Generic Community System Specification

A Proposed Format for Reporting the Results of Microgrid Optimization Analysis

March 2018

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NREL/TP-5000-70581

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1.0 Introduction

This document provides a proposed format for reporting the results of microgrid optimization analysis. The proposed format assumes that the modeling is conducted as part of a renewable energy retrofit of an existing isolated diesel micro-grid, although the format can certainly be adapted for other situations.

2.0 Proposed Outline

Executive Summary

Note: *The executive summary describes the analysis at a high level but with enough detail to allow a reader to understand the analysis, the rationale for undertaking the analysis, the preferred alternative, and why, as well as the other alternatives analyzed and the reasons for those alternatives not being chosen. The executive summary highlights the methodology, basic assumptions, and the most important risks, barriers, and limitations that could impact the preferred outcome and the alternatives. The executive summary should be very concise and to the point.*

A. Project background and rationale
B. Community overview
C. Energy overview
D. Techno-economic modeling methodology and results
E. Key conclusions.

1. Introduction

Note: *Provide a short overview of the situation and motivation for the analysis.*

A. Analysis and proposed project context
B. Report organization.

2. Community Overview

Note: *Use this section to provide an overview of the community.*

A. Location with map
B. Population, population trends
C. Number of homes, enumeration of major community facilities, dominant industries and economic drivers, major commercial loads, etc.

3. Community Electricity and Heating Infrastructure

Note: *Use this section to provide an overview of the electricity generation infrastructure. Diesel fuel costs, diesel fuel consumption, electrical generation costs, and electrical consumption are interrelated. Similarly, thermal loads, heating oil costs, and heating oil consumption are interrelated. This outline shows discussion of the different elements separated into several sections (A, B, C, D …). Discussion of the individual topics can be consolidated into fewer sections or presented in a different order if each topic is addressed. For example, discussion of thermal loads, heating oil consumption, and heating costs could be consolidated into one section.*

A. Existing Power Station
   - Existing or envisioned units (# of units, make and models, power rating, age)
   - Existence (or not) of waste heat recovery and specifics of that system
   - Fuel consumption curves
   - Operating strategy
   - Replacement and maintenance schedule

- Capital and operating costs (actual or modeled)
- Utilization assessment (examine metric such as kWh/gal, compare diesel sizes to load histogram)
- Fuel storage capability and fuel delivery process.

B. Existing Heat Production Infrastructure. ***Note:*** *Describe the technologies used to provide heat to the community (e.g., oil-fired stoves, wood stoves, waste heat recovery, etc.) The discussion can be organized by technology type or customer class.*
   - Residential
   - Community
   - Existence (or not) of heat recovery on the diesel generators.

C. Fuels (diesel, heating oil, propane, wood, etc.). ***Note:*** *For each fuel addressed, discuss the following: usage (actual or potential), costs (past, current, anticipated), utilization limitations (storage, resource availability, etc.)*
   - Diesel fuel (used in the power plant)
   - Heating fuel
   - Other (as needed).

4. Community Energy Needs

Note: *The purpose of this chapter is to give a comprehensive overview of end use energy demand in the community for the market sectors included in the analysis (typically one or more of electrical, thermal, and transportation). Items of interest include the average load, peak load, diurnal variation, and seasonal variation. To the extent permitted by the available information, break out the aggregate load by customer category or by major consumers. Discuss any activity driving the seasonal or diurnal load (e.g., fish processing plant operating in the summer). Discuss any anticipated or possible changes in future loads due to population changes, planned facilities, or changes in economic activity.*

A. Loads Overview: measurement and quantification, uncertainty estimates
   - Relative sizes of electrical, thermal, and transportation consumption (perhaps use a pie chart to show this)
   - Description of the basic motor vehicles types in the community and how they are used
   - Relative fuel consumption for the electrical, thermal, and transportation loads
   - Sources of data.

Note: *Detailed electricity production and cost data for Alaska communities are available in the annual Power Cost Equalization reports. Data on heating oil consumption and costs are somewhat harder to find and less detailed. If annual heating oil consumption data are available, then that can be combined with building data and climate data in a building loads model to generate a time series thermal load profile. Detailed data on transportation fuels and usage will likely be hard to determine in the absence of a specific community-wide transportation assessment.*

B. Electric Loads
   - Current consumption patterns
     - Sources of data
     - Characterization of current electrical loads (total annual consumption; seasonal and diurnal patterns; max, average, and min loads). ***Note:*** *Examples of useful plots include*

time series plot, histogram, diurnal profile (annual or monthly), bar chart showing monthly consumption
    - Summary of different electrical loads or load categories. ***Note:*** *If data permit, break out major loads or customer categories.*
- Historical and (anticipated) future consumption. Discuss reasons for any changes. ***Note:*** *Include a table (and perhaps a chart) showing annual generation and sales for the past few years.* Discussion of electricity generation versus electricity sales. ***Note:*** *Compare electricity generated vs. electricity end use vs. electricity sold. A large difference between energy generation and energy use may indicated a need for distribution system or metering upgrades to reduce losses.*

C. Thermal loads
- Current consumption patterns
    - Data sources
    - Characterization of current thermal loads (may have to use fuel consumption as a proxy) (total annual consumption; seasonal and diurnal patterns; max, average, and min loads; load types [e.g., residential heating, fish processing, etc.]). ***Note:*** *Examples of useful plots include time series plot, histogram, diurnal profile (annual or monthly), bar chart showing monthly consumption*
    - Summary of different thermal load type categories (e.g., residential heating, fish processing). ***Note:*** *If data permit, break out major loads or customer categories*
- Past and (anticipated) future consumption. Discuss reasons for any changes ***Note:*** *If the data are available, include a table (and perhaps a chart) showing annual consumption and sales for the past few years.*

D. Transportation Loads
- Current consumption patterns
    - Data sources
    - Characterization of current transportation-based fuel use specific to different fuels, including total annual consumption, seasonal and diurnal patterns. ***Note:*** *Examples of useful plots include time series plot, histogram, diurnal profile (annual or monthly), bar chart showing monthly consumption.* If portions of the transportation load are being considered for electrification, typical time of day usage with seasonal variation will be needed.
    - Summary of different transportation load categories; divide by vehicle class and fuel type
    - "End use of transportation" (e.g., going to school, going to work, transporting export goods, transporting tourists, etc.)
- Past and (anticipated) future consumption. Discuss reasons for any changes. ***Note:*** *If the data are available, include a table (and perhaps a chart) showing annual miles traveled and fuel sales for the past few years by vehicle type.*

5. Energy Efficiency Opportunities

Note: *In this chapter, discuss energy savings and implementation cost for each potential opportunity. Possible energy efficiency opportunities are listed below.*

A. Electricity and thermal end use benchmarks (e.g., MMBTU/sq. ft./year, etc.). Comparison with regional averages and current benchmarks
B. Opportunities to improve end use electrical energy efficiency
C. Opportunities to improve end use thermal energy efficiency (weatherization, etc.)
D. Reduction of electrical distributions system losses

E. Feasibility of upgrading infrastructure to increase power factor, reduce losses, etc.
F. Waste heat recovery
G. Demand side management/load shifting
H. Availability and applicability of heat pumps.

6. Grid extension (if applicable)

   Note: *It may make financial sense to interconnect two relatively close communities (up to 20 to 30 miles). If a grid extension is possible, an analysis combining both communities should be conducted. The analysis would be similar to one conducted for a single community but would account for the costs and savings of the grid extension.*

7. Transportation Transition Opportunities

   Note: *This section should provide an overview of opportunities to reduce imported fuel in the transportation sector. For each vehicle type identified, describe how fuel efficiency may be improved or transitioned to other fuels, such as electricity. It may be appropriate to start with vehicles that are part of city or community facilities as these are more likely to be transitioned away from imported fuels in the near term. Other transportation options that could be used to reduce overall community fuel consumption, such as the development of vehicle avoidance programs, should also be described.*

8. Component Performance and Cost Overview

   Note: *This chapter should provide an overview of any equipment being considered for the new or expanded, high imported fuel displacement power system. Such technology/components include wind, solar, hydro, biomass, batteries, converters, etc. Each in-place or possible technology may merit its own section. For the potentially viable resources, discuss resource availability, performance and cost assumptions, uncertainties, etc. A final chapter/section may summarize additional technologies that were considered but (for whatever reason) deemed infeasible. Separate sections should be included for each technology under serious consideration.*

   Each technology section (A, B, C …) that is considered as part of the analysis should include the following information as applicable:
   a. Technology description
   b. Resource
   c. Performance
   d. Lifespan
   e. Capital cost
   f. Operating cost
   g. Other discussion.

9. System Modeling

   Note: *This chapter should include a full description of the techno-economic analysis conducted as part of the system assessment including, at a minimum, the following sections.*

   A. Analysis Methodology Overview, to include analysis approach, tools used, constraints, modeling limitations, how different options are evaluated and ranked (i.e., what is being optimized); for example, upfront cost, life-cycle cost, rate of return, fuel consumption, technology maturity, etc.

B. Simulation Inputs. ***Note:*** *Consider including a table, perhaps in an appendix, that lists all inputs. The text can focus on the key analysis inputs. A sample analysis inputs and assumptions table is provided at the end of this document.*
   - Economic assumptions
   - Energy efficiency opportunities (anticipated cost, expected life, and load reduction)
   - Resource assumptions
   - Component performance and costs assumptions.

C. Sensitivities. ***Note:*** *Consider listing the sensitivities in a table.*

10. Modeling Results

Note: *This chapter should provide an overview of the results of the analysis. There are many ways to present the results, depending on the intended audience, modeling tool(s) used, analysis approach, analyst preference, situation, etc. In addition to presenting a specific preferred architecture, effort should be devoted to giving the reader some level of insight into what factors are driving the analysis results. The results should, as appropriate, provide a clear description of the recommended solution as well as some additional optional solutions that may highlight different aspects of the potential system design based on discussions with the local parties. As an example, a least-cost option may be provided in addition to an option that provides the most imported fuel savings, although not necessarily the least cost. The chapter should include the following sections:*

A. Technical Modeling Results: System Configurations
B. Economic Modeling Results: One or more of Net Present Value, Net Present Cost, Levelized Cost of Energy, Rate of Return
C. Sensitivity Analysis Results and Discussion. ***Note:*** *The sensitivity discussion should then highlight reasons why different technical options should be considered based on the sensitivities considered.*

11. Conclusions

Note: *This chapter should provide a short summary of the results, potential further or expanded analysis, and next steps to be considered as part of the project development process. Topics could include:*
A. Analysis-specific conclusions (e.g., recommended system configuration)
B. General conclusions (major take-always and the "so-what" behind the analysis results)
C. Analysis limitations and caveats
D. Potential further or future analysis
E. Future work.

References

Glossary

Appendix: Table listing all analysis inputs and assumptions; an example is provided below.

Appendix: Listing of Analysis Inputs and Assumptions

Note: *While it often makes sense to discuss the values of the various analysis inputs and assumptions in the text, it is convenient for the reader to have all the values listed in one place. The contents of the table will vary somewhat based on the analysis purpose, approach, and tools used.*

Table A-1. Sample Table Listing Analysis Inputs and Assumptions

Item	Value	Note
Annual electric load (kWh)	1,790,000	Average load – 205 kW
Peak electric load (kW)	360	
Annual thermal load (kWh_{th})	8,596,000	Average load – 980 kW_{th}
Peak thermal load (kWth)	3,700	
Generator capital cost ($)	$0	Assume use of current generators
Generator replacement cost ($)	$73,600	
Generator operating cost ($/hr)	$15.64	
Generator lifetime (operating hours)	60,000	Specify whether the value is total generator lifetime or time between rebuilds
Generator no-load fuel consumption (gal/hour)	0.0200	
Generator marginal fuel consumption (gal/kWh)	0.2400	
Generator minimum load (% of rated power)	30%	
Diesel fuel cost ($/gal)	$4.50 ($1.19/L)	
Heating oil cost ($/gal)	$5.00 ($1.32/L)	
Transportation fuel ($/gal)	Not considered	Different transportation fuels may be in use, but typically gasoline is the primary source
Wind turbine capital cost ($/turbine)	$700,000	Cost of controls to allow operation of the two wind turbines present
Wind turbine replacement cost ($/turbine)	$560,000	Discounts as above for additional turbines
Wind turbine O&M cost ($/year/turbine)	$17,500	Discounts as above for additional turbines

Item	Value	Note
Wind turbine lifetime (years)	20	
Average wind speed (m/s)	6.44	
Height above ground for which the average wind speed applies (m)	29	
Wind speed shear factor	0.15	Used to adjust the wind speed from the reference height to a different height
Wind turbine hub height (m)	50	
Average wind speed @ hub height (50 m) (m/s)	6.99	
PV capital costs (panels, racking, and installation) ($/kW$_{DC}$)	$3,000/kW$_{DC}$	
PV O&M costs ($/year/kW$_{DC}$)	$10/kW$_{DC}$/year	
Battery capital cost ($)	See notes	$50,000 fixed $700/kWh (marginal)
Battery replacement cost ($)	See note	75% of CAPEX
Battery lifetime (years)	See note	Based on usage
Converter capital cost ($)	$50,000	$50,000 fixed $875/kW (marginal)
Converter replacement cost ($)	See note	75% of CAPEX
Converter lifetime (years)	15	
Inflation rate (%)	1%	
Discount rate (real) (%)	3%	Sensitivity - high discount rate: 7%
Analysis period (years)	20	

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