Potential of Solar Power on the University of Texas Campus

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Fig. 01 The University of Texas at Austin first Solar Photo voltaic installation on the main campus, installed as shading devices on the top of Manor Parking Garage (Image Source: Fred C. Beach, Ph.D.)

Introduction

Roofspace on the campus of the University of Texas at Austin (UT) has great potential to produce renewable energy through the integration of solar photovoltaic and thermal panels. Unlike other renewable forms of energy, solar technologies can be integrated into the built environment making them one of the few options for onsite renewable energy generation for the UT Campus. The roof space of the campus provides large areas to capture solar energy for use at locations where energy is demanded. However, there are substantial social and economic barriers that will inhibit the University from developing the full potential of its solar energy resources. Economically, the price of solar energy is too high in comparison to current electrical generation on campus. Socially, the aesthetic and cultural value of the UT campus's red clay-tiled roof space surpasses the value to be potentially gained by covering them with solar collectors. This paper examines the potential of solar energy on UT campus taking into account both the social and economic barriers to its development. The solar potential is determined through models derived from GISc (Geographic Information Science) techniques, which incorporate the analysis of raw solar potential with a feasibility assessment. The results of this model are analyzed with consideration of both the social and economic barriers to widespread solar adoption.

State of Solar Development on UT Campus

The University of Texas at Austin, located in central Texas, has an exceptional potential for solar energy production. Additionally, there is interest among many campus stakeholders in the development of this solar potential. Although the economic barriers have made solar energy infeasible on the UT Campus, the University has worked in securing

Fig. 02 Solar Panel installation on the top of Manor Parking Garage (Image Source: Fred C. Beach, Ph.D.)

outside sources of revenues to offset costs of installing solar systems on campus. These subsidies are a way forward for the early development of solar energy on campus until the prices of solar installation are reduced through development of more efficient manufacturing processes.

In June of 2011, UT installed the largest solar panel system in the Austin area through the use of a 1.6 million dollar grant from the State Energy Conservation Office. With a total investment of 2 million dollars, UT installed a 400,000 kilowatt-hours solar panel system in open fields at the Pickle Research Campus, a research facility located in Northwest Austin. While this project is not on the UT Main Campus, off-siting renewable energy generation may be a way for UT to increase its share of renewable energy generation in its overall energy matrix.

In August of 2011, UT Main Campus installed its first large solar photovoltaic system. The solar panels were installed on the top of the Manor Garage (see Figure 2). This adoption of solar panels on the Main Campus was facilitated through a research grant given to the Webber Energy Group, a UT mechanical engineering research team, which will study the performance of three different types of solar panels under the same conditions. This is an example of a demonstration project that not only serves to advance research, but also to change public perception of solar technologies. The Manor Garage was chosen due to its high visibility, located between Darrel K Royal-Texas Memorial Football Stadium and the Mike A. Myers Track and Soccer Stadium near the interstate highway system. UT's choice to locate its first large-scale solar photovoltaic system in one of the most visible places on campus makes a statement about the value solar energy (see Figure 1). This stands in contrast to conventional architectural design strategies where solar panels are hidden from the public.

Solar thermal installations were part of the construction of newer buildings on campus, including the Student Activity Center (SAC) and the Norman Hackerman Building (NHB). New construction on UT campus is planned to meet silver status in the LEED Rating System, which encourages the installation by rewarding points for generating energy onsite. Future construction on campus will most likely include onsite energy generation, which for the near future will use solar thermal. Existing construction is where UT's solar potential lies.

The University's development of solar energy outlines the general strategies for future development:

- Pursue subsides and research grants to offset costs.
- Off-site solar systems from the main campus to where costs are less.
  for installation.
- Use the adoption of LEED Rating system to encourage the

integration of solar energy development into new building design.
- Utilize existing roof space on campus to install solar power system.

This paper focuses on existing roof space on UT campus, and how to map out the potential for solar energy development.

Urban Solar Mapping using LiDAR

Mapping of solar potential was done through the use of Light Detection and Ranging (LiDAR) and Geographic Information Systems (GIS) to model the solar radiation on the roof space of The University of Texas at Austin Main Campus. LiDAR has the capability to accurately create thousands of measured points in three-dimensional space.[1] When mounting these systems to a plane, airborne LiDAR expands the geographical range and quickly scans large areas like metropolitan regions in matter of hours[2]—similar to sonars used by ships but airborne with high resolution. With the use of a differentially corrected global positioning system (dGPS) both in the plane and on the ground, the LiDAR system is able to scan the surface of the Earth through laser pulses, measure return times of the pulses, and calculate ranges from the known positions of the plane.[3] This is processed into a point cloud, which is a collection point measurement for surfaces in Cartesian coordinates (x,y,z).

LiDAR mapping is a popular method for topographic, hydrographic, and vegetative surveying.[4] This study uses it in an unconventional way for a novel application of urban mapping, or mapping out the built-environment.

Fig. 03 Example of unfiltered LiDAR elevation modeling

The raw data file generated from the laser sensor returns a sample from all objects that are in line of sight from the air including buildings and other structures. In topographic mapping, the buildings and other man-made structures are filtered out with breaklines, and the remaining points are interpolated to create a bare earth digital elevation model.[5] In this study the breaklines were reversed, removing the terrain and other surfaces from the point cloud, which was used in interpolating a digital roof elevation model. Figure 3 gives an example view of processed LiDAR in urban area with vegetation cover. Normally what is shown in yellow is filtered out to create the bare earth elevation model; this study takes the opposite approach.

Creating a Digital Roof Elevation Model

Figure 5 shows the general procedures used to make the raw LiDAR files into solar radiation map of the roofspace of UT Campus. The raw LiDAR data came in standard LAS format, which is a text format (ASCII) of x,y,z coordinate values and a return intensity value. The data was created for the Capitol Area Council of Government (CAPCOG) in 2007 by Sanborne Mapping Company. The horizontal resolution was 1.4 meter spacing between points and was collected in Federal Emergency Management Agency (FEMA) standards. Horizontal accuracy is +/- 1 meter and vertical accuracy was +/- 18.5 cm. The LiDAR data was filtered to give only the last return value, mapping out where the laser terminated and could not travel further. This gave a point cloud of the terrain, roads, and structures on the surface of the Earth for the

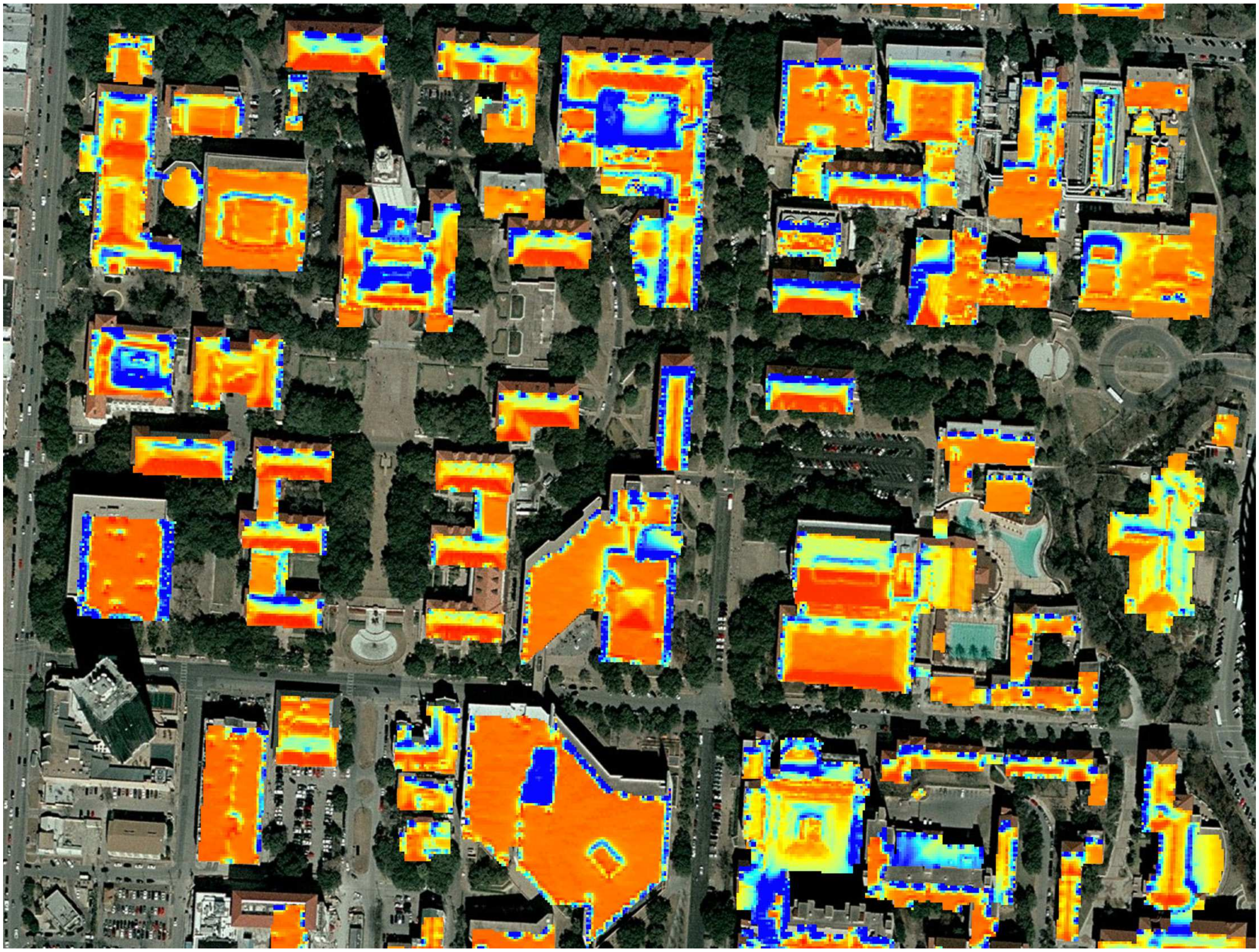

Fig. 04 Resulting solar radiation map where pixel values correspond to the total annual global radiation in watts per square meter.

region. Then with the use of a building inventory from the county appraisal district, the point files were extracted for only return values over the buildings. These were then processed using the buildings' footprints as break lines creating a digital roof elevation model, interpolating the elevation at all part of the roofs.

Tree coverage was determined using 2006 color infrared aerial photography created by CAPCOG.[6] The images were processed creating a Normalized Difference Vegetation Index (NDVI) in the urban environment, by subtracting

$$NDVI = \frac{(Near\ Infrared - Visible\ Red)}{(Near\ Infrared + Visible\ Red)}$$

the visible red wavelength (0.4–0.7 μm) from the near infrared wavelength (0.75–.4 μm) and dividing by its sum. This NDVI was then classified into vegetation types and subsetted to produce only canopy vegetation.

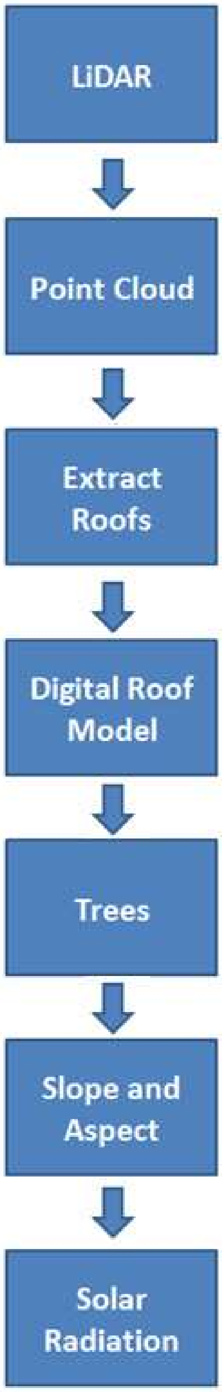

Fig. 05 The workflow for solar mapping.

This raster then was vectorized to create canopy coverage data for the campus. This is necessary because LiDAR pulses are able to travel through tree foliage. This results in the identification of elevation points that were mapped under the canopy. The roof model was modified setting elevation value under trees to null, removing them from further modeling. The rationality is that solar radiation under the canopy is too weak to make the addition of solar panels in those locations economically feasible.

The Digital Roof Model was created for existing buildings on UT campus with the exception of culturally significant buildings like the Main Tower, Littlefield house, and other buildings that would hold historical value to conserve in current state without major architectural changes. Additionally, buildings with utilized roofspace were also eliminated (i.e. Central Cooling Stations where roofs serve as vents). In all, a total of 109 Main Campus buildings were used for the model. The digital roof model did include the slanted roof buildings on campus with red clay tiles to determine the amount of solar energy not being captured due the cultural barrier.

Modeling Solar Ration (Insolation)

Incoming solar radiation, or insolation, has been heavily researched and well-developed tools exist in standard GIS software packages, like ArcGIS from ESRI, to measure it.[7] The calculated insolation maps were derived from digital roof elevation models, using an insolation model established by Pinde Fu,[8] which accounts for atmospheric conditions, elevation, surface orientation, and influences of surrounding topography.[9] These were used in the final calculations of the solar radiation potential. For the solar radiation, three maps were used: the visible sky (viewshed map), the sun's

$$\text{Annual PV Electrcity}\left(\frac{\text{(KWh)}}{\text{(Year*m}^2\text{)}}\right) * $$

$$\text{Cost of Conventional Electricty}\left(\frac{\$}{\text{KWh}}\right) = $$

$$\text{Breakeven Point (\$/Year)}$$

position in the sky across a period of time (sunmap), and the sectors of the sky that influence the amount of incoming solar radiation (skymap). These collections of maps were used to calculate the total amount of solar radiation (global radiation) per area for the entire year creating a total solar production for the year in watt hours per square meter. Figure 4 shows the resulting solar insolation layer overlayed over a aerial photography of UT campus.

The total solar radiation hitting the rooftops of UT Main Campus every year is 4,465 GWh/year. The social barrier of not building solar panels on slanted roofs with red tiles reduces solar radiation potential to 1,939 GWh/year, which results in 43 % less insolation. However, the 1,318,875 square meters of flat roof space still provide an ample amount of insolation for the collection of solar energy.

Roof Type	Roof Area (m^2)	Total Insolation (GWh/year)
Total Roofs	3,435,700	4,465
Flat Roofs	1,318,875	1,939

PV modules have a typical efficiency of 12% conversion from insolation radiation to electricity.[10] Using the following equation for converting total insolation to Annual Energy Generated, the campus has the

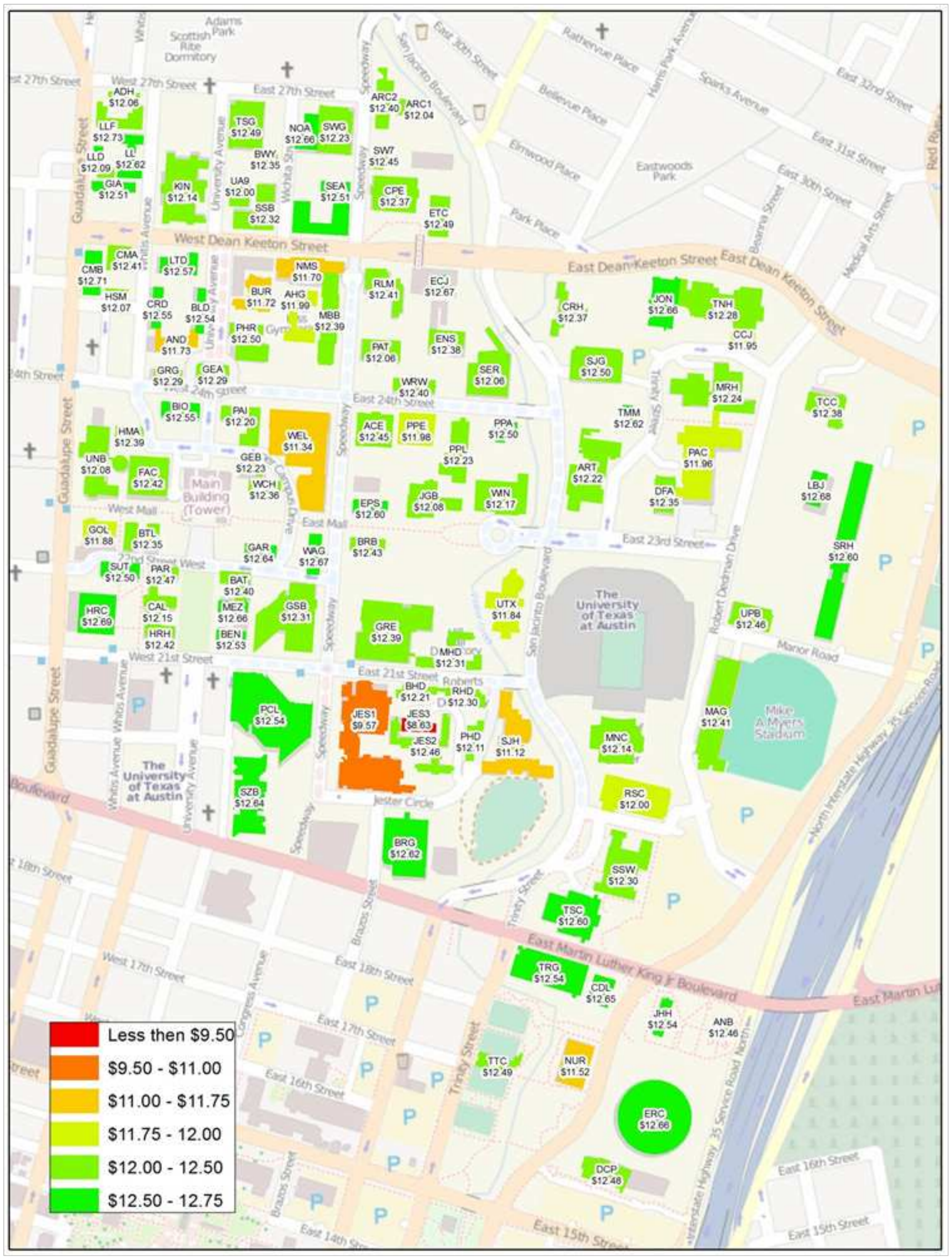

Fig 06 Breakpoint cost for solar PV installation (dollars per square meter per year)

potential to generate 232 GWh per year with flat roofspace on campus.

*Annual Energy Generation (GWh) = Total Insolation (GWh) * Efficiency of PV System*

Social barriers reduce the amount of solar energy potential, but there is a still substantial amount of roofspace available. The only barrier preventing wide spread adoption is economic.

Economic Analysis

The University of Texas produces its own electricity on the campus through a natural gas power plant. The plant is very efficient and economical. The cost of electricity production on campus is 7 cents per kilowatt-hour. This low cost of electricity is an economic barrier to the adoption of solar photovoltaic, as any installation of solar photovoltaic panels would have to compete with the natural gas generation. Solar mapping provides an idea of how much solar energy can be generated, but without economic feasibility development it will not occur. To determine the economic feasibility of installation of solar technologies, the following formula was applied:

Figure 6 shows the results of the breakeven point analysis on a map of UT campus. The buildings highlighted in green through yellow would have the best potential for solar energy. The buildings with orange and red are the worst. The average breakeven point was $12.25 per square meter per year. Depending on the payback period the economic feasibility can be determined by multiplying it by the breakeven value. Assuming a payback period of 10 years, the University can install solar PV systems that cost $122.50 per square meter. Currently the price to install solar PV is $1.40/Wh for a typical solar system.[11] Translated to area, this will cost about $1,400 per square meter installed, more than 10 times the break-even point. Without a substantial drop in the price of solar panels the economic barriers are too great even with a forward thinking view of a 10-year payback period.

Discussion

The price of solar PV is dropping significantly as shown in Figure 4.

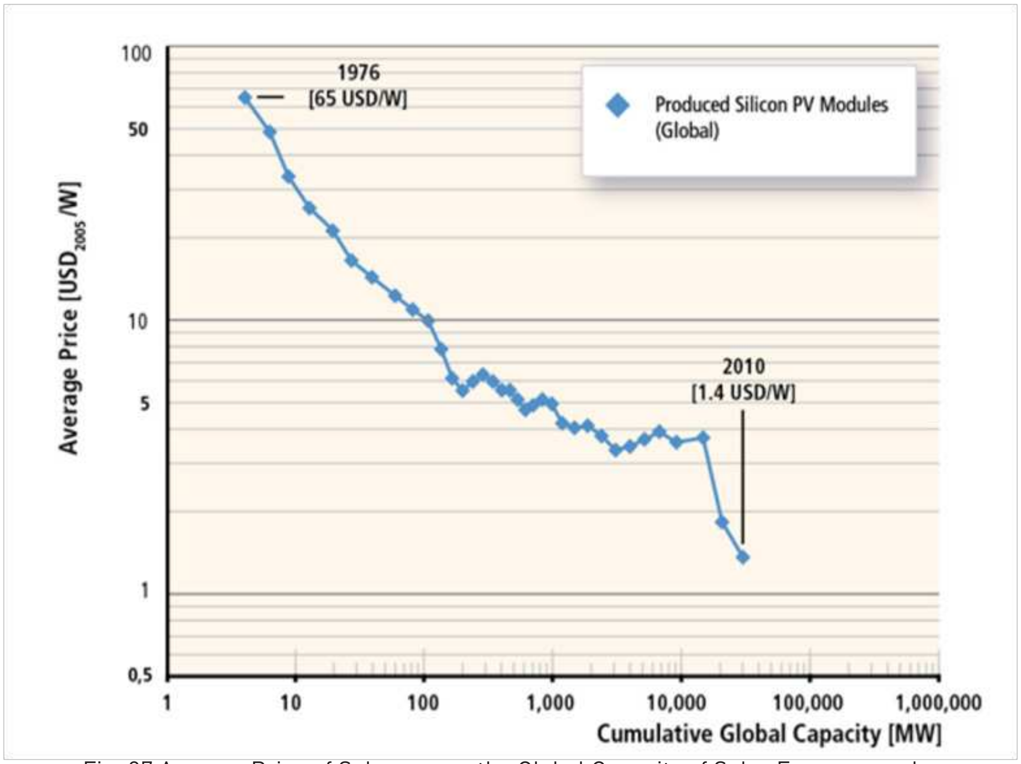

Fig. 07 Average Price of Solar versus the Global Capacity of Solar Energy: graph demonstrates learning curve of production leading to drops in solar energy price.

Demand for solar PV is growing and economies of scale as well as the learning curve effect are causing a drop in price. Over the last 30 years the price of solar energy has decreased by a factor of ten.[12] Projected costs by the International Energy Agency shows that it will continue to drop through 2050[13] with a possibility of a 50% drop in price by 2020.[14] As solar becomes more affordable and efficient, the economics of solar will become more favorable.

Subsidies and grants can play an important role in making solar energy more competitive as they directly affect the price of a solar installation as shown in the following formula.

Cost ($/Area) =
Price of Panel ($/Area) +
Price of Installation ($/Area) -
Subsidy ($/Area)

Currently this is the method being used to reduce the price of solar installation at UT. Both solar installations at UT were made possible in a large part by state grants. Coupling solar development with research allows the University to develop its solar portfolio while also pursuing its core mission.

Conclusion

This analysis demonstrates that the UT Campus has significant potential for generating solar energy, even without placement of PV arrays on its treasured red-tile roofs. As a public institution committed to sustainability research, the University of Texas could use its extensive solar potential for ongoing research and development on solar energy production. Furthermore, although extensive installation of solar panels cannot be justified solely on an economic savings basis today, the price of solar PV is dropping and solar power may be economically advantageous for the University in the future (see Figure 7).

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