1. Introduction

Solar power is the use of the sun's energy and photovoltaic cells to generate electricity. This process provides electricity without emitting harmful greenhouse gases, and is economically efficient as the photovoltaic cells are a one-time purchase for upwards of 30 years of free electricity. The Clean Wolverines believe that the use of solar photovoltaic cells on campus is an approach to the University of Michigan's (U-M) sustainability goal of reducing greenhouse gas emissions by 25% from 2006 levels by 2025 and help reach their eventual goal of carbon neutrality. The Clean Wolverines have proposed a scenario in which solar energy on roof-top carports could mitigate 90% of campus greenhouse gas emissions and help reach its ultimate goal of carbon neutrality. The Clean Wolverines have modeled how the use of solar arrays on U-M's campus is the most cost effective and worthwhile way to incorporate solar energy into U-M's energy mix.

2. Methods & Approaches

1. GIS spatial analysis on ArcMap - Mapped the area (in square meters) of 62 buildings, parking lot, and parking spaces on the University of Michigan campus (See detailed description below in section 3).

2. Excel data compilation of results from ArcMap to calculate DC system size, solar output per year, current carbon-dioxide emissions mitigated by solar energy (conservative and optimal), various all-in upfront costs of solar arrays:
   a. DC System Size (kW) - calculated using PV-Watts calculator through NREL
   b. Current CO2 Emissions (kW/yr)
   c. Mitigated: 5,360 MTCO2/yr

3. GIS Study

GIS (Geographic Information System Mapping Technology) is a computer software and web application by Esri that allows you to gather and analyze data on the rooftop or ground area of a building, parking structure or parking lot.

The bulk of the data collection was done using ArcGIS, a GIS software by Esri. We collected the data by drawing 62 polygons that represented rooftops or land space on the University of Michigan's south, central, medical and north campuses. Polygons are spatial drawings of vector data in a single plane that represent the usable area (in square meters) of a space on a map of Ann Arbor and U-M's campus. They were drawn on the south-facing rooftops while avoiding any obvious rooftop obstacles such as HVAC systems or uneven ground. They were also drawn on parking lots and parking structures. From the usable area (in square meters) measurements acquired from ArcGIS, analyses were performed to determine the usable square meterage of the space, solar output if each space was converted to solar arrays, the DC system size, total installed system capital costs and the quantity of greenhouse gases mitigated.

3.1. Results

The 62 polygons shown here represent all the U-M buildings, parking structures and parking lots that we chose to include in our GIS analysis. This scenario is not feasible because it is not economical to put solar on all buildings and parking lots. These results can be used as a thought experiment to show what could happen on U-M's campus if all 62 structures had solar panels installed.

5. Solar Carports

For the top 5 parking lots with the highest potential for producing solar energy, solar carports present an opportunity to incorporate more renewable energy while also mitigating greenhouse gas emissions at the University of Michigan. The carports would increase the university's renewable energy consumption while also mitigating greenhouse gas emissions. To cite industry specialists, the all-in upfront cost for solar carports is approximately $2.25 per watt capacity to $2.50 per watt capacity. These costs reflect construction and cost of the silicon crystalline panels, but do not reflect operation and maintenance costs.

5.1. Benefits of Solar Carports

1. Space saving solution in urban city pressed for space
2. Solar carports will not decrease the number of parking spaces in any of the lots
3. Panels provide covered coverage for vehicles from inclement weather such as rain, and snow.
4. Panels provide covered coverage for the parking lot itself from inclement weather thus decreasing maintenance costs over time.
5. Electric vehicles could plug in directly at parking lots and access truly renewable energy on site.
6. Act as a visual representation of the university's efforts to implement renewable energy on campus.

5.2. Challenges for Ground-Level Solar Panels

1. Additional costs associated with leveling the ground and deforestation
2. Land used for ground-level panels takes away land that could be used for other university development.
3. Visibility by the Ann Arbor community is not guaranteed for panels that are on ground-level.
4. The 6 polygons analyzed represent all the parking lots and structures on U-M's campus that we chose to include in our GIS analysis. The current greenhouse gas emissions from these structures are minimal and placing solar on all parking lots and structures would mitigate almost 3 times the greenhouse gas emissions currently produced by these parking lots and structures.

7. University Recommendations

Through our GIS exploration of solar potential for U-M's buildings, parking structures and parking lots, we found that the optimal and most feasible course of action for U-M regarding on-campus photovoltaic installation is to install solar carports on five of U-M's largest parking lots. We conclude that the five largest lots are North Campus 51, South Campus 4 and 5, Medical Campus 73, South Campus 7, and North Campus 37, in order largest to smallest.

Placing solar carports on top of the five largest parking lots with the greatest solar potential would enhance the university's renewable energy portfolio, and provide additional protection from Michigan weather for cars and vehicles that park in the lots, without compromising the number of parking spaces. This investment would lead to the installation of 11 acres of solar glass on U-M's Ann Arbor campuses, thus demonstrating to students, alumni and the Ann Arbor community that U-M is committed to its sustainability goals, supportive of renewable energy technologies, and looking towards the future.

8. Conclusions

Implementing solar energy at the University of Michigan is feasible and it is economically efficient to construct solar carports on top of large parking lots owned by the university. The Clean Wolverines used GIS technology to map areas to place solar panels, and have found high demand on campus parking lots on the North, Medical and South campuses. Including solar panels at these areas will help the University of Michigan strive to meet the 2020 sustainability goal of 25% reduction in greenhouse gas emissions and the eventual future goal of university carbon neutrality.

Acknowledgements: We thank the University of Michigan Earth and Environmental Science Department, the University of Michigan Energy Institute, Mark Lindquist, Elena Essa, Susan Fancy, Nick Sobalier, Peter Knoop, Mark Lindquist, Andy Berti, Andrew Hinson, Ken Keeler, Steve Miki and the rest of the Clean Wolverines for providing support and feedback on this research.

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3. "University of Michigan Long-Term Sustainability Goals and Objectives".