

Assessment of Rooftop Space for PV Panels at SCU

Introduction

We chose this project for the purpose of discovering where the most solar energy can be harvested on campus, as Santa Clara University seeks to reach one megawatt of solar energy in the future. We researched the viability of several buildings scattered throughout campus to see not only if we could reach 1 MW, but also how we could most efficiently harvest the energy.

Initial consultations were conducted with the Head University Architect, Don Akerland, and the Assistant Vice President of University Operations, Joe Sugg. They guided our focus on the three most viable buildings, where we eventually chose the Leavey Event Center, the Malley Fitness Center, and the Facilities building.

We began the research by calculating the number of solar panels that would fit on each roof, taking into account obstacles including piping and parapets. Many other variables also needed to be taken into account. We calculated the amount of energy yield from the solar panels at four different degrees: 0° (flat), latitude -15°, latitude, and latitude +15°. The latitude of Santa Clara, CA is 37.35°. We also considered shade, not only from the slanted solar panels, but also from the parapets and other roof obstacles. Finally, we also considered aesthetics. While solar panels facing direct south receive the most direct sunlight and thus produce the most energy, the buildings we selected did not face direct south. We therefore sought to solve the dilemma of installing solar panels to look more aesthetically pleasing and with more ease of installation and maintenance, or to install them where they can produce the highest possible potential energy.

In researching the many variables, we attempted to produce the most plausible plan for SCU to reach their goal.

Methods

1. Researching previous accomplishments on and near campus. National Semiconductor has been using Santa Clara University as a test location for a new product called SolarMagic™ that would isolate inefficiencies in PV panels. The facilities building, which serves as SolarMagic™'s test site, already supports 50,000 watts of solar power. SCU installed water-heating panels on top of Walsh Hall and McLaughlin Hall in the 1980's, however, they have been out of commission for nearly a decade.
2. Establishing buildings on campus that receive a significant source of solar radiation. We deemed the Leavey Event Center, Malley Fitness Center, and the Facilities building the most feasible sites for extensive solar power infrastructures. Walsh Hall, McLaughlin Hall, Lucas Hall, the Learning Commons, and Benson Memorial Center all remain reasonable candidates for PV panels, but they may present architectural problems.
3. Mapping and surveying the potential sites for maximum load of PV panels. We

contacted Don Akerland, Head Architect of SCU, to provide us with building plans in order to measure the roofs and locate any obstacles (air-conditioning units, heater vents, flag poles, etc.).

4. Providing data considering multiple situations. We used simple trigonometry to determine the maximum number of panels at specified tilt angles while allowing now shading. To accomplish this more efficiently, we developed a Microsoft Excel program to calculate this data from any desired set of inputs.

A bird's eye view of campus shows the various buildings considered. Marked in red and clockwise from top left are Malley, Leavey, and Facilities.



(Above) Joe Sugg surveys the existing solar panels on the roof of the Facilities building. Photo courtesy of Charles Berry, University Photographer.

Results

Leavey Event Center (94.183L x 49.98W)					
Tilt	# of Panels Long	# of Panels Wide	Total # of Panels	Theoretical Power Output (kW)	Theoretical Energy Produced (kWh)
Flat	60	47	2820	888.3	4397.08
Latitude -15° (22.35°)	60	29	1740	548.1	3014.55
Latitude (37.35°)	60	25	1500	472.5	2622.38
Latitude +15° (52.35°)	60	23	1380	434.7	2282.17

Facilities Building (25.399L x 26.417W)					
Tilt	# of Panels Long	# of Panels Wide	Total # of Panels	Theoretical Power Output (kW)	Theoretical Energy Produced (kWh)
Flat	16	25	400	126	623.7
Latitude -15° (22.35°)	16	15	240	75.6	415.8
Latitude (37.35°)	16	13	208	65.52	363.6
Latitude +15° (52.35°)	16	12	192	60.48	317.5

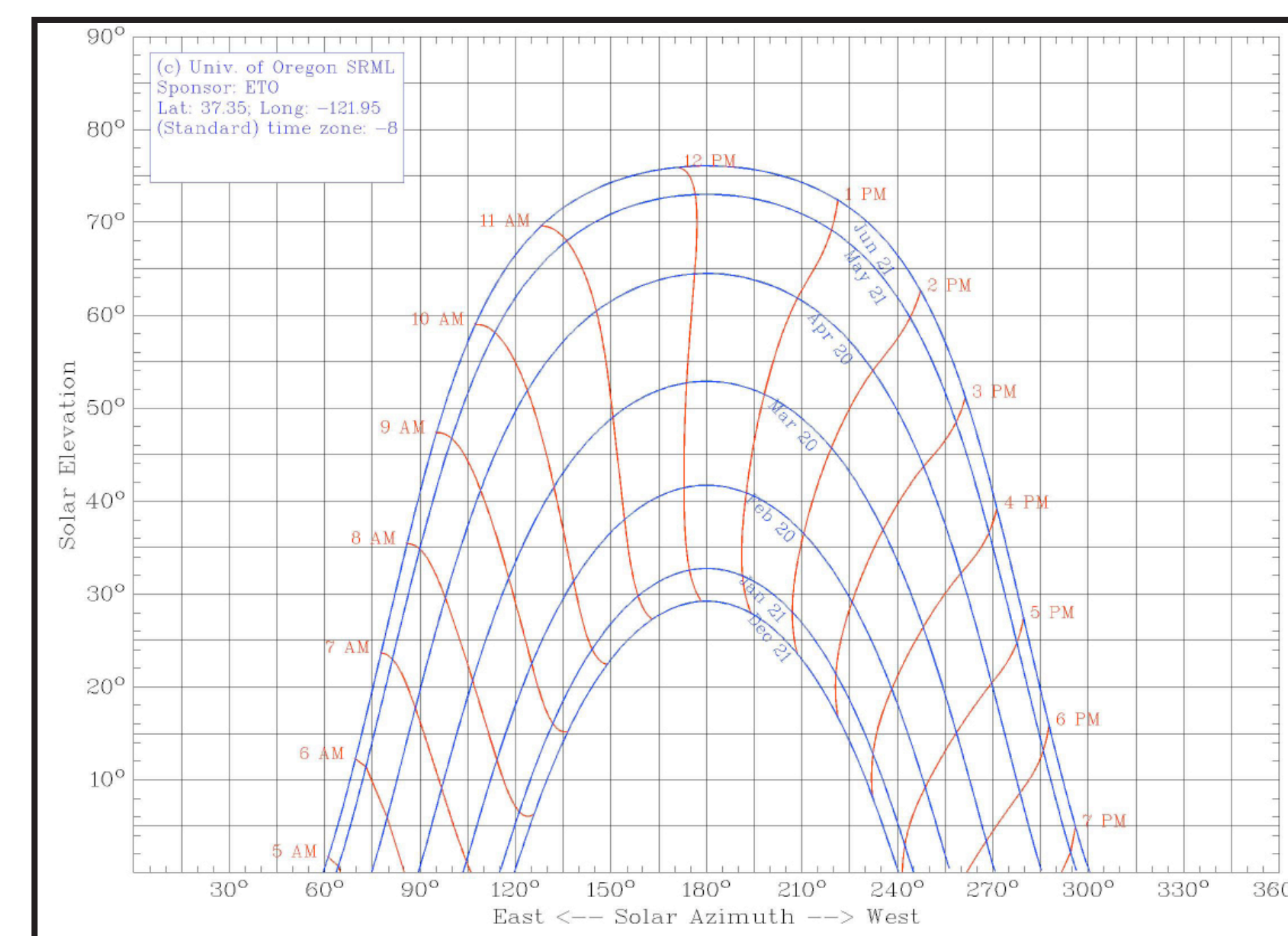
Malley Fitness Center (42.9L x 18.117W)					
Tilt	# of Panels Long	# of Panels Wide	Total # of Panels	Theoretical Power Output (kW)	Theoretical Energy Produced (kWh)
Flat	27	17	459	144.585	715.69
Latitude -15° (22.35°)	27	10	270	85.05	467.77
Latitude (37.35°)	27	9	243	76.545	424.82
Latitude +15° (52.35°)	27	8	216	68.04	357.21

The Winners: The final results yielded the three best buildings on campus for a solar setup: the Facilities Building, Leavey Event Center, and the Malley Fitness and Recreation Center. All of these buildings had large amounts of flat roof space and were tall enough that they would have little shade from other buildings. Visibility of solar panels would also be minimal from ground level which would help maintain the aesthetics of campus. The Facilities Building already contains solar panels, so adding more makes sense.

Alternative Locations: While many roof panels of the library were slanted to incorporate solar panels, the library is not the best choice for several reasons. First, the copper material of the roof does not allow for drilling holes, so mounting the panels without damaging the roof would be difficult. Second, the shade created from different parts of the roof would also lower the solar output tremendously. Finally, the panels would be clearly visible and therefore would have to fit into the existing architecture, sacrificing performance. Overall, the problems with the library make it a logical choice further down the road when Santa Clara is more solar-based but not for the current project.

Placement: The tilt and placement of panels affects the energy produced. We decided to use Sun Power 315W panels for our calculations. The proposed arrays assume the panels are parallel with the building and tilted on the length side. If the panels were all placed flat on the building, the theoretical output is the highest because you can fit the most panels on the roof. Because there is no shading, the panels can be placed closer together. However, this leaves little or no space for maintenance crews to clean the panels and would cost the most because it would use the greatest number of panels. The sheer number of panels yields the highest output, but each individual panel sees fewer peak sun hours than one that is tilted.

Efficiency: A panel tilted at latitude would provide the most energy per panel. The panels have to be spaced so they do not shade one another, but this then leaves room for cleaning and is cheaper because fewer panels can fit on the roof. However, despite being more efficient, the sheer volume of flat panels that fit in that same space makes the latitude setup produce less total output. Because the panels then have a height variable, the view from the ground once again needed to be taken into consideration so as to preserve the aesthetics of campus.

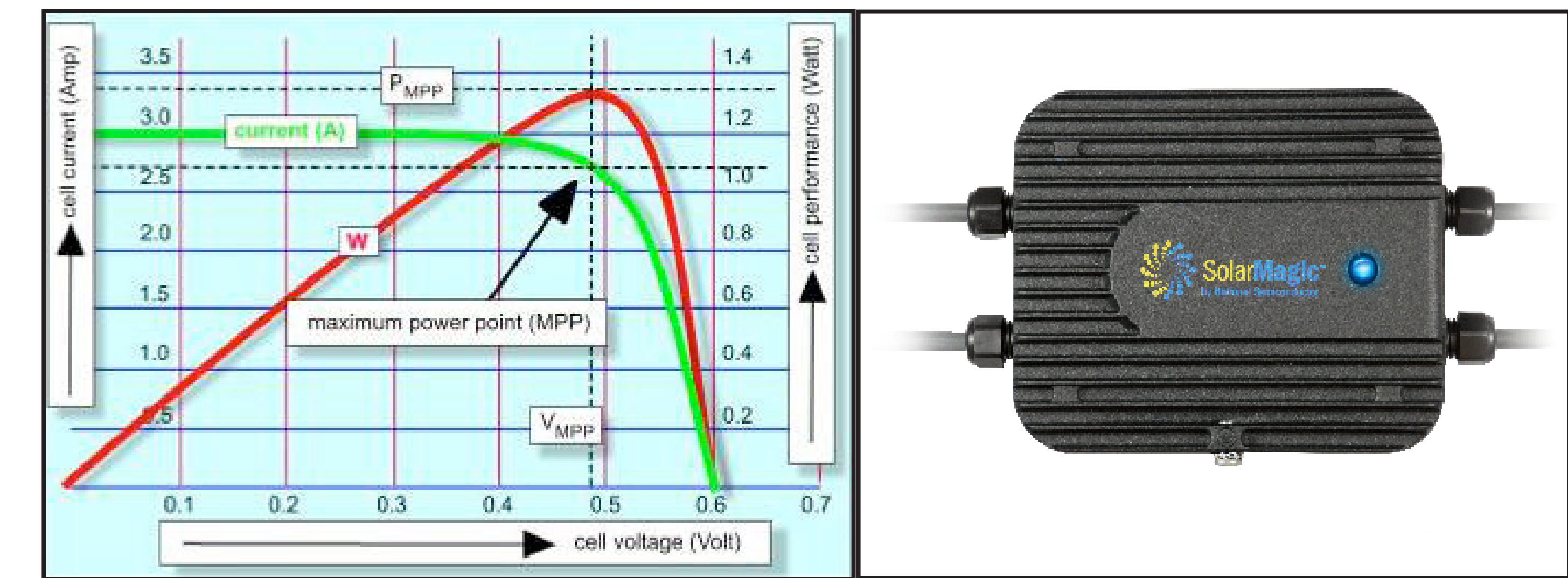


A solar azimuth chart: The sun path charts plot the sun's elevation angle and azimuth angle over a day, as seen from a given location. For example, on June 21, at 10:00AM in Santa Clara, CA the sun will be approximately 61 degrees above the horizon. Sun charts are used to identify if and when objects will cast a shadow on the panels.

Design Impediments and Future Solutions

Shade and reflection can be a big problem for photovoltaic arrays. Because of how solar panels are built and connected to one another, they have what is called a Maximum Power Point (MPP). Partial shading or additional light from a reflective surface on a single panel can push an entire photovoltaic array away from its MPP, in turn reducing the efficiency of the entire system. This reduces the total power output, and increases the payback period for an already expensive system. For these reasons, photovoltaic arrays should not be designed and built in locations where a single roof vent, flagpole, or reflective surface will create uneven lighting conditions on even a small portion of an array.

It is for these reasons that we chose not to assess buildings such as Swig, and a number of the Engineering and Science buildings. Not surprisingly however, there are some solutions to these problems that can be found locally in the Silicon Valley. National Semiconductor has developed a product called SolarMagic™ which helps to minimize the losses incurred when PV arrays do not operate at their MPP. The SolarMagic™ device is connected to each solar panel in an array, and ensures that each panel's operates at its MPP taking into account non-ideal lighting conditions. With this technology, up to 50% of the energy lost due to panel output mismatch can be restored. This can increase the efficiency of the entire PV array, and eliminate the biggest design constraints engineers face in designing and installing solar arrays.



(Left) This graph represents the power output for a single solar cell. The red line corresponds with the total power of the cell, and the green corresponds with the total current. The red line peaks at the solar cell's maximum power; the green shows available current from cell at the point of maximum power where the two lines intersect with the same point on the x-axis (just before .5 V). (Right) This is an example of the SolarMagic™ technology.

Conclusion

Through our research we have developed a helpful guide providing the potential placements, energy outputs, and costs of applying solar panels on Malley Event Center, Leavey Fitness Center, and the Facilities Building. By looking at the energy outputs we have calculated that installing one megawatt of solar energy on campus is very feasible. With Santa Clara University looking to supply the school with a megawatt of solar power in the event of an emergency, we hope this research will be a steppingstone towards that goal.

Acknowledgements

We would like to thank Joe Sugg for providing us with information on Santa Clara's future solar plans as well as aesthetics guidelines for campus buildings, Don Akerland who supplied us with the blueprints of our potential installation sites, John Giddings of National Semiconductor, who was kind enough to meet and discuss his SolarMagic™ product with us. Most importantly, we are very grateful to Professor Tim Healy, who assisted us with our calculations, provided important information about solar energy and technologies, and kept our project pointed in the right direction.

This project was created by a team of freshman students as a part of the Sustainability Living Undergraduate Research Project (SLURP). The team members include Alexander Ray, Caitlin Millar, John Seubert, Laughlin Barker, and Russell McIntosh.