Designing a Neighborhood Microgrid

Envisioning a Microgrid for the Parker Village Neighborhood in Highland Park, Michigan

Technical Appendix

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March 2022

Methodology

UCS used the Hybrid Optimization of Multiple Energy Resources (HOMER) Grid Version 1.8.6 (Pro Edition) to analyze solar and battery storage configurations for the Parker Village neighborhood. HOMER is an energy system optimization and financial analysis model designed to analyze distributed generations and microgrids at the customer and local levels. HOMER Grid models a power system's physical operations and its life-cycle cost, which is the total cost of installing and operating the system over its lifespan. HOMER enables users to compare many different system options based on their technical and economic benefits. The model has two optimization algorithms. The grid-search algorithm simulates all the feasible system configurations to search for the least-cost systems and displays a list of configurations sorted by net present cost; it then simulates hourly operation of each technology configuration (T. Lambert, Gilman, and Lilienthal 2006; HOMER Energy LLC 2020).

Assumptions Underlying the HOMER Analysis

FINANCIAL ASSUMPTIONS

Our financial analysis assumed that investments would be made in 2023 and the projects would have a 25-year lifetime. HOMER calculated the net present cost of each component in the system, and of the system as a whole, at a 7 percent nominal discount rate.

The Federal Solar Investment Tax Credit (ITC) is currently a 26 percent federal tax credit against the tax liability of residential and commercial investors in solar energy property. It is scheduled to ramp down to 22 percent in 2023 (Database of State Incentives for Renewables and Efficiency 2021). Battery systems that are charged by a renewable energy system more than 75 percent of the time are eligible for the ITC.

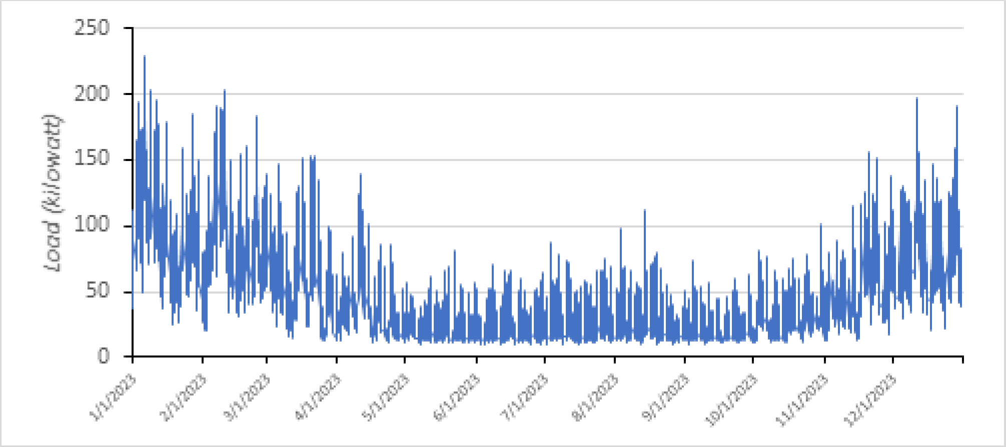
BUILDING STOCK AND ELECTRICITY DEMAND

The scale and the shape of a local electric load is an important determinant for (1) the size of microgrid system needed for the community, (2) the resources to be adopted to meet the load, and (3) the system operation on an hourly or sub-hourly basis. We estimated the neighborhood's potential electric demand based on the building stock and characteristics described in the Park Village comprehensive plan (Figure 1; Table 1). To figure out the typical load shape by each building type, we used the end-use load profiles for the US building stock data[1] collected, simulated, and released by the US Department of Energy (DOE) (NREL 2021a). Considering its building characteristics, location (climate), and possible appliance specifications, we selected a generic load sample for each building category (see Table 2) from the database. In the selection process, we assumed all the buildings in the neighborhood would be fully electrified and especially use electric heat pumps for their heating and cooling equipment. We then scaled up the load profiles by the number of buildings in each category (see Table 1). Finally, we assembled the electric loads and created a composite load profile of the entire community. The composite load profile was used for the load input to the distributed energy system modeling.

Figure 1. Parker Village Comprehensive Plan

Source : Paul Bierman-Lytle, Sustainable Environment Associates Corporation (SEAS).

Figure 2. Estimated Composite Load Profile of the Parker Village Community



Data Source : UCS estimation based on data from NREL and the Parker Village comprehensive plan.

Table 1. Building Stock of the Parker Village Community

Sector		Total Size (sq. ft.)	Per Unit Size (sq. ft.)	Number of Buildings	Number of Units
Residential	Single-Family Homes	TBD	TBD	18	N/A
	Four-Family Rehab	TBD (assumed 4,000)	TBD (assumed 1,000)	1	4
	Fourplex Residential	6,000	1,500	1	4
	Duplex Residential	4,000	2,000	1	2
Commercial	Building A	Total of A & B	Varies	1	8
	Building B	43,480	Varies	1	34
	Lynn Townsend Center (community gathering space)	TBD (assumed 25,000 from Google mapping tool)	N/A	1	1
	Aquaponics Garden (needs power) and Farmers Market (outdoor space)	N/A	N/A	0	0
	Hoop Greenhouses	1,440	720	2	
	Refit Shipping Container	320	N/A	1	1
	Trailer Café	400	N/A	1	1
No Structure	Fruit Orchard Structure	N/A	N/A	0	N/A

The electric load of the Aquaponics Garden and Farmers Market, Hoop Greenhouses, and the Fruit Orchard Structure were not included in the hourly demand estimation.

Table 2. Building Characteristics of the Sample Load Profiles Used for the Electric Load Estimation

Sector		Location (Climate Zone)	Building Type (sq. ft.)	Heating/ Cooling	Water Heater Fuel/ Efficiency	Cooking Range	Clothes Washer	Lighting	Freezer/ Refrigerator
Residential	Single-Family Homes	Detroit, MI (5A)	Single family, detached (1,500–2,499)	Heat pump	Electric premium	Electric	Standard	100% Incandescent	National average
	Four-Family Rehab	Detroit, MI (5A)	Single family, detached (3,000–3,999)	Heat pump	Electric standard	Electric	Energy Star	100% LED	National average
	Fourplex Residential	Detroit, MI (5A)	Multifamily, 2–4 units (0–1,499 per unit)	Heat pump	-	Electric	-	100% Incandescent	-
	Duplex Residential	Detroit, MI (5A)	Multifamily, 2–4 units (1,500–2,499 per unit)	Heat pump	Electric standard	Electric	-	100% Incandescent	-
Commercial	Building A	Detroit, MI (5A)	Small office building (26,250)	Electricity	Electricity	n/a	n/a	n/a	n/a
	Building B	Detroit, MI (5A)	Small office building (26,250)	Electricity	Electricity	n/a	n/a	n/a	n/a
	Lynn Townsend Center (community gathering space)	Detroit, MI (5A)	Small office building (17,500)	Electricity	Electricity	n/a	n/a	n/a	n/a
	Refit Shipping Container	Detroit, MI (5A)	Warehouse	Electricity	Electricity	n/a	n/a	n/a	n/a
	Trailer Café	Detroit, MI (5A)	Quick-service restaurant	No heating	Electricity	n/a	n/a	n/a	n/a

TECHNOLOGY COST AND PERFORMANCE

Tables 3, 4, 5, and 6 show the cost and performance assumptions for solar photovoltaics (PV), storage, and backup generator technologies used for our HOMER analysis.

Solar PV. The cost assumptions are based on NREL’s moderate scenario of the 2021 Annual Technology Baseline (NREL 2021b).

Table 3. Commercial Solar PV Cost in 2023

Solar PV	
Capital cost (2021$/kW)	1,593
Operations and maintenance (O&M) cost (2021$/kW-yr)	17

Storage. We used the cost and performance assumptions of commercially available battery storage (Tesla Powerpack 2.0). We used a 2020 price quote (F. Lambert 2020) and assumed that it would stay at the same level until 2023.

Table 4. Storage Cost and Performance in 2023

Storage	
Technology specification	Tesla Powerpack 2.0
Energy capacity (kWh)	210
Capital cost (2021$)	184,451
Lifetime (yrs)	10

Backup generators. For the capital cost and O&M cost of the backup generators, we used the default assumptions of generic backup generators built in the HOMER Grid model. For the fuel cost assumptions, we used the Annual Energy Outlook (AEO) 2021 reference case of the US Energy Information Administration (EIA). Specifically, we used the regional price forecast of the East North Central census division, where Detroit is located (EIA 2021).

Table 6. Gas Generator Cost and Performance in 2023

Natural Gas Generator	
Capital cost (2021$/kW)	1,700
O&M cost (2021$/operating hour per kW)	0.02
Fuel cost (2021$/m^3)	0.256

Outage assumptions. We assumed that (1) the total capacity shortage in the system would not be above 1 percent of the total annual electric load of the community and (2) the system could tolerate a capacity shortage of up to 20 hours per year.

MODELING RESULTS: RECOMMENDED SYSTEM CONFIGURATIONS

The HOMER modeling recommended a variety of microgrid system configurations. Table 7 shows the possible technology combinations.

Table 7. Recommended System Configurations

Scenario	**PV (MW)***	**Storage**		**Backup Option****				**Initial Investment Cost (2021 million $)**	**NPC*** (2021 million$)**
		Number of batteries (Tesla Powerpack)	Total storage capacity (MWh)	Fuel/grid connection	Capacity (kW)	Hours of operation per year	Capacity factor (%)		
PV + Storage + Diesel Backup	1.1	20	4.2	Diesel	100	312	3.49	4.35	7.87
	1.1	20	4.2	Diesel	150	216	2.39	4.39	7.91
	1.1	30	6.3	Diesel	50	396	4.32	5.75	10.8
	1.1	30	6.3	Diesel	100	209	2.28	5.80	10.8
	1.1	30	6.3	Diesel	150	138	1.53	5.84	10.9
	1.1	30	6.3	Diesel	200	107	1.18	5.88	10.9
	1.1	30	6.3	Diesel	300	72	0.79	5.94	11.0
PV + Storage + Natural Gas Backup	1.1	20	4.2	Natural gas	100	312	3.49	4.47	7.91
	1.1	20	4.2	Natural gas	150	216	2.39	4.57	7.99
	1.1	20	4.2	Natural gas	200	167	1.83	4.67	8.07
	1.1	20	4.2	Natural gas	250	136	1.48	4.77	8.14
	1.1	30	6.3	Natural gas	150	139	1.53	6.02	11.0
	1.1	30	6.3	Natural gas	200	107	1.17	6.12	11.1
	1.1	30	6.3	Natural gas	300	72	0.79	6.30	11.2
					% of Grid Purchases****				
PV + Storage + Grid Backup	1.1	5	1.1	Grid connection	5.50			2.13	3.35
	1.1	10	2.1	Grid connection	3.38			2.85	4.80
	1.1	20	4.2	Grid connection	1.90			4.28	7.76
	1.1	30	6.3	Grid connection	1.08			5.72	10.7

** Considering the total available land and roof size of the neighborhood, we limited the PV size to 1.1 MW.*
*** Grid-separated systems normally require backup generators for their resilience and reliability. The backup generators are recommended for use during the winter peak, only when the solar PV and storage cannot meet the power demand of the community.*
**** Net present cost (NPC) of each microgrid system option. The transmission costs to distribute the power to each individual building in the community were not included in the NPC calculation.*
***** The portion of the power supply (kWh) covered by the grid connection to the total power supply. In the grid backup scenario, we assumed the primary grid would be able to supply the backup power to the microgrid under the DTE Electric Company's R3 (standby, secondary) tariff. It is usually a required service for customers operating onsite generation facilities to serve some portion, or all, of their load. This standby tariff serves the power supply requirements that are normally served by the customer's onsite generators (DTE, n.d.a, n.d.b).*

ENDNOTES

1. National Renewable Energy Laboratory (NREL), Lawrence Berkeley National Laboratory (LBNL), and Argonne National Laboratory have developed and released a database of end-use load profiles representing all major end-uses, building types, and climate zones in the US commercial and residential building stock. The detailed data collection and simulation methodologies can be found online (NREL 2021a). The simulated sample load profiles in the database are presented in 15-minute intervals. The load database has been publicly accessible since October 2021.

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