Solar Microgrid Feasibility Study
City of Ann Arbor

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Introduction

• City primary objectives:
  • Resiliency of power supply to critical City infrastructure
  • Reduction of GHG emissions
    • 25% city-wide by 2025 = 568,000 Metric tonnes CO$_2$e/yr

• Today's presentation:
  • Potential sites for microgrids and renewable energy generation
  • Explanation of assumptions and methodology
  • Assessment of production, emissions, cost
  • Significant opportunities for renewable energy
  • Policy concerns
  • Final recommendations and ongoing work
Solar Site Selection

• Total City-owned Sites: 212
• Sites selected for further consideration: 60
• Sites selected for microgrids (solar + battery) for resiliency:
  • Fire Stations 1, 2, 3, 4
• Sites with significant solar potential:
  • Maynard Parking Structure
  • Landfill
  • Ann Arbor Public Schools
• Sites not included:
  • City Hall/Ann Arbor Police Department
  • Water Treatment Plant
Generation Technologies and Sites Not Evaluated

- Solar: Sites not selected for detailed study
  - City Hall/Ann Arbor Police Department – Low solar generation
  - Water Treatment Plant – High solar generation, but load data not available

- Other generation technologies not evaluated in detail:
  - Hydroelectric on two unpowered dams – no City assets nearby
  - Expanded hydroelectric at two powered dams
  - Wind
  - Geothermal
  - Biomass
  - Methane at Wastewater Treatment Plant – given recent renovations, assume this was addressed if viable
Important Takeaways

• Microgrids for Fire Stations
  • Opportunities to provide resiliency
  • Small emissions reductions

• Solar PV for Landfill and Schools
  • Large surface area for solar arrays provides significant opportunities to reduce city-wide emissions and meet climate goals
Methods

• ArcGIS for site assessment
  • Building area footprints from City of Ann Arbor Data Catalog

• NREL PVWatts model for solar PV production ratios
  • TMY3 weather data for Ann Arbor
  • Validated with production data from operating solar projects in southeast Michigan

• NREL System Advisory Model (SAM) for battery storage

• NREL Life Cycle Analysis (LCA) values to estimate total life-cycle emissions reductions
Assumptions

- **Solar Arrays**
  - 34° tilt, south-facing
  - Standard (15%) efficiency
  - Fixed Rooftop – buildings
    - 177 kWh/m²/yr
  - Fixed Open Rack – parking lots/structures, open space
    - 179 kWh/m²/yr

- **Solar Array O&M Coverage**
  - 50% Landfill & Parking
  - 62.5% Rooftop (NREL 2016) actors

- **SAM**
  - System sized for storage & resiliency cases, 6hr peak load
  - Li-ion battery

- **System Cost**
  - $1.75/Watt installed

- **Battery Cost**
  - $600/kWh installed (Bloomberg)

- **Emissions**
  - DTE 2016 Fuel Mix
  - NREL 2013 Emission Factors
### Results: Fire Stations 2, 3, 4

<table>
<thead>
<tr>
<th>Site</th>
<th>Load (MWh/yr)</th>
<th>Solar Generation (MWh/yr)</th>
<th>Avoided Electricity Cost ($/yr)</th>
<th>PV Cost ($)</th>
<th>Payback Period (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>22.2</td>
<td>39.4</td>
<td>5,910</td>
<td>58,400</td>
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<tr>
<td>4</td>
<td>40.0</td>
<td>56.8</td>
<td>8,520</td>
<td>84,300</td>
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</tbody>
</table>

- General payback for rooftop solar PV systems: 10 years
Results: Fire Stations 2, 3, 4

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<tr>
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<th>Load (MWh/yr)</th>
<th>Solar Generation (MWh/yr)</th>
<th>Avoided Electricity Cost ($/yr)</th>
<th>PV Cost ($)</th>
<th>Battery Size (kWh)</th>
<th>Total Cost ($)</th>
<th>Payback Period (yrs)</th>
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</thead>
<tbody>
<tr>
<td>2</td>
<td>22.2</td>
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<td>3</td>
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<td>84,300</td>
<td>38.5</td>
<td>107,000</td>
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</tr>
</tbody>
</table>

- General payback for systems with batteries: 13 years
- Sized for 6 hour storage
- Total LCA emissions reductions: 81.4 tonnes CO$_2$e/year
Battery Operating Scenarios

• Emergency Discharge vs. Load Leveling
  • Financially equal if purchase/sale price are equal
  • Ability to load level – benefit if purchase/sell prices diverge
    • Shorter payback period
# Results: Fire Station 1

<table>
<thead>
<tr>
<th>Site</th>
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<th>Solar Generation (MWh/yr)</th>
<th>Avoided Electricity Cost ($/yr)</th>
<th>PV Cost ($)</th>
<th>Payback Period (yrs)</th>
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</thead>
<tbody>
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<td>1</td>
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<td>186</td>
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</table>

- High load – large battery required
  - **Battery Size:** 628 kWh
  - **Total Cost (Battery Cost):** $653,000 ($377,000)
  - **Payback Period:** 23 years

- LCA emissions reduction: 93.4 tonnes CO$_2$e/year
Locations evaluated for solar potential only; i.e., no battery
• Maynard Parking Structure
• Landfill
• Ann Arbor Public Schools
### Results: Maynard Parking Structure

<table>
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<tr>
<th>Site</th>
<th>Solar Generation (MWh/yr)</th>
<th>LCA CO$_2$e Reductions (tonnes/yr)</th>
<th>Avoided Electricity Cost ($/yr)</th>
<th>PV Cost ($)</th>
<th>Payback Period (yrs)</th>
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</thead>
<tbody>
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<td>Maynard</td>
<td>497</td>
<td>249</td>
<td>74,500</td>
<td>737,000</td>
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</tbody>
</table>

- Does not reduce parking capacity
### Results: Landfill

<table>
<thead>
<tr>
<th>Site</th>
<th>Solar Generation (MWh/yr)</th>
<th>LCA CO$_2$e Reductions (tonnes/yr)</th>
<th>Avoided Electricity Cost ($/yr)</th>
<th>PV Cost ($)</th>
<th>Payback Period (yrs)</th>
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</thead>
<tbody>
<tr>
<td>Landfill</td>
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<td>20,300</td>
<td>6,080,000</td>
<td>59,500,000</td>
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</tbody>
</table>

- Land footprint: 120 acres
  - Solar array area: 56 acres

- Can generate 90% of annual electricity consumption for city-owned properties with solar PV

- Potential for a pilot community solar program

- Partnership with University of Michigan
### Results: Ann Arbor Public Schools

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<th>PV Cost ($)</th>
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<tr>
<td>Pioneer</td>
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<tr>
<td>Skyline</td>
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<td>1,980</td>
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<tr>
<td>Clague</td>
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<td>624</td>
<td>187,000</td>
<td>1,840,000</td>
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</tr>
</tbody>
</table>

• All Ann Arbor Public Schools (32 total):
  - **Total rooftop potential**: 22,800 MWh/year
  - **Total parking lot potential**: 12,400 MWh/year
  - **Total LCA emissions reductions**: 17,600 tonnes CO₂e/year
Significant Opportunities

- Solar plus storage for resiliency of some city-owned sites
- On-site natural gas generator at any site as an additional non-spinning reserve (for backup power and load leveling)
- Large-scale solar to grid for parking structures and landfill
  - Landfill represents opportunity for large-scale solar farm
  - Pilot Community Solar projects can be possible with further negotiation
    - Power Purchase Agreements have enabled landfill solar farms in other states
      - Examples: Rochester, NY; Brooklyn, OH
- School partnerships for community solar or microgrid sites
Policy Issues

• Generic barriers to microgrids and solar PV include:
  • Local zoning laws
  • Lack of tax incentives
  • Lack of solar access laws/easements

• Michigan/Local barriers
  • Vague or restrictive zoning laws, tax status can limit investment in PV and microgrids
  • Regulatory changes may be seen within the next year
  • No state laws directly enabling community solar

• Conclusion: behind-the-meter or utility-connected?
Conclusions

- Properties analyzed could meet the city’s 2015 renewable energy goals, but not CAP carbon reduction goals
- Resiliency for Fire Stations 1, 2, 3, and 4 is possible
  - Could be combined with solar and/or wind
  - Larger microgrid with other downtown city-owned properties
- Public Schools have potential for community solar and microgrids
- Landfill is a potential site for community solar or possible partnership with U of M in cooperation with local utility
Final Recommendations for City Action

• Explore investment options for large-scale solar farms
  • Potential partnerships between Public Schools, City, and U of M
  • Enable public participation via community solar
  • Explore financing using Power Purchase Agreement

• Assess local zoning laws that may affect microgrid (electric and heat) installations, especially on new construction

• Partner with community and utility to finance microgrids for student rental properties throughout city?
Future Work

• Close the gap between CAP carbon emissions goals and identify low-emissions energy potential – more study needed:
  • Renewable generation sources in addition to solar PV
  • Resiliency for Wheeler Center and Water Treatment Plant
  • Conversion of diesel generators to natural gas (decreases CO$_2$e)
  • Core downtown microgrid of city-owned assets

• Working with AAPS to conduct a detailed assessment of school properties, including a robust project template for use in future assessments (U of M Fall 2017, Simon and Arnuk)
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• Josh Macdonald, City of Ann Arbor
• Department of Earth and Environmental Sciences
References


• (NREL 2013) LCA Harmonization Project – https://www.nrel.gov/analysis/sustain_lca_results.html

