Solar Microgrid Feasibility for the City of Ann Arbor

Will Arnuk[1], Krysten Dorfman[1], Emma Forbes[1], Ahana Shanbhogue[2], Nick Soberal[3], Adam Simon[1], Susan Fancy[3]

1: College of LSA - Department of Earth and Environmental Sciences **2**: College of Engineering - Department of Civil and Environmental Engineering **3**: University of Michigan Energy Institute

Introduction

Given the task from the City of Ann Arbor of assessing the feasibility of solar-powered microgrids, this study began by selecting ideal city-owned sites, evaluating generation and storage capabilities, followed by calculating respective CO_2 emissions. With these findings, recommendations are made for solar panel and battery sizing in order to produce a resilient, carbon-reducing arrangement of microgrids within the City.

What is a Microgrid?

- A microgrid is a group of nearby interconnected energy resources with clearly defined electrical boundaries. It can connect and disconnect from the grid, operating as grid-connected or in island mode. Although able to draw from diverse energy sources, this study focused exclusively on solar-powered microgrids due to limited land availability and overall simplicity.

What are the City's goals?

- Under the Climate Action Plan, the City of Ann Arbor aims for a 25% reduction in greenhouse gas emissions by 2025. In addition to cutting emissions, another main goal of the City's Energy Office is to self-generate therefore increasing resiliency for key assets in the event of power loss.

Site Selection

Only public, city owned sites within city limits were considered for the implementation of solar panels not including City Park green space. Sites were chosen for investigation after filtering through properties owned by the city and discussing with the city council which areas were ideal for development. Of 145 sites considered, 33 sites were chosen for investigation.

Energy Production

In order to obtain potential solar energy production, a solar ratio must be multiplied by the given area of a site. The solar ratios were calculated in kWh/m^2/year using NREL's **PVWatts**. PVWatts utilizes peak solar radiation, solar panel efficiency, system losses and panel orientation in its calculation. According to NREL's TMY3 weather file, as well as relevant load data, peak solar net production occurs on **March 28th,** when load is relatively low compared to solar radiation intensity.

In order to obtain the land area for each site, individual shapefiles were created in ArcGIS and then imported into **GeoPlanner for ArcGIS** where polygons represent the area for a particular site in m^2. The land area for each site was reduced by 20% in order to account for the land loss due to operations and maintenance. Solar energy generation was estimated in GeoPlanner by selecting individual sites and converting them from their original land use to land used to produce solar energy (Figure 2).

Table 1: Only 23 sites with load data available are presented in this table. Solar energy is calculated using PVWatts with standard solar panels, with assumed 14% panel efficiency. Cost is based off of Lazard's Levelized Cost of Energy (LCOE), using the unsubsidised costs for energy for solar energy, not including battery storage. * indicates that annual solar energy production exceeds the annual load for that site.

Site Name	Solar Energy (MWh/yr)	Cost ($)	Site Name	Solar Energy (MWh/yr)	Cost ($)
Fire Station 1	199	21192	Buhr Park Bath House	180	19129
*Fire Station 2	42	4479	Gallup Park Canoe Livery	21	2282
*Fire Station 3	70	7521	*Mack Swimming Pool	298	31724
*Fire Station 4	61	6461	*Burns Senior Center	61	6464
*Fire Station 6	132	14012	*Cobblestone Visitor Center	30	3185
*William Parking	570	60663	*Farmer's Market	232	24757
*First/Huron Parking	995	105958	Northside Community Center	18	1954
*Ann/Ashley Parking	605	64399	Veteran's Bath house	255	27173
*Maynard Parking	849	90415	*Airport Administration Building	366	38994
*Liberty Parking	450	47906	*Ann Arbor Municipal Building	788	83918
Forest Parking	557	59370	*Wheeler Center	1351	143976
*Swift Run Landfill	24068	2563270			

Carbon Dioxide Emissions: Solar vs. Utility Fuel Mix

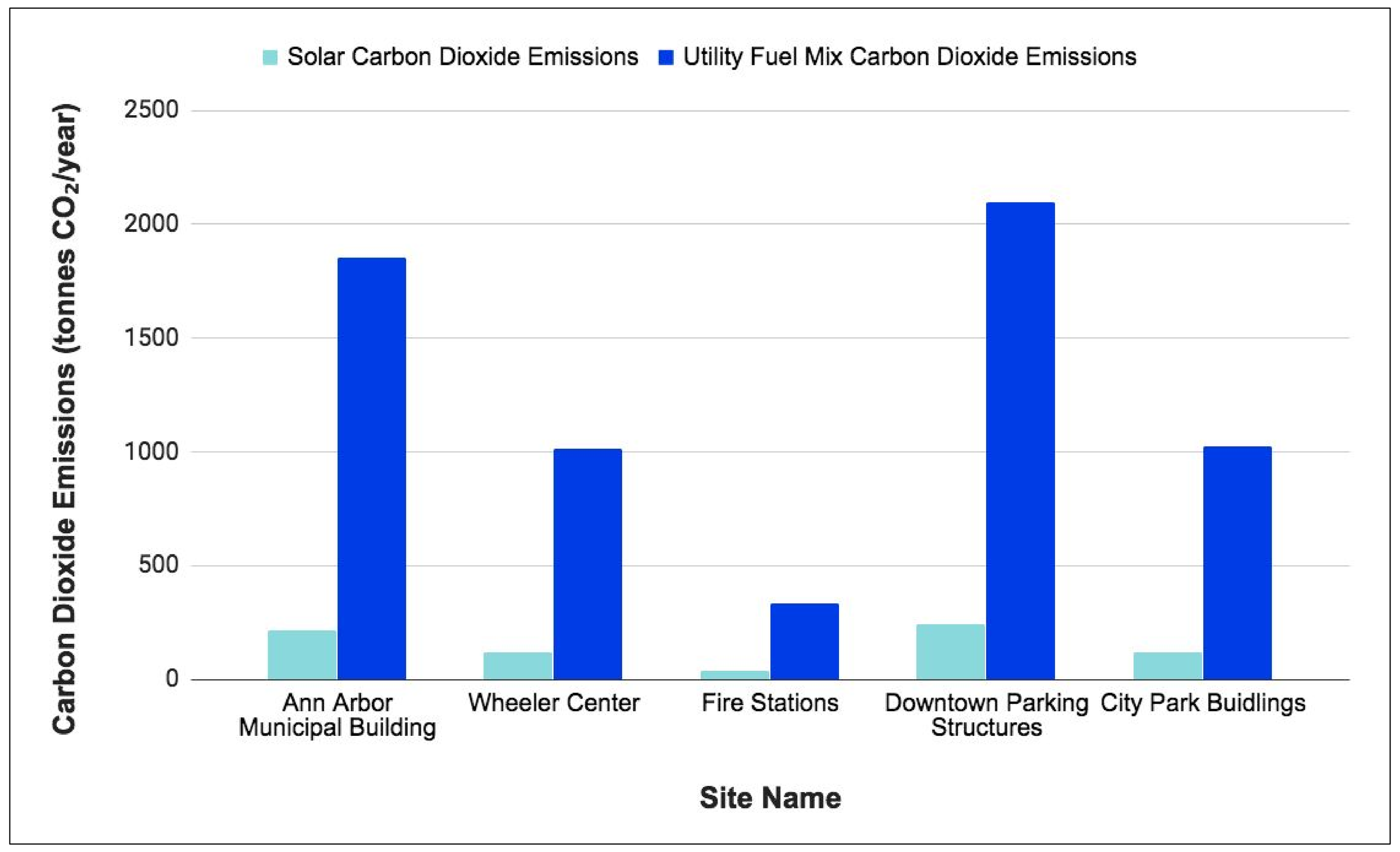

Figure 1. CO_2 values were calculated based on emission estimates provided by NREL. The utility provider is DTE, with their current fuel mix consisting of 69% coal, 18% nuclear, 4% natural gas, and 9% renewable energy sources. 22 of the sites investigated are presented in this figure.

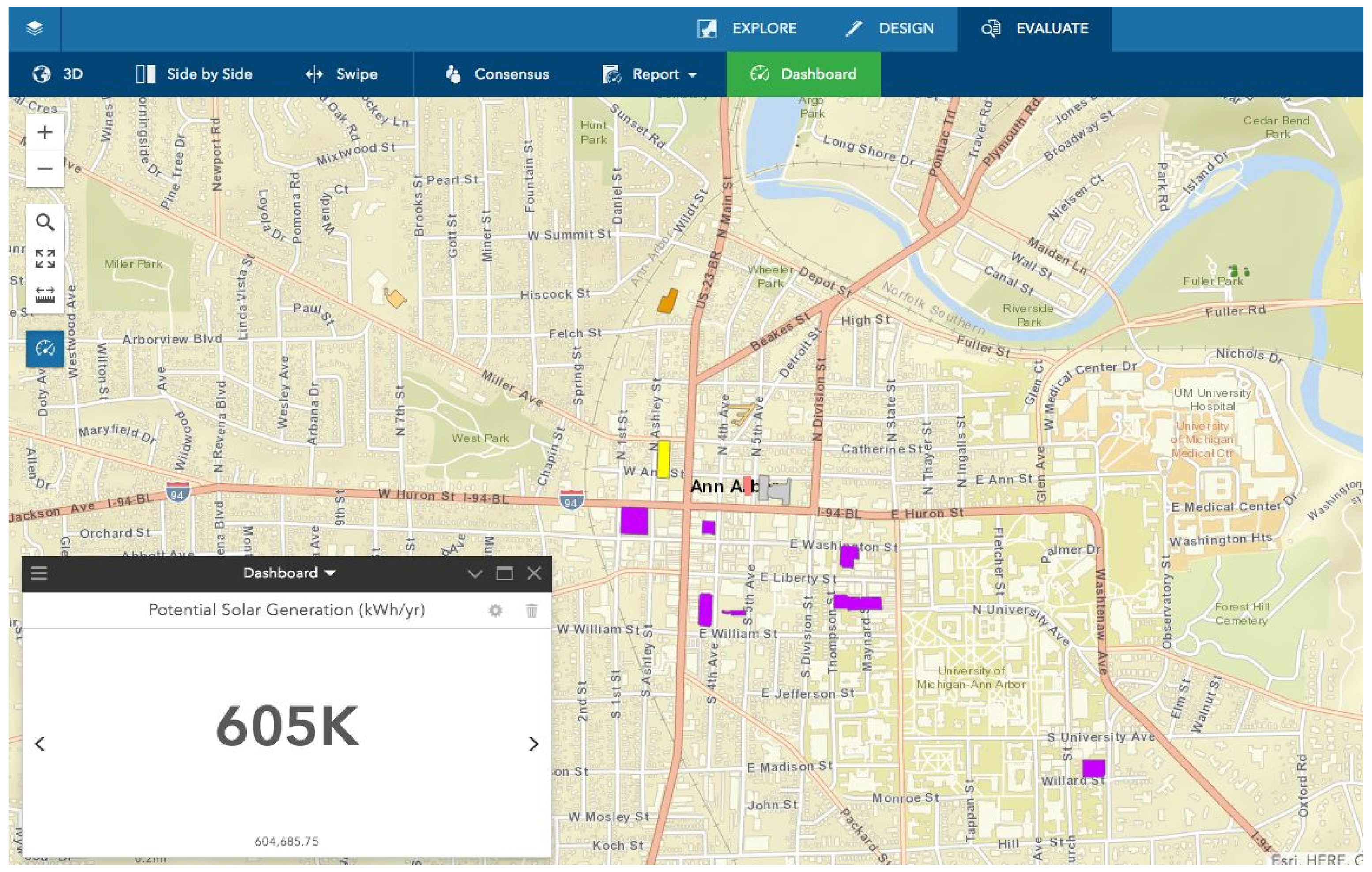

Figure 2. GeoPlanner for ArcGIS Scenario, converting Ann/Ashley Parking to solar

SAM Time Series Energy to Load Distribution (kW)

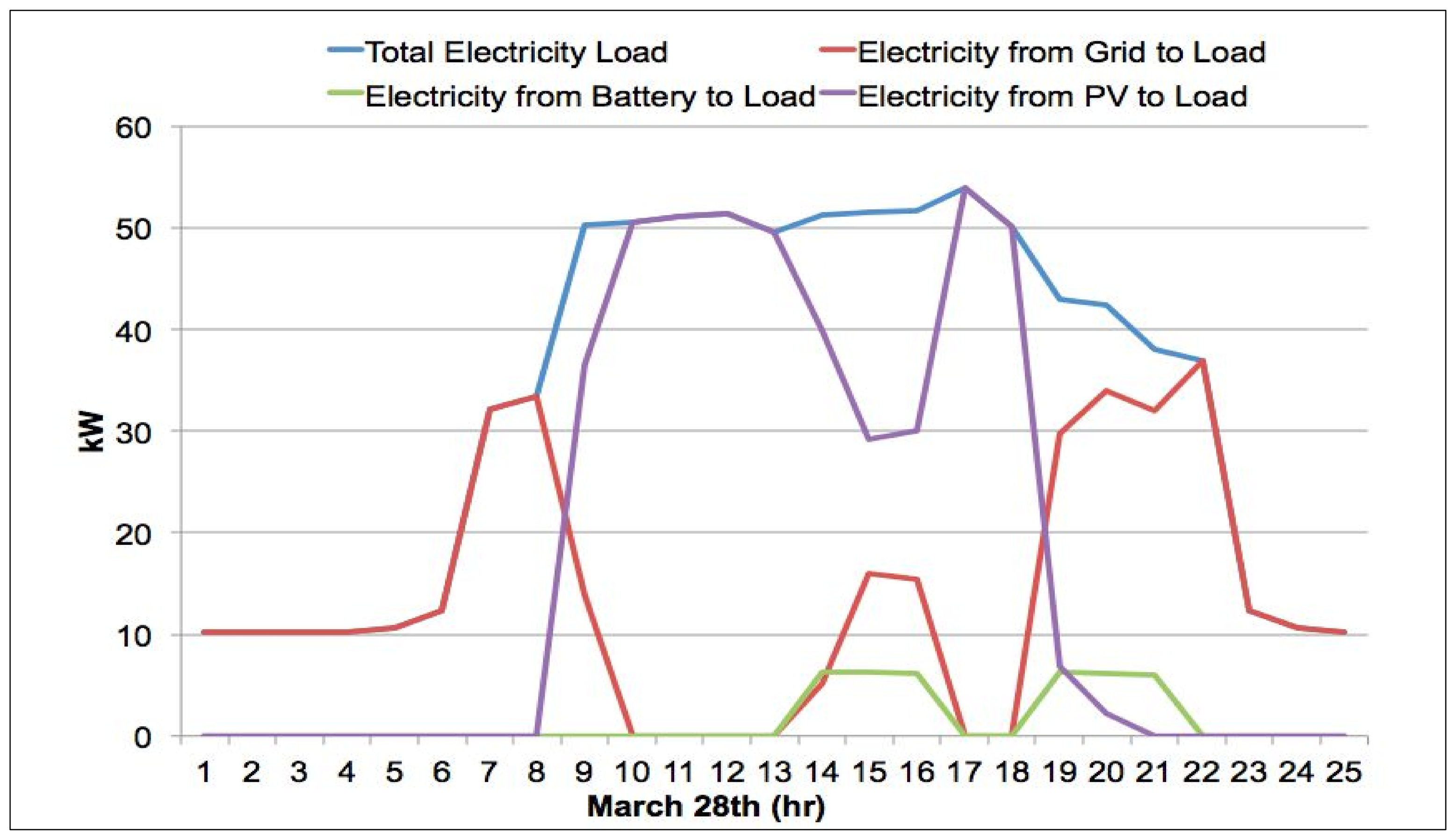

Figure 3. The total electricity load for the Mack Pool on March 28th is met by a combination of energy outputs from the PV, battery (sized to a 6 hour peak) and the remaining pulled from the grid. The PV met approximately 54% of the total load, the battery 4.5% and the grid 41.5%.

Carbon Dioxide Emissions

In order to determine the carbon footprint of a solar microgrid, a Life Cycle Assessment (LCA) was completed, accounting for greenhouse gas emissions throughout the lifetime of an energy source (Figure 1). NREL has determined the greenhouse gases emissions for a variety of energy sources in gCO_2/kWh based on LCA. Fossil fuels have high values, e.g. coal emits 870 gCO_2/kWh, while renewable energy sources have relatively small values, e.g. solar emits 72g CO_2/kWh.

Battery Storage

A battery component was desired to achieve the City of Ann Arbor's goal of resiliency, providing a backup six hours of power to subsidize low PV energy generation. The team used **NREL's SAM (System Advisor Model)** to size the respective battery capacities for the chosen sites. SAM is an extensive model with core inputs being the module and inverter types, needed panel array size and monthly load data.

To model battery storage, battery type was specified as well as the manual dispatch distribution, defining the time periods that the battery would charge and discharge. Both Lead Acid and Lithium Ion battery types were modelled due to the advantages each possess. Lead Acid is low maintenance and durable while Lithium Ion is much lighter and has an overall longer life cycle with faster charging and discharging capabilities.

Given the monthly load data for the selected buildings, the six hour peak was calculated by breaking down the peak month into hourly data. SAM was then modelled by varying battery capacities until the displayed energy output from the battery to the load met and/or exceeded the calculated six hour peak. This method was repeated for both battery types. The overall distribution of energy sources is shown in Figure 3.

Results

Solar Energy Production

- Energy produced by solar would provide 79% of the total energy needed.
- Energy produced by solar exceeded annual load for 16 of the sites studied.

Battery Sizing

- The calculated battery sizes necessary for the chosen sites range from 10 kWh to 220 kWh for buildings with higher loads.
- Lead Acid batteries consistently needed a larger capacity than Lithium Ion to meet the desired output.

Reduced Carbon Emissions

- For the sites studied, switching to solar would reduce carbon dioxide emissions by 88%, far exceeding the City's goals outlined in the Climate Action Plan.

Cost

- Costs based on the LCOE for solar energy (Table 1) are comparable to the average cost for coal and natural gas.

Recommendations

Energy Production

- For sites where energy production does not exceed load, we recommend implementing peak shaving and demand response techniques in order to cut costs and carbon dioxide emissions.
- We recommend that the city work with Ann Arbor Public Schools to investigate potential solar installation, as the schools have a significant land footprint.

Cost and Policy

- There are significant costs associated with **private** distribution lines. Average total transmission, distribution and administration, cost per customer during the years 1994–2014 was found to be approximately $727/year in real 2015 dollars.
- Due to legal and regulatory concerns, it is recommended that the City work with the existing utility, DTE, to add renewable generation capacity, while remaining grid-connected.

Further Study

- We recommend an in depth economic study regarding the cost of solar implementation. In current economic forecasts, the price of solar energy will become increasingly more affordable, making the solar microgrid even more feasible.

References

The City of Ann Arbor (2012). *City of Ann Arbor Climate Action Plan* (Updated 2015).
Lazard (2016). *Levelized Cost of Electricity Version 10.0*
DTE Energy (July 2016). *Customer Connections*
NSRDB (2015). 1991-2005: *Typical Meteorological Year 3*
National Renewable Energy Laboratory (2015). *SAM Photovoltaic Model Technical Reference.*
University of Texas at Austin (2016). *Trends in Transmission, Distribution,and Administration Costs for U.S. Investor Owned Electric Utilities*, 30

M UROP

ENERGY INSTITUTE
UNIVERSITY OF MICHIGAN