MASSACHUSETTS DOER COMMUNITY CLEAN ENERGY RESILIENCY INITIATIVE
APPENDICES: TOWN OF ACTON

Attachments:

- Appendix A: Modeling Assumptions
- Appendix B: Supporting Documentation

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Appendix A: Modeling Assumptions

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Massachusetts DOER Community Clean Energy Resiliency Initiative
Tables of Assumptions by Technology

Natural Gas Combined Heat and Power

Table 1. Combined Heat and Power

Parameter	Value	Units	Sources/Notes
Capital cost	$3,500	$/kW	NREL
Variable O&M cost	$0.06	$/kWh	NREL
O&M cost	$0.0225	$/kW/hour of operation	Assume 75% CF
APS rebate	($0.03)	$/kWh	Cadmus APS data
Overhaul frequency	20,000	hours of operation	Engineering assumption
Replacement cost	$583.33	$/kW	Assume 1/6 of capital cost
Fixed cost	$91	$/kW-yr	Engineering assumption
Fuel cost	Rate	$/m^3	
Peak electrical efficiency	33%	--	Engineering assumption
Minimum output as percentage of nameplate	50%	--	Engineering assumption
Net peak fuel efficiency (thermal and electrical)	60%	--	Engineering assumption

Table 2. Small-Scale (Less than 300 kW) Combined Heat and Power

Parameter	Value	Units	Sources/Notes
Capital cost	$4,000	$/kW	Vendor information
Availability	96%	--	Vendor information
Capital cost – hydronic loop	$50,000	$	Vendor information
Capital cost – islanding switchgear	$50,000	$	Vendor information
Utility rebate	$56,000	--	Vendor information

Biomass Combined Heat and Power

Table 3. Biomass Combined Heat and Power

Parameter	Value	Units	Sources/Notes
Capital cost	$6,067	$/kW	NREL
Fixed cost	$91	$/kW/year	NREL
Variable O&M cost	$0.06	$/kWh	NREL
APS rebate	($0.03)	$/kWh	Cadmus APS data
Overhaul frequency	20,000	hours of operation	Engineering assumption
Replacement cost	$1,011	$/kW	Assume 1/6 of capital cost
O&M cost	$0.05	$/hour of operation	Assume 75% CF
Peak electrical efficiency	24%	--	Engineering assumption
Minimum output as % of nameplate	50%	--	Engineering assumption

Table 4. Biomass Combined Heat and Power Fuel (Wood Pellets)

Parameter	Value	Units	Sources/Notes
Density	200	kg/m^3	Engineering assumption
Energy content	19	MJ/kg	Engineering assumption

Natural Gas Reciprocating Engine

Table 5. Natural Gas Reciprocating Engine Technology

Parameter	Value	Units	Sources/Notes
Capital cost	$1,000	$/kW	Vendor info
Overhaul frequency	25,000	hours of operation	Vendor info
Replacement cost	$300	$/kW	Vendor info
O&M cost	$0.01	$/kW/hour of operation	Vendor info
Minimum power output	50%	of rated power output	Vendor info
Efficiency at 100% output	30%	electricity out / fuel energy in	Vendor info
Efficiency at 50% output	25%	electricity out / fuel energy in	Vendor info

Solar Photovoltaics

Table 6. Solar Photovoltaics (Direct Ownership)

Parameter	Value	Units	Sources/Notes
Installed cost	$4.22	$/kW	Cadmus data
O&M cost	$20	$/kW/year	Cadmus data
Lifetime cost	20	years	Typical PV guarantee
Replacement cost	$4.22	$/kW	Estimated
Capacity factor	14.39%		MA DOER

Table 7. Solar Photovoltaic (Power Purchase Agreement)

Parameter	Value	Units	Sources/Notes
PPA cost	$0.10	$/kWh	Cadmus assumption (coastal and central MA)
Annual production	1,261	kWh/kW/year	Calculated based on capacity factor
Cost/year	$126.1	$/kW/year	Estimated
Capacity factor	14.39%		MA DOER

* Net metering, calculated annually, assuming net-metered energy cannot exceed grid purchases by more than 1/3.

Battery Storage

Table 8. Battery Storage

Parameter	Value	Units	Sources/Notes
Capital cost	$800	$/kWh	SANDIA, 1 kWh lead acid battery and management system
Replacement cost	$500	$/kWh	HOMER assumption
O&M cost	$10	$/kWh/year	HOMER assumption

Fuel Cells

Table 9. Fuel Cells

Parameter	Value	Units	Sources/Notes
Capital cost	$10,000	$/kW	NREL
Overhaul frequency	50,000	hours of operation	Estimated
Replacement cost	$10,000	$/kW	Assumption
O&M cost	$0.01	$/kW/hour of operation	Estimated
Minimum power output	75%	of rated power output	Engineering assumption
Efficiency at 100% output	60%	electricity out / fuel energy in	CCERI minimum eligibility
Efficiency at 50% output	60%	electricity out / fuel energy in	CCERI minimum eligibility

Fuels

Table 10. Fuel

Parameter	Value	Units	Sources/Notes
Diesel	$0.80	$/L	Vendor information
Gasoline	$1.00	$/L	Assumption
Propane	Rate	$/L	Community
Heating oil	$0.80	$/L	Assumed; heating oil = non-road diesel
Natural gas	$0.50	$/m^3	Assumed, if no other data provided
Natural gas	$1.4835	$/therm	Calculated
Wood pellet energy content	5	MWh/tonne	Calculated
Wood pellet energy content	18	MJ/kg	Biomass Energy Center
Wood pellet cost	$200	$/tonne	MA DOER
Wood pellet cost	$0.011	$/MJ	Calculated
Wood pellet cost	$1.172	$/therm	Calculated

Emissions

Table 11. Emissions

Parameter	Value	Units	Sources/Notes
NPCC New England (NEWE) GHG Intensity	420	gCO2e/kWh	Union of Concerned Scientists
Biomass GHG intensity	0	gCO2e/kWh	Assumption
PV GHG intensity	0	gCO2e/kWh	Assumption
Battery GHG intensity	0	gCO2e/kWh	Assumption

CADMUS

Battery Storage for Energy Resiliency

There are many factors to consider when selecting a battery storage technology for a backup power system, including initial capital costs, maintenance requirements, energy and power needs, useful lifetime, charging requirements, and siting and environmental considerations. There are a variety of battery chemistries available with unique cost and performance attributes – common types include:

- Flooded lead acid batteries,
- Sealed lead acid batteries,
- Lithium-ion batteries and,
- Other types. Including nickel, hybrid, and flow batteries.

Table 1 provides a brief overview of select battery technologies, including approximate cost (inclusive of battery management system and balance of plant equipment), as well as relative rankings of energy density, maintenance, cycle life, depth of discharge, and average lifetime in standby applications.

Table 1. Baseline and Clean Energy Generation Scenario Costs and Emissions

Battery Type	Cost/kWh	Maintenance Requirements	Energy Density	Cycle Life/Depth of Discharge	Average Lifetime
Flooded lead-acid	$200-$400	High	Moderate	Moderate	Moderate
Sealed lead-acid	$400 - $800	Low	Low	Low to Moderate	Low
Lithium Ion	$1,000- $1,600	Low	High	Moderate to High	High

Flooded Lead Acid (FLA)

Flooded lead acid (FLA) batteries are one of the oldest technologies available that is suitable for backup storage in a resiliency application. FLA are typically the lowest cost solution, though have shorter lifetimes, higher maintenance requirements and safety concerns versus other technologies. The electrolyte in the FLA battery is a liquid that needs to be equalized periodically to ensure it is well mixed, which in turn helps extend battery lifetime. During equalization the battery is subjected to a high charge current and can generate hydrogen gas, an explosive gas that requires adequate ventilation. Maintenance requires measuring the specific gravity of cells and periodically adding distilled water to replace liquid lost to evaporation during charging.

Benefits of FLA Batteries

- Low initial cost
- Widely available and used in renewable energy and backup power applications

Drawbacks of FLA Batteries

- Require equalization charging and monitoring of electrolyte
- Sensitive to depth of discharge and temperature
- Capacity is reduced at high discharge rates

Figure 1. 350 kWh Flooded Lead Acid Battery Bank

- Require sufficient ventilation/airflow to prevent buildup of hydrogen gas

Sealed Lead Acid Batteries (SLA)

Sealed lead acid (SLA), or valve regulated lead acid (VRLA), batteries offer a compromise between cost and maintenance. SLA batteries generate very little hydrogen gas compared to FLA batteries and thus require little maintenance, making them suitable for remote installations. Typically constructed with lead-calcium plates, the two most common types of SLA batteries are absorbed glass mat (AGM) and gelled electrolyte (GEL). Generally, GEL batteries recover quicker from deep discharge, though have lower charging and discharging rates as compared with AGM batteries..

Benefits of SLA Batteries

- Minimal maintenance requirements
- Widely available and used in renewable energy and backup power applications

Drawbacks of SLA Batteries

- Sensitive to depth of discharge and temperature
- Low energy density (will require more space to store batteries than other technologies)
- Capacity is reduced at high discharge rates

Lithium-ion Batteries

Lithium-ion (Li-ion) batteries are a relatively new technology which has benefited from the popularity of hybrid automobiles and research in the area of lightweight, high-density energy storage. While the cost of Li-ion batteries has come down in recent years, they remain two to three times more expensive than lead-acid batteries. Li-ion batteries can generally tolerate deeper and more frequent discharge cycles than lead acid batteries and are less impacted by variations in temperature or discharge rate. These types of batteries, though initially more expensive, may be more cost-effective over time in cold or hot weather applications where frequent charging and discharging is expected. For occasional use in climate-controlled areas, Li-ion may not be as cost-effective as lead acid type batteries.

Benefits of Li-Ion Batteries

- Require less space for same energy storage
- Minimal effects of temperature and discharge rate on capacity
- Deep discharges have minimal effect on cycle life compared to lead acid technologies

Drawbacks of Li-Ion Batteries

- Expensive compared to other technologies
- Relatively new for small-mid scale renewable energy and backup power applications

Other Battery Technologies

The battery industry is evolving quickly and there are many other types of batteries entering the marketplace. Compared with the technologies mentioned here, however, some of these new technologies are not yet widely used in backup power applications.

Appendix B: Supporting Documentation

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CADMUS

MEMORANDUM

To: Dean Charter, Town of Acton

From: Ryan Fahey and Charlie McClelland, Cadmus

Subject: Request for Information – CCERI Technical Assistance Application

Date: August 18, 2014

Please provide written responses to questions outlined in the Request for Information below by Tuesday September 2, 2014. Submission of responses prior to this date is encouraged.

Introduction

The Cadmus team will be developing a model for the proposed critical facilities and proposed resiliency components identified by the Town of Acton in the Community Clean Energy Resiliency Initiative (CCERI) Technical Assistance application. In order to provide the most robust analysis and recommendations for the proposed added resiliency components, the Cadmus team requires additional documents and information, listed below.

Request for Information

1. What is the roof age/condition at the DPW Facility and Public Safety Facility?
2. Please explain the critical functions performed by the Red House and Library.
3. Interval data will greatly enhance the analysis provided.
    a. The simplest way is for Acton to provide a signed waiver allowing the Cadmus consulting team to access utility interval usage data on your behalf.
    b. Alternatively, Acton may develop a narrative of energy usage for each facility. In this case, we will be developing an expected energy usage profile for weekend and weekdays during the various seasons of the year. In the absence of interval data, please provide a narrative of typical building occupation during each of these times. Narrative could include qualitative statements about, among other things
        i. When is energy usage likely to be highest
        ii. Is the facility used on weekends?
        iii. How does the winter/summer/fall/spring weather influence energy usage?
        iv. How does summer occupancy [and energy usage] differ from winter usage?
4. Please provide one year of utility bills for electricity and gas for the Public Safety Facility and DPW Facility. Please provide monthly demand (kW) data in Acton CY2013 Utilities.xlsx. Also, please describe how the "PelleVerde" solar PPA electricity is allocated across the facilities.

Please feel free to contact us with any questions or concerns.

Kind Regards,

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