# Project 4:
# University of Houston Strategy Application

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# UNIVERSITY OF HOUSTON APPLICATION


## ABSTRACT

This Paper proposes a conceptual plan for the University of Houston. The approach is broken up in three scales: large, medium, and small. At the large scale, an electricity generation and storage strategies are proposed. A series of solar photovoltaic arrays are deployed on 5 existing parking structures on the campus and one future parking structure that is currently under construction. At the medium scale, a design is proposed for the arrangement of the photovoltaic arrays on the topmost level of garage 5. At this same scale, a water use strategy is proposed to water a roof garden coupled with a material strategy to increase thermal comfort and reduce UHI effect. Finally, at the small scale, a design proposal for the garage roof is proposed that makes the garage rooftop safer, more habitable, more desirable, more usable, and more enjoyable for students.

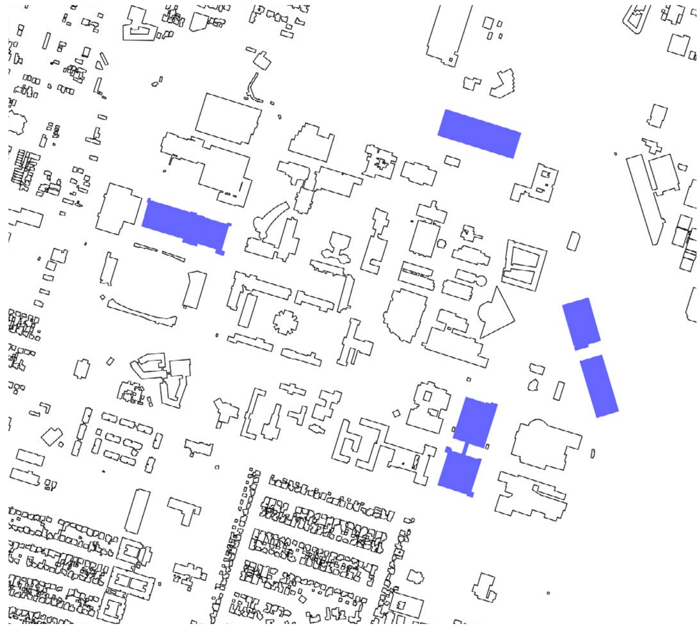



***Figure 1.*** *University of Houston Building footprints (Parking Garages shown in purple)*

## 1.0 COMMUNITY IMPACT

Simulation software, Climate Studio, is used to predict the potential electricity generated by deploying solar PV arrays on all University of Houston parking garages. In total, the six rooftop surface areas combined cover approximately 797,767 square feet or 18.31 acres (see *fig.1*). For the purposes of this paper, three alternative scenarios are presented. The simulation is run for 70, 50, and 30 percent effective roof areas. The results are output in kWh per month and MWh per year for each of the alternative scenarios. All simulations are run assuming a PV efficiency of 20%, which is the typical efficiency of commercial photovoltaics (Systems). Additionally, given the heights and loca-

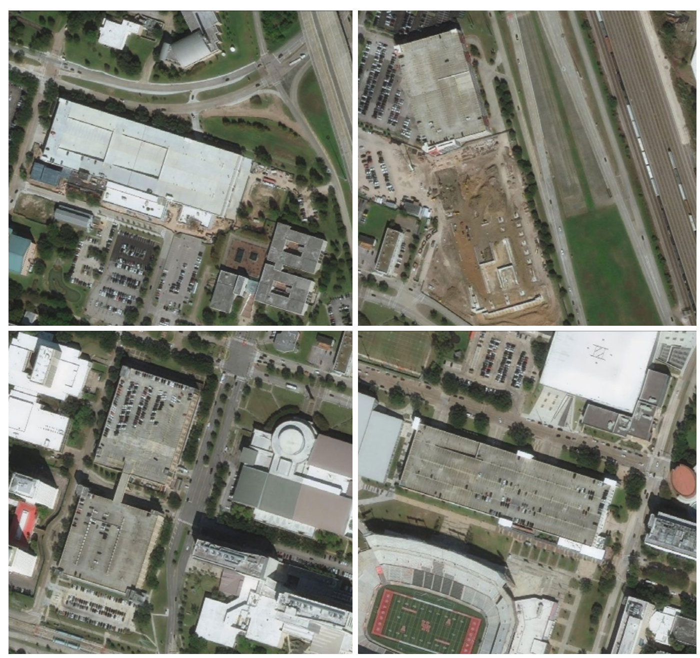


***Figure 2.*** *Aerial images of UH parking garages. TL: garage 5; TR: East Garage & Garage 6 Construction site; BL: Welcome Center Garages; BR: Stadium Garage*

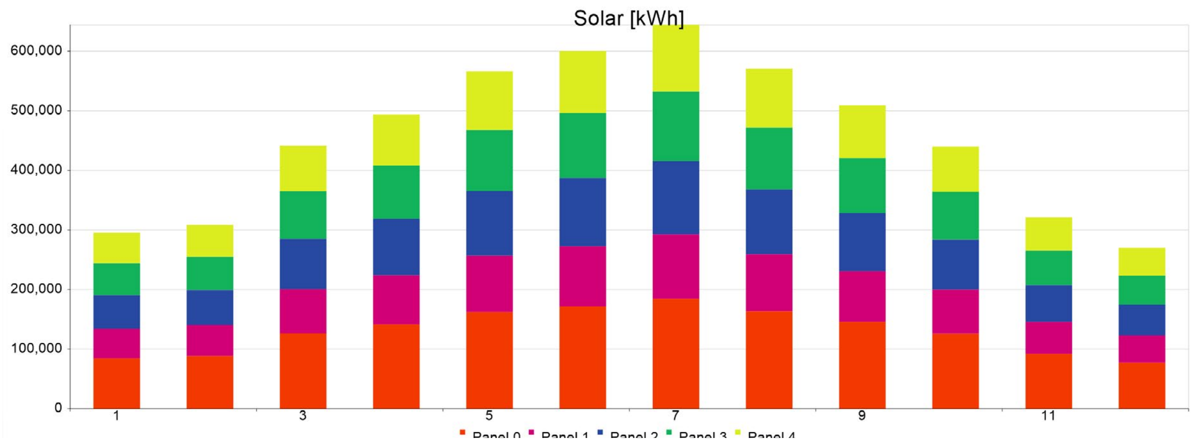



***Figure 3.*** *Monthly potential electricity generated by proposed solar panels on all parking garage roofs at thirty percent effective roof area*

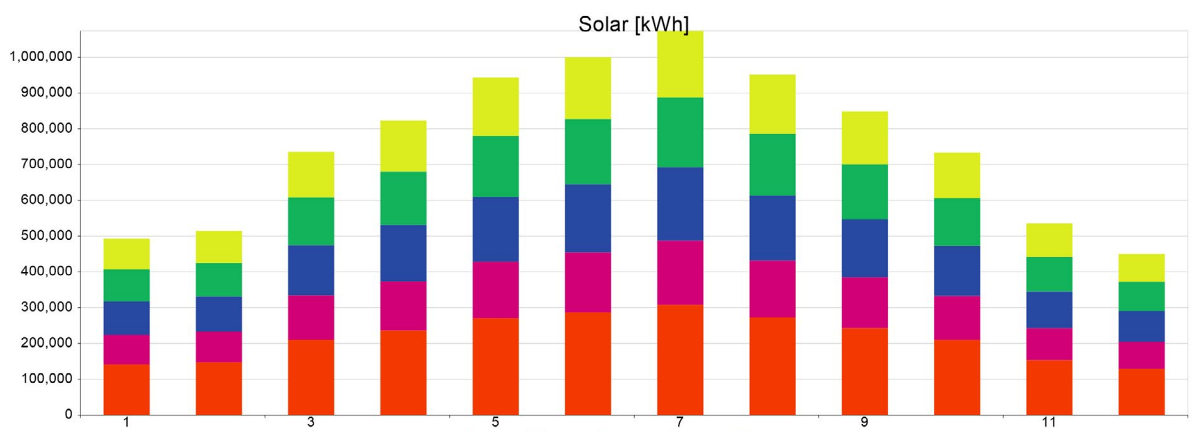



***Figure 4.*** *Monthly potential electricity generated by proposed solar panels on all parking garage roofs at fifty percent effective roof area*

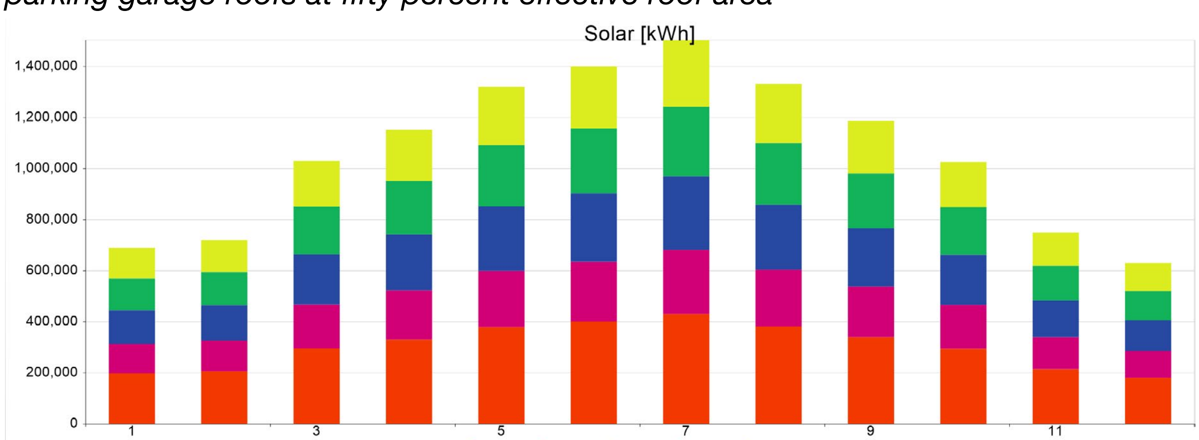



***Figure 5.*** *Monthly potential electricity generated by proposed solar panels at seventy percent effective roof area*

tions of the garages (see fig. 2), the simulations assume that there are no shadows being cast on the solar panels from the context, meaning surrounding vegetation or buildings.

At thirty percent effective roof area, the proposed deployment of solar panels could generate 5,461 MWh/yr (see fig.3). At fifty percent effective roof area, the proposed deployment of solar panels could generate 9,101 MWh /yr (see fig. 4). At seventy percent effective roof area, the proposed deployment of solar panels could generate 12,743 MWh/yr (see fig. 5).

## 2.0 CURRENT CONDITIONS

Garage 5 lies on the north side of the University of Houston and is adjacent to both the College of Architecture and Design and the Law Center building. Bordering the north face of garage 5 is Elgin Street. For this reason, Garage 5 has recently been renamed Elgin Street Garage. From this point on garage 5 will be referred to as Elgin Street Garage.

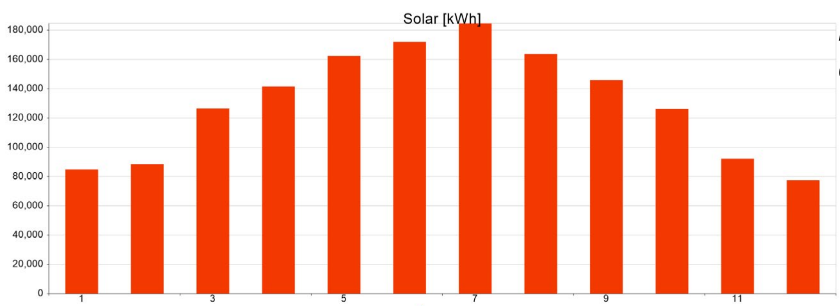



***Figure 6.*** *Elgin Street Rooftop PV at 30% effective roof coverage*

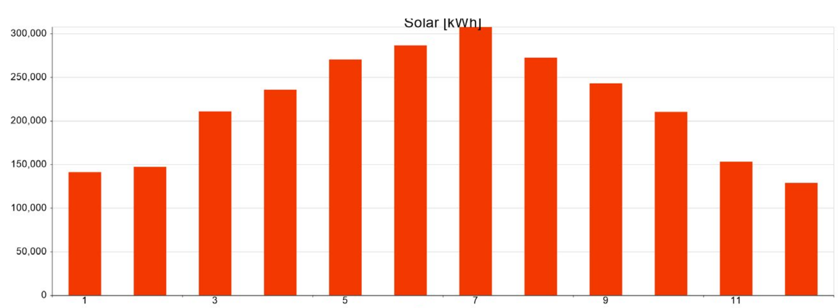



***Figure 7.*** *Elgin Street Rooftop PV at 50% effective roof coverage*

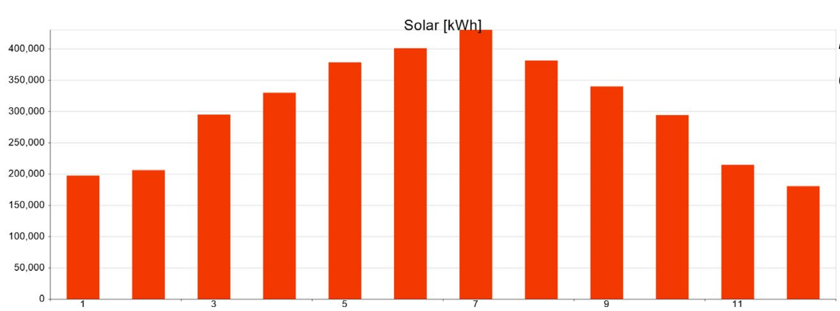



***Figure 8.*** *Elgin Street Rooftop PV at 70% effective roof coverage*

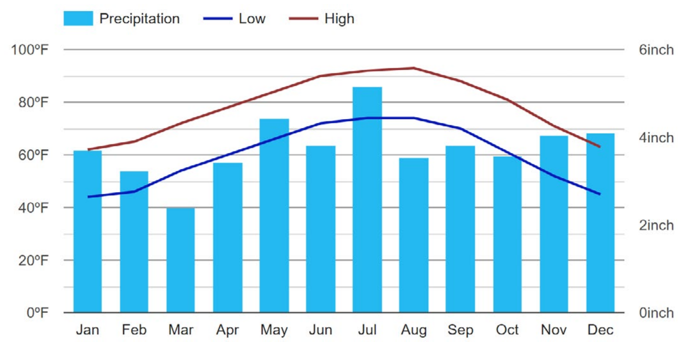
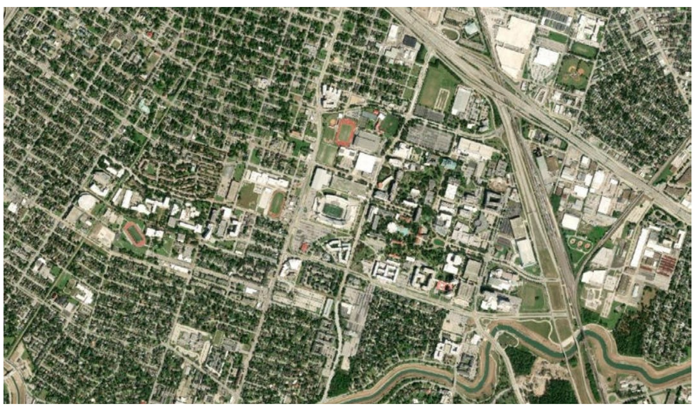



***Figure 9.*** *Houston Climate Data (usclimatedata. com)*



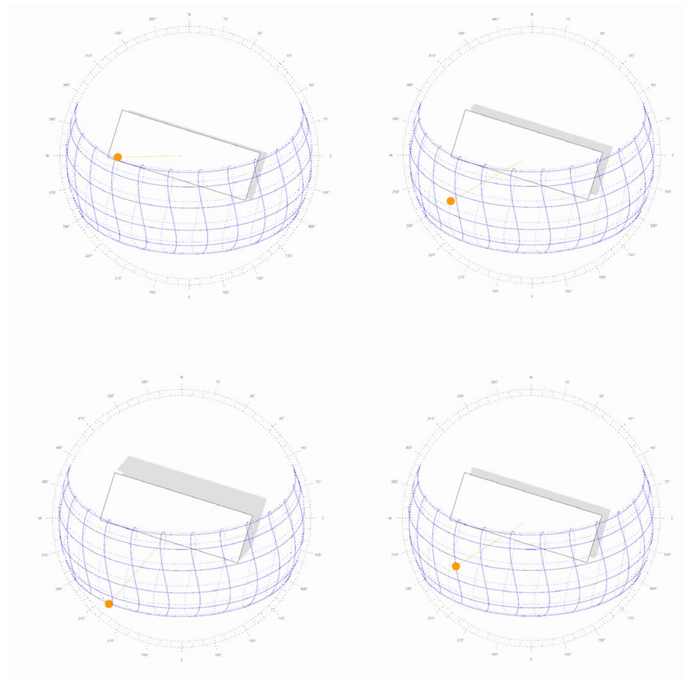


***Figure 10.*** *Solar study of Elgin Street Garage at 3PM. TL: Summer Solstice; TR: Fall Equinox; BL:Winter Solstice; BR Vernal Equinox*

***Figure 11.*** *Garage 5: Elgin st. Garage (https://www.uh.edu)*

Surrounding the ground floor of Elgin Street Garage, an arrangement of formidably large oak trees increases the aesthetic and comfort aspects of the garage and its peripheral sidewalks. The southern face of the garage is directly attached to the recently completed art and architecture building. The garage is five levels including the ground level. At the west side of the garage is a standard, one level parking lot. Beyond this parking lot, in the distance, past a large canopy of trees and a jumbled agglomeration of overpasses, is an excellent view of the downtown CBD skyline. During the sunset, the silhouettes of the tall buildings are highlighted from behind by the setting sun, and the mega size of these is enhanced and made static by the movement of vehicles in the foreground. When the weather is favorable, it is easy to stand on the rooftop of the garage, leaning on its edge during twilight, appreciating the incredible view. However, this often happens in complete solitude since the rooftop is rarely occupied. It can get too hot during the day and people prefer to leave their vehicles in the lower, covered levels. This condition is the basis for the medium scale intervention.

## 2.1 ENERGY USE

The roof of Elgin Street garage has an area of 173,503 square feet and is open air. The four levels below it measure the same approximate surface area but are defined as partially enclosed by Energy Star. Based on Energy Star Portfolio data (see fig. 12), a partially enclosed parking garage that operates 24 hours a day is estimated to consume 8.967 kBtu/ft2/yr; while an open air parking garage is estimated to consume 2.989 kBtu/ft2/yr (EnergyStar). Coupling this data with the gross garage area, it can be deduced that the Elgin Street Garage consumes about 1,975.8 MWh per year.

| Parking Type | End Use | Engineered Allowance | Assumed Hours of Operation | Parking Area Site Energy |
|---|---|---|---|---|
| Open Parking | Lighting | 0.15 W/ft² | 16 Hours/day | 2.989 kBtu/ft²/yr |
| Partially Enclosed Parking (No Walls) | Lighting | 0.30 W/ft² | 24 Hours/day | 8.967 kBtu/ft²/yr |
| Completely Enclosed Parking (Walls) | Lighting | 0.30 W/ft² | 24 Hours/day | 8.967 kBtu/ft²/yr |
| | Ventilation | 0.29 W/ft² (On) | 6 Hours/day | 2.39 kBtu/ft²/yr |
| | | 0.01 W/ft² (Setback) | 18 Hours/day | |
| | Heating (if present) | 0.009354 kBtu/ft²/yr/ $HDD_{Base40F}$ | Based on Ventilation and Degree Days | 0.009354 kBtu/ft²/yr/ $HDD_{Base40F}$ |

***Figure 12.*** *Estimate Energy Use intensity of Parking Garages (Energy Star)*

At 70% roof coverage, based on the Climate Studio simulations, the roof has an electricity generation potential of 3,652 MWh of electricity annually (see fig. 6). At 50% roof coverage, the roof has an electricity generation potential of 2,609 MWh of electricity annually (see fig. 7). Least of all, at 50% roof coverage, the roof has an electricity generation potential of 1,565.4 MWh of electricity annually (see fig. 8). This last scenario does not generate enough electricity to power the garage. However, the 70% and the 50% effective roof coverage scenarios generate surplus of electricity annually. This electricity can be used to charge electric vehicles or stored in a battery to discharge for other buildings during peak hours and help reduce electricity costs for the University.

## 2.2 COMFORT

These photovoltaic panels would also increase the comfort of the rooftop space by

With Shade

Without Shade

**Fig 13.** Hourly Mean Radiant Temperature (MRT) differential for the entire year

increasing shaded areas. In addition to this, the rooftop of Elgin Street Parking Lot, if re-painted entirely with a high albedo paint, would reduce the amount of heat absorbed and the released into the environment by the parking structure (Sailor) re. Because of the scale of this paint intervention, the high albedo paint would have a minimal effect on urban heat island (UHI) and might create glare problems. Still, coupled with the shade provided by the photovoltaic panels, and some plants that shade the rooftop even more, the interventions could prove to be sufficient to make the space more attractive for students.

To validate the increased comfort on the rooftop of Elgin Street Garage with the new shading structures, the Universal Thermal Climate Index (UTCI) was used to measure performance. This Index is the most used by meteorologists to measure what the weather feels like for a person (Mackey, Galanos and Norford). It considers the dry-bulb temperature, the radiant temperature, relative humidity, and the wind speed (Mackey, Galanos and Norford). EnergyPlus Weather (EPW) files contain some of this information as measured from the weather station located in the IAH airport. However, EPWs do not contain data for radiant temperatures or for localized wind speeds as these are highly determined by immediate contexts (i.e. shading, buildings massing, etc.). In this proposal, the only elements that interact with the radiant temperature calculation are the solar PV shading structures.

The SolarCal model of ASHRAE-55 was used to “calculate Mean Radiant Temperature (MRT) as a result of outdoor shortwave solar shining directly onto people as well as longwave radiant exchange with the sky” (Mackey, Galanos and Norford). For calculating the MRT, the model assumes a brown-skinned person (skin short-wave absorptivity) wearing darkish clothes (short-wave absorptivity) is standing outside facing their back to the sun. With the shading devices, 0% of the person’s body is exposed to direct radiation and 10% of the sky is within view. Without shading, the same person is standing fully exposed out in the open. Figure 13 shows the resulting MRT values for both cases.

The MRT results were input into a UTCI calculator along with annual relative humidity and wind speed values measured from IAH weather station. the UTCI calculations demonstrate that the weather will be uncomfortably hot outside for 109 days of the year without shade, compared to 89 days with shade (see fig. 14-15). That is a 20-day difference. Being able to spend time outside in Houston is valuable, so increasing the numbers of days that it is comfortable to be outside adds value to the

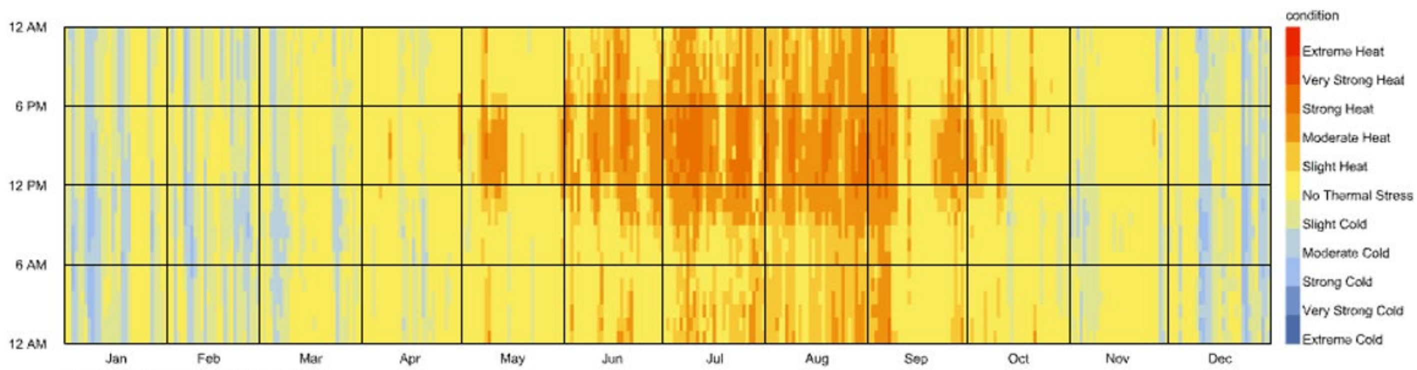



**Fig 14.** UTCI with shade
24.60% of the year too hot
51.83% of the year with no thermal stress
23.57% of the year too cold

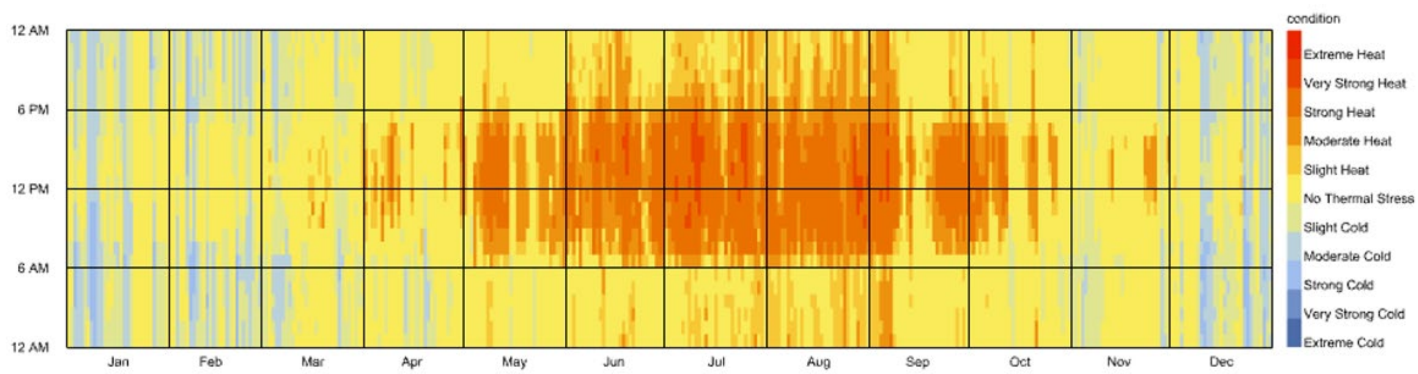



**Fig 15.** UTCI with no shade
29.92% of the year too hot
48.71% of the year with no thermal stress
21.37% of the year too cold

Elgin Street Garage Rooftop.

**SMALL SCALE:**

Because of their materiality, solar PVs can be optimum surfaces for collecting rainwater. Glass, being a nonabsorptive material, can be exploited in a design that efficiently redirects rain into a rainwater harvest system (Shenga, Mari and Ariffin). The water "Rooftop collected rainwater is usually used for toilet flushing, laundry and garden irrigation and typically supplies 25% of the domestic drinking water use" (Shenga, Mari and Ariffin). However, for this proposal, the rainwater would be used mainly to irrigate the gardens on the rooftop of Elgin Street Garage.

To accompany the roof garden, this proposal suggests a series of urban furniture interventions and an integrated lighting solution. The arrangement of these makes use of the newly added shaded areas on the Elgin Street Garage rooftop to enhance the comfort of the space so that people can now sit and socialize when they enjoy the views of downtown that are available from the structure. At night, the lighting not only makes the parking lot safer, but also increases the aesthetic value of the rooftop as well as its usability and occupancy schedule. The lamps are LED and are powered by the surplus electricity generated by the solar PV arrays. Along with the rainwater harvest system, these LEDs are integrated into the design of the PV structure. At night and during the day, the view of downtown and the sustainable design interventions proposed make Elgin Street Garage Rooftop a space for pleasure and respite for architecture students to enjoy after long days in studio.

**CONCLUSIONS & FURTHER RESEARCH:**

Rooftop levels of University of Houston Parking Garages are underutilized. This is likely because the spaces are uncomfortable, even though many of the rooftops enjoy unique views of the campus and the city. Installing Solar PV structures on all garages could make the rooftops more useful. At 50% and 70% effective roof area coverage, all garages potentially generate more electricity than they consume. This surplus electricity can be stored in an electric vehicle fleet or in AES battery systems for discharge during peak-demand hours. As demonstrated for Elgin Street Garage (Garage 5), the solar photovoltaics can be designed to integrate several additional sustainable and ecological solutions. The shading provided by the PV structures increases the comfort of the rooftop spaces. Rainwater harvested by the same structures can be used to irrigate a rooftop garden that makes the space much more pleasant to be in. After sundown, the rooftops are illuminated by LEDs that convert the elevated spaces into beacons for socializing and enjoying views of the city.

Further research is necessary to carry this proposal through into reality. At the large scale, high resolution information about the University's energy use could help determine how to make use of the estimated surplus electricity generated by the Rooftop PVs. This same data could help in calculating the size of the AES battery and thus the placement of it. At the medium scale, a cost estimate of the panels and the gardening elements would aid in developing phased plan that incorporates planning. At the smaller scale, a fully realized and detailed design for the solar PV structures would also help in the estimation of cost as well as in the advancing of the concept's viability. The comfort calculations could also be more detailed and informed. For example, UTCI is significantly influenced by wind speeds and directions (Mackey, Galanos and Norford). A wind speed simulation would further increase the accuracy of the estimates. Also, UHI effect might play a role in the estimates. Performing a simulation to generate an EPW file as is possible with the Urban Weather Generator (UWG) software would also make the UTCI calculations more accurate (Mackey, Galanos and Norford).

Still, at this very conceptual level, the proposal presents an attractive design solution for the University of Houston Campus. Converting all rooftops into habitable, electricity generating spaces would positively impact the image of the Campus.

LIST OF TRATEGIES:

•**Energy Use**

o Energy Use from Solar PV arrays

o Battery from AES storage

o Storing PV generation in Electric Vehicles

•**Quality of air and ventilation**

o PV arrays over the top floor will reduce direct solar radiation and cool spaces.

o Variety of plants could further help cool spaces through evapotranspiration.

•**Water use**

o capturing rainwater will help water plants on roof

•**Daylight and views**

o Added shade from the Solar PV array will make spaces more comfortable

o Added interventions and comfort will enable students to enjoy the great views of the city and the campus from the top of parking garages.

•**Use of materials for environment**

o Painting the garages with high albedo will reduce the heat absorption of the parking structure, reducing UHI effect

•**Use of materials in environment**

o Plants

o Seating

o Shading

o Tables

o Snack machines

o Lighting makes garage more attractive.

•**Human safety**

o Lighting Solutions makes garage safer after sundown

**Works Cited**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