can be used to meet RES Tier 1 requirements.

[12] "Updated Capital Cost Estimates for Utility Scale Generating Plants", page 21-3, US Energy Information Agency, April 2013

Figure 5.13



Source: "2016 Regional Electricity Outlook," page 22, ISO-New England, January 2016.

Fuel Cell (Renewable NG)

Resource Description

Fuel cell generators convert natural gas to hydrogen and generate electricity through an ionic transfer, not combustion, which also produces heat and water. They are scalable and can range from single units with a capacity of a few hundred kW to larger multi-MW generators. They can have multiple applications, including behind-the-meter, grid connected, micro-grid, or combined heat and water uses.

Resource Analysis

Resource Effectiveness

Energy

Fuel cells are efficient energy producers, with a capacity factor in the 90% range. These units are generally viewed as providing constant baseload energy, versus having the ability to ramp up and down throughout the day. The inability to ramp up and ramp down would impact their usefulness in terms of balancing intermittent renewable resources.

Capacity

Due to their consistent operation and steady output, fuel cells are an excellent capacity supply resource. Two 2.5 MW fuel cell facilities, both located in Connecticut, cleared FCA 10 in February 2016, introducing fuel cells into active participation in the FCM for the first time.

Renewability

As with the other natural gas fired generators included in the alternatives analysis, fuel cells can operate with standard natural gas (fossil fuel) or with renewable natural gas. The costs included in Figure 5.12 reflect the use of standard natural gas. Use of renewable natural gas would push variable costs significantly higher. If renewable natural gas is used, fuel cells would qualify as eligible Tier 1 resources. Additionally, because they are quite scalable, a fuel cell facility of 5 MW or less would also qualify as an eligible Tier 2 resource, which BED could apply to its Tier 3 requirement.

Resource Access

Availability

BED is not aware of any existing fuel cell generators in Vermont at this time. However, the vast majority of BED's service area is within the Vermont Gas Systems natural gas service territory, making the technology feasible from a fuel availability standpoint. There is also renewable natural gas availability in the BED service area and given the potentially for relatively small-scale fuel cell generators, powering one with renewable natural gas may be feasible. Generally speaking, a generator less than 5 MW could be sited within an area approximately the size of several tennis courts, making site availability somewhat less challenging than other types of generators. Additionally, based on the participation of several fuel cell generators in the most recent FCM auction, there appears to be ongoing development of fuel cells in the ISO-NE region.

Ownership

It does not appear there are any existing fuel cell generators in Vermont that BED could purchase, but it also does not appear there are any major impediments to BED's development and ownership of such a facility in Vermont.

Resource Cost

Initial Cost

Among the generation options evaluated, on a per kW basis, the initial cost of fuel cell generator is higher than all the renewable and other natural gas-fired generation types, and is surpassed only by nuclear.

Ongoing Cost

Most fuel cell operators do not treat O&M on a fixed basis, and consequently, all O&M expenses are shown below on a variable basis.[13] Therefore ongoing variable O&M costs for a fuel cell are the highest among all the generation options evaluated. The levelized cost of energy range, $117 – $185, is relatively moderate and comparable to several other generation options. While not specifically rated in the risk assessment report, a natural gas fuel cell would face the same fuel cost risk as other natural gas generators that face pipeline constraints and potential winter cost spikes. Additionally, the levelized cost is based on using standard natural gas as fuel. At this time, renewable natural gas is substantially more expensive than standard natural gas, which would likely push the levelized cost of energy for a fuel cell above the other generation options considered. However, it should be noted that a fuel cell less than 5 MW using renewable natural gas would be Tier 2/Tier 3 eligible and could help BED avoid a $0.06 per kWh alternative compliance payment under the RES.

Consistent with BED Goals

Fuel cells utilizing standard natural gas would not be consistent with BED's renewability goals, but fuel cells using renewable natural gas would be. A renewable natural gas fuel cell generator built in Burlington or nearby would be consistent with BED's net zero goals as well.

Resource Risk

Like the combined cycle natural gas generator, fuel cells operating on standard natural gas would expose BED to the same increased cost risks associated with pipeline constraints in New England. There are risks associated with using a relatively new fuel source such as renewable natural gas. With renewable natural gas being a recent offering by Vermont Gas Systems, it us unknown whether a fuel cell using renewable natural gas would face any supply challenges that would impact fuel cell operations or economics.

---

[13] "Updated Capital Cost Estimates for Utility Scale Generating Plants", page 15-3, US Energy Information Agency, April 2013

Resource Conclusion

Fuel cells produce constant baseload energy and are excellent capacity-supply resources. The levelized cost of energy using standard natural gas is moderately high, but comparable to other resources. However, if renewable natural gas were used to make a fuel cell an eligible Tier 1 or Tier 2 resource, the O&M costs would likely exceed other renewable resource options. Accordingly at this point, a fuel cell decision tree path was not included.

Long-Term Renewable Contract (non-wind)

Resource Description

For the purposes of this analysis, a generic utility scale (over 5 MW) hydroelectric generator is being used to evaluate the merits of a long-term renewable resource contract.

Resource Analysis

Resource Effectiveness

Energy

Run of the river hydro is an intermittent resource whose output is uncontrollable. However, under the terms of a contract, BED could specify either a firm or unit contingent amount of energy to be supplied by a particular resource or group of hydro resources. Additionally, hydro units with storage capability can be excellent providers of capacity under present market rules due to their ability to move the output to different times of the day.

Capacity

Hydro contracts can be crafted to include capacity in addition to energy, however, like other intermittent resources; hydro is not a strong capacity resource.

Renewability

Run of the river hydro is a renewable resource and would be a Tier 1 eligible resource. Additionally, depending on the particular hydro resource, the unit(s) could produce higher value RECs that could serve as a revenue source for BED (as is the case with the Winooski One facility).

Resource Access

Availability

There are many existing hydroelectric generators of varying sizes and classes throughout Vermont and the ISO-NE region. BED has entered into contracts for hydropower in the past and believes hydro contracts continue to be available as a supply resource.

Ownership
This option is intended to evaluate a contract, not ownership.

Resource Cost

Initial Cost
Not applicable.

Ongoing Cost
The ongoing costs of a run of the river hydro plant are all classified as fixed O&M, resulting in an estimated cost of $15.34 per kW-year. This is the second lowest among the renewable supply options considered that also have no variable O&M or fuel costs. The estimated levelized cost of energy is $95.52 per MWh, which makes it quite competitive with both renewable and non-renewable resource options. For the purposes of this analysis, BED assumes the contract price for hydro energy would need to reflect the levelized costs.

Consistent with BED Goals
From a renewability standpoint, a contract for existing hydro energy is consistent with BED's goals. If the unit is within close proximity to Burlington or within Vermont, such a contract could also be consistent with BED's net zero target.

Resource Risk
Because this resource option is specifically a contract for hydroelectric power, it is possible to avoid some of the normal renewable resource intermittency issues by entering into a firm delivery contract. Nonetheless, even with a firm contract, some risk of non-performance remains, which would expose BED to market energy prices. A defaulting counter-party would be liable for liquidated damages intended to make BED whole (covering any resulting increased energy costs), but there is a risk that a counter-party would not be in a financial position to pay the liquidated damages.

Resource Conclusion
A contract for hydro would allow BED to efficiently match its energy supply resources to its needs. Hydro can also provide capacity supply, although it is quite minimal relative to the energy supplied in run-of-the-river units. The energy purchased through a contract, provided it includes the related RECs, would qualify under Tier 1. Given the number of hydro units throughout Vermont and the ISO-NE area, BED believes it is a resource with ample availability.

Assuming contract prices are similar to the estimated levelized cost of energy, a contract for hydropower could be cost-competitive with other renewable supply options.

Long-Term Non-Renewable Contract

Resource Description

For the purposes of this analysis, a nuclear facility was used to evaluate a long-term contract for a non-renewable resource.

Resource Analysis

Resource Effectiveness

Energy

Nuclear generators provide constant baseload energy and are regarded as strong energy producers with a capacity factor in the 80%-90% range. Nuclear generators are not well-suited to provide the fast start and flexible output that is needed to balance the frequent supply changes related to intermittent resources.

Capacity

Due to their reliable nature and consistent output, nuclear generators are strong capacity supply resources.

Renewability

While a nuclear generator does not produce measurable air emissions, its use of non-renewable uranium classifies it as non-renewable resource. More broadly, a BED contract for a long-term non-renewable resource would not be eligible under Tier 1. If BED wished to retain its 100% renewability, it would need to purchase RECs to cover the purchased non-renewable energy, assuming such replacement RECs are available.

Resource Access

Availability

The number of nuclear generators in the ISO-NE region and the share of regional energy supplied by them has been in decline for several years, and is expected to continue to decline. The share of the region's installed capacity supplied by nuclear dropped from 18% in 2000 to 13% in 2016, and is projected to be just 11% in 2024.[14]

[14] "Key Grid and Market Stats", ISO-New England, http://www.iso-ne.com/about/key-stats/resource-mix#air-emissions

Ownership

This option is intended to consider a contract for energy, not resource ownership.

Resource Cost

Initial Cost

Under a contract, BED would not be directly responsible for initial capital costs. Nonetheless, nuclear has the highest initial cost estimate among the resources evaluated as well as the highest initial cost risk rating (very high) and the longest construction lead time (six years).

Ongoing Cost

The fixed O&M costs are significantly higher than the other non-renewable resources evaluated while the variable O&M costs are the lowest. With the exception of combined cycle natural gas and onshore wind, the nuclear levelized cost of energy ($107-$151) appears to be competitive with other renewable and non-renewable resources, prior to the application of any renewable energy subsidies.

Consistent with BED Goals

Due to its non-renewable classification, nuclear power (and other non-renewable resources) are not consistent with BED's renewability and net zero goals.

Resource Risk

If natural gas prices remain at historically low levels, natural gas generators are expected to continue to out-compete nuclear generators in the wholesale energy markets.[15] The continuation of state-sponsored renewability targets will enhance the economic competitiveness of those resources compared to nuclear generators.

Resource Conclusion

As more economic natural gas generation and wind resources are on the rise in the ISO-NE region, nuclear power is on the decline, with two major plant retirements occurring within the last few years. While BED could benefit from the consistent energy and capacity supply it would offer, a long-term contract for a non-renewable resource such as nuclear would not position BED well in terms of Tier 1 or its own renewability goals.

[15] "2016 Regional Electricity Outlook," page 9, ISO-New England, January 2016.

Other New Renewable DG less than 5MW

Resource Description

For the purposes of this analysis, a behind the utility meter (but not net-metered) solar array of less than 5 MW was used.

Resource Analysis

Resource Effectiveness

Energy

In the northeastern US, solar only has a capacity factor of approximately 14%. While solar can effectively reduce peak usage and thereby lower transmission and capacity costs, it is not a strong energy resource if looked at from a pure output standpoint. However, solar energy production tends to correspond with times of high energy wholesale prices, increasing its value as compared to the same kWh amount of baseload energy. As described in Chapter 3, solar can also be paired with battery storage to perform a variety of functions.

Capacity

For small distributed generation behind the utility meter resources that would not participate in the FCM, capacity value is evaluated based on their ability to reduce load during the ISO-NE peak. BED is strongly summer peaking, as are Vermont and ISO-NE. The production curve for solar aligns well with these peak days and is predictable (at least on peak days). By passively reducing BED's loads at times when charges for transmission and capacity are set, and energy prices are high, solar can be a strong capacity resource. However, increased densities of behind the meter are likely to move the ISO-NE peak to hours later in the day, and correspondingly reduce the capacity benefit of behind-the-meter solar. ISO-NE recognized solar is not rated highly for capacity under current market rules (approximately 10% of nameplate) which is why ISO-NE recognized solar is comparatively rare.

Renewability

Solar PV is a renewable resource that would be eligible under Tier 1. Additionally, distributed generation (not net-metered) under 5 MW would be eligible for Tier 2 and could be applied to BED's Tier 3 requirement. Alternatively, solar resources can also be qualified in several states to produce high value RECs that could be a revenue stream for BED.

Resource Access

Availability

By its nature, distributed generation is smaller in scale and requires less land for siting purposes than utility-scale generation. However, Burlington is a densely populated area with limited open land, which makes siting a solar array up to 5 MW challenging. BED has already taken steps to utilize rooftop space within the City's control for solar PV arrays, but believes additional rooftop and brownfields opportunities do exist. The cost of solar panels has fallen recently, and continued panel cost reductions are expected. For these reasons, solar PV is viewed as an available resource.

Ownership

BED currently owns two behind the utility meter solar arrays and has experience developing such projects. The City of Burlington owns many buildings and land within the City making BED ownership of additional solar PV arrays feasible.

Resource Cost

Initial Cost

Among the renewable resource options considered, a distributed generation solar PV array has the highest initial cost at approximately $5,995 per kW of installed capacity. The resource risk assessment rates the initial cost risk of a distributed generation solar array to be low.

Ongoing Cost

The ongoing costs of a solar array less than 5 MW consist of the fixed O&M costs, which are approximately $11.94 per kW-year, with no variable O&M costs. The levelized cost of energy ranges from $158-$28, with the upper range higher than any other resource evaluated. However, the distributed generation resource of less than 5 MW would be eligible under Tier 2 and could be applied to Tier 3, helping BED avoid a $0.60 per kWh alternative compliance payment under the RES.

Consistent with BED Goals

A behind the utility meter solar array under 5 MW would be consistent with BED's renewability goals and could directly support its net zero target.

Resource Risk

With a capacity factor of just 13-15% on average, the effectiveness of solar as an energy resource is limited in New England. Because ISO-NE is currently summer peaking during daylight hours, solar functions as a good capacity resource, reducing load during peak periods. However as noted above, as more solar resources come online, it is anticipated that the ISO-NE peak will shift later and later in the day, potentially moving beyond the time of solar production. Therefore, unless energy storage becomes a more economic option, there is a risk that the capacity and transmission value of solar will decrease over time.

Resource Conclusion

While solar has a low capacity factor, particularly in the northeast, solar can serve as an effective capacity resource by reducing load during the ISO-NE peak. Solar PV under 5 MW would also be an eligible Tier 1 and Tier 2 resource and could help BED meet its RES Tier 3 requirement. In terms of BED's renewability goals and net zero target, solar PV would be a very effective and supportive resource. However, given BED,s demographics and ISO-NE market rules, BED currently expects that solar development in Burlington will, in large part, be net-metered solar. Solar generation in other utility service territories could (and would) be considered when advanced, but the imposition of transmission (i.e. "wheeling") charges by the host utility severely hurt the economics of solar located outside Burlington.

Utility Scale Storage

Resource Description

Energy storage can take many forms, including several types of batteries, pumped hydro, and flywheels, among others. Storage can be viewed as a unique resource because many of the technologies operate both as a supply resource and a load resource.[16] This analysis discusses a 25 MW/100 MWh utility-scale, ISO-recognized lithium ion battery storage system that could replace a fossil-fuel powered peaker unit.

Resource Analysis

Resource Effectiveness

Energy

A battery storage system does not generate electricity, but rather serves as a control device that allows a utility to select the timing of when energy supply is delivered; or captured and stored from intermittent renewable resources. Battery storage can also serve as a dispatchable energy supply resource. Similarly, storage can respond quickly to rising demand, participate in the day ahead and real time energy markets, as well as provide various grid services such as regulation services[17] Lithium ion batteries are considered to have relatively

---

[16] "How Energy Storage Can Participate in ISO-New England's Wholesale Electricity Markets," page 3, ISO-New England, March 2016.

[17] "How Energy Storage Can Participate in ISO-New England's Wholesale Electricity Markets," page 5, ISO-New England, March 2016.

strong energy density, meaning the amount of energy (kWh) capable of being discharged is high compared to its physical volume.[18] While lithium ion batteries are among the most efficient batteries available, with efficiency ranging from 80-93%, losses do occur when energy is stored and later discharged (meaning that storage is not "generation" itself but in fact increases net generation needs). The battery configuration considered in this analysis is intended to replace a peaker unit, and therefore is not anticipated to serve as an energy supply resource.

Capacity

A battery's power density, or its capacity to discharge energy over a timeframe, is also important when considering battery storage as a capacity resource. And while not a net producer of energy, as discussed above, a storage device ability to "relocate" energy can allow it to serve as a capacity resource. The system considered in this analysis could discharge a sustained 25 MW for four hours. The maximum output of the battery system is therefore the same as BED's existing Gas Turbine, which is a significant capacity resource for BED. At this time, however, no battery storage has cleared as capacity resource in an FCA. To compare battery storage to other capacity supply resources, it is important to consider the cost per kilowatt-month. The battery storage peaker unit is estimated to cost $20.89/kW-month, which is well above both the $6.75-kW-month of a traditional peaker unit and the most recent FCA clearing price of $7.03/kW-month.

Renewability

The renewability of a battery storage system depends on the source of energy used to charge the batteries. Because 100% of BED's energy is from renewable resources, a battery storage system located within the BED distribution system would assume that same level of renewability. If BED no longer sourced 100% if its energy from renewable resources, and assuming the batteries were not directly charged from a renewable resource, the storage system would be assigned the same proportion of renewability as the rest of the BED load. However, because battery storage is not an energy generator, it would not help BED fulfill any Tier 1 or 2 requirements.

[18] "Levelized Cost of Storage Analysis – Version 1.0", page 5, Lazard, November 2015.

Resource Access

Availability

Storage technologies are continually improving and advancing[19]. As of January 2016, 94 MW of battery storage were being proposed in the ISO-NE region[20], although none is serving as peaker unit replacements at this time. Therefore, it does not appear any existing facilities are available to BED. Based on a review of existing battery storage installations available from http://www.energystorageexchange.org/, it appears a 25 MW/100 MWh battery storage system would require approximately one acre of land. The siting of such a storage facility within the ISO-NE region, with future availability to BED, appears to be reasonably feasible.

Ownership

While not immediately feasible, BED's ownership of a 25 MW/100 MWh battery storage system or shared ownership of a larger system is possible in the future. ISO-NE has indicated it anticipates energy storage to become an increasingly important part of the regional power system and has released information on how battery storage units can participate in its wholesale energy markets. BED anticipates battery storage systems to become more prevalent in future years as costs continue to decline.

Resource Cost

Initial Cost

Like several other technologies, the cost of battery storage has fallen substantially in recent years, and continued falling prices are expected over the next several years. For lithium ion batteries, cost decline expectations are based on increased manufacturing scale, a reduction in required high cost materials, and improvements in battery chemistry/design.[21] While battery capital costs are usually quoted on a dollars per kilowatt hour basis, the capital costs for the 25 MW/100 MWH peaker unit included in the November 2015 "Levelized Cost of Storage Analysis – Version 1.0" by Lazard were converted to dollars per kilowatt to ease comparison with other resources. At $3,407/kW, battery storage is over triple the cost of a traditional peaker unit. The Lazard analysis does cite industry

---

[19] How Energy Storage Can Participate in ISO-New England's Wholesale Electricity Markets," page 1, ISO-New England, March 2016.

[20] "2016 Regional Electricity Outlook," page 22, ISO-New England, January 2016.

[21] "Levelized Cost of Storage Analysis – Version 1.0", page 17, Lazard, November 2015.

expectations that capital costs will continue to decline, with a median predicted cost decrease of 47%.[22]

Ongoing Cost

The estimated levelized cost of storing and discharging energy from a battery storage peaker unit is $348 - $714 per MWh. This cost is well above all the other supply resource options evaluated. As noted above, capital cost reductions are anticipated, which will help make battery storage more economical on a levelized cost basis in the future. The ability for a single battery storage unit to serve multiple functions, such as capacity and regulation, could also improve its economics. However, "in practice, a single energy storage system may provide services across multiple use cases, although the feasibility of multiple application energy storage units may be limited by operational and design factors (e.g. sizing for a particular use case could preclude participation in another)."[23] BED's evaluation of the economics of storage contained in the technology chapter is predicated on this ability to access multiple value streams.

Consistent with BED Goals

When paired with a renewable portfolio or specific intermittent renewable resources, battery storage is consistent with and supportive of BED's goals. Battery storage can smooth out intermittent renewable generation, making it possible to rely on intermittent renewable resources for a larger portion of BED's power supply needs. Specific to a battery storage peaker unit, the ability to replace a fossil-fuel fired peaker is directly supportive of BED's renewability goals.

Resource Risk

Unlike a typical generator, a battery storage system has a specific discharge duration beyond which it could not supply power. For the 25 MW/100 MWh peaker replacement storage system, its runtime at maximum power would be four hours, at which time it would need to recharge. If there were a long duration event, or two back-to-back events, requiring peaking capacity, reserves, or emergency back-up, it is possible a battery storage system could not offer the same performance as a fossil fuel fired peaker.

Resource Conclusion

Using battery storage as a peaker unit is not currently economically competitive with a fossil fuel fired peaker unit. Given the structure of the New England FCM, this price difference would

---

[22] "Levelized Cost of Storage Analysis – Version 1.0", page 17, Lazard, November 2015.
[23] "Levelized Cost of Storage Analysis – Version 1.0", page 6, Lazard, November 2015.

tend to indicate that storage is not yet a viable capacity option. Declining battery capital costs and the potential for battery storage to fulfill multiple revenue-producing roles could improve battery storage economics in future years, making it a more cost-effective method to meet Burlington's renewability and net zero goals. In addition, where storage can leverage additional value streams such as avoiding a transmission/distribution upgrade (see T&D chapter) or provide critical reliability, it may be desirable today though such cases are by their nature unique and difficult to model in generic terms.

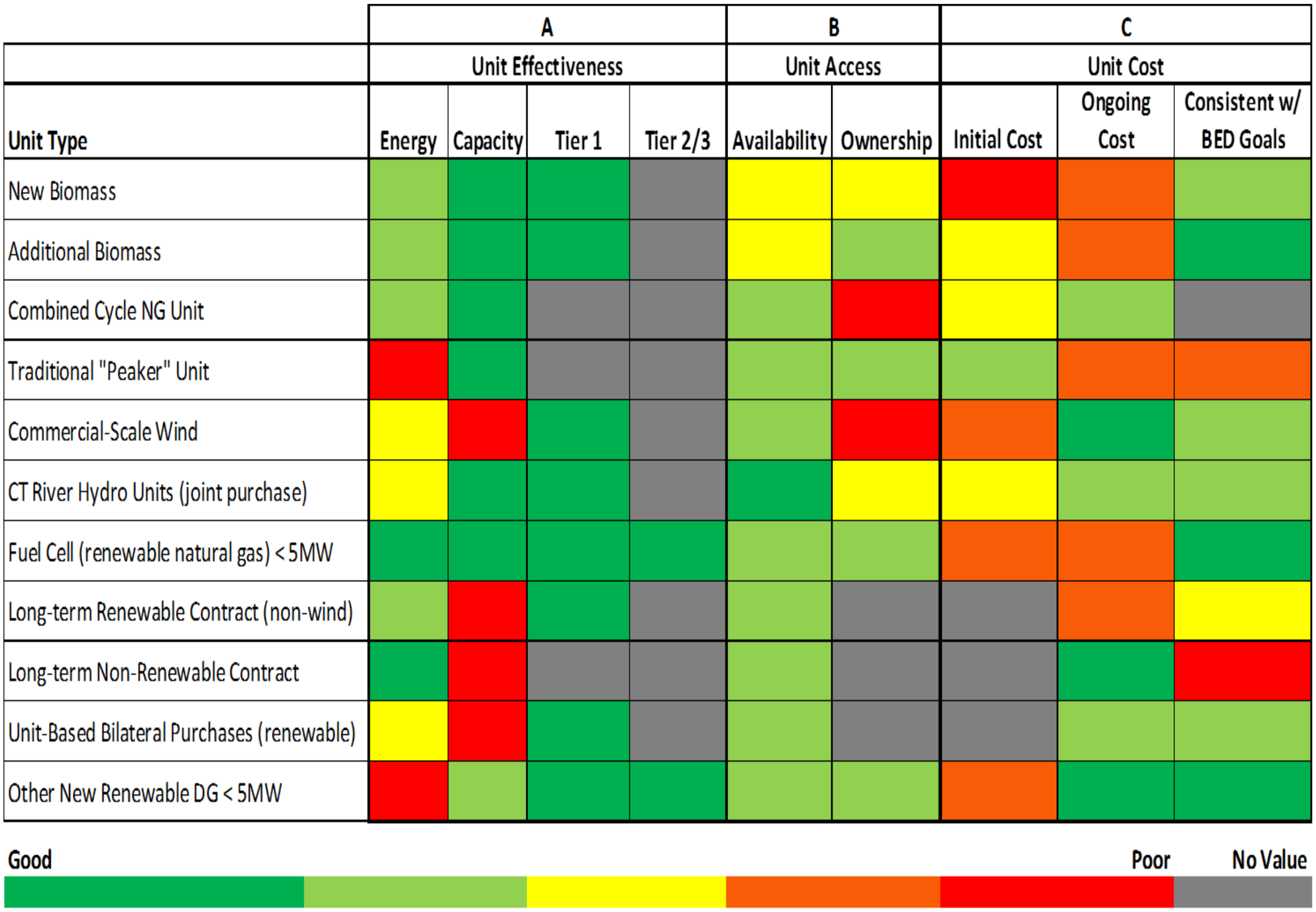
Overall Conclusion

As noted, BED currently has sufficient amounts of energy supply to reliably serve its customers in accordance with 30 V.S.A. §218c. Indeed, BED maintains ownership and/or control over resources that are capable of supplying nearly 95 percent or more of its energy requirements. However, because BED's energy comes from renewable resources, BED is substantially short on capacity. This shortfall or capacity gap is a function of ISO – NE's reliability protocol that significantly de-rates resources that are intermittent, such as Wind, solar (if ISO-NE recognized) and run-of-river hydro dams. Irrespective of its current capacity position, BED does not anticipate that future increases in capacity costs will impose significant upward rate pressure. This is because expenses associated with capacity costs are relatively small compared to its energy and transmission costs.

With regard to BED's status as a 100 percent renewable provider, BED is highly dependent on the continued operation of the McNeil Biomass plant. However, the economics of the McNeil plant have been more challenging with the fall in wholesale market energy prices and it will likely need additional capital investments over the next 5 – 7 years to maintain its reliability. Should the McNeil plant be retired, BED would need to search for cost effective replacement energy and capacity, which would be a considerable challenge as most new generation in New England is natural gas. However, it is important to note that the current district energy project that is currently under review has the potential to improve McNeil's effective value.

In the matrix below, a comparison of the various resources are compared to one another. As the legend illustrates, those resources with the highest number of green colored boxes generated the greatest number of benefits in terms of their effectiveness, accessibility and costs.

Figure 5.14


A
Unit Effectiveness
B
Unit Access
C
Unit Cost
Unit Type
Energy
Capacity
Tier 1
Tier 2/3
Availability
Ownership
Initial Cost
Ongoing Cost
Consistent w/ BED Goals
New Biomass
Additional Biomass
Combined Cycle NG Unit
Traditional "Peaker" Unit
Commercial-Scale Wind
CT River Hydro Units (joint purchase)
Fuel Cell (renewable natural gas) < 5MW
Long-term Renewable Contract (non-wind)
Long-term Non-Renewable Contract
Unit-Based Bilateral Purchases (renewable)
Other New Renewable DG < 5MW
Good
Poor
No Value