# TTP 289A Project Report
# Ghausi Hall Energy Study

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Contents

# I. EXECUTIVE SUMMARY

This report describes the analysis process used by team Ghausi to develop energy saving measures to bring demands down and to utilize renewable technology (PV) to provide onsite energy generation for Ghausi Hall, the Civil and Environmental Engineering Laboratory building at UC Davis. The first option in our path to net zero energy involves first reducing the site energy of Ghausi Hall through low energy building technologies. These building technologies can involve daylighting, high efficiency HVAC equipment, natural ventilation, and evaporative cooling. One case that was considered was reducing the air flow in the building by half to achieve energy savings similar to the Vet Med 3B building that uses a combination of 4 and 6 air changes per hour depending on in the building. The second option in our path to net zero energy involves using renewable energy sources available within the building's footprint available at the site. Renewable energy sources can include PV, solar hot water, and wind. For this project only PV was considered. The roof of Ghausi Hall did not have adequate space for PV installation, therefore the parking lots west and south of the building were considered. The parking lot on the west side was estimated to be 24,847 feet squared and the parking lot on the south side was estimated to be 30,720 feet squared. It is presumed that a 1 kW PV system takes about 80 square feet. In addition, it is estimated that 5 solar panels make about 1 kW.

# II. PROJECT BACKGROUND

## A. Abbreviation

| Terms | Abbreviation |
|---|---|
| ZERO NET ENERGY | ZNE or NZE |
| Chill Water System | CHW |
| Heating Water System | HHW |
| Energy Use Intensity | EUI |
| Air Change per Hour | ACH |
| Square Feet | sf |
| Net Present Cost | NPC |
| Power Purchase Agreement | PPA |

1 MBTU =1000 BTU

## B. PROBLEM & CLIENT BACKGROUND

The UC Davis campus is paying more than $20 million a year in energy bill. About two third of that are from laboratory buildings. For this reason, the 2013-14 Strategic Energy Partnership Program (SEPP)-funded energy projects run by the Facilities Management Energy Conservation Office (FM ECO) on campus will be focused on reducing energy usage in laboratory buildings. A project in Briggs Hall last year is saving well over $300,000 in energy costs per year. But there are still many opportunities in that building that are left untouched. The following questions are addressed by the FMECO:

- How much more energy can we save?
- What opportunities are there to generate or recover energy?
- Is a Net Zero Energy lab retrofit possible?

C. PROBLEM STATEMENT

Ghausi Hall is a 67,000 square foot three story engineering lab building built in 1999. It has an Energy Use Intensity (EUI) of 203 MBtu/sf. The current goal is to save at least 2.7 x $10^3$ MBtu of energy per year. The current project is looking at upgrading air handling equipment and controls, installing heat recovery, and adding occupancy sensors to every lab for unoccupied setbacks of temperature and possibly ventilation rates as well. Our student team will look into what additional measures could be included and what the path to NZE would look like here.

For our team, there are two main elements to this projects: developing strategies to reduce energy usage and generating on-site energy. First of all, a literature review on similar projects will be presented. This will provide strategies being done by similar buildings to save energy. For onsite generation, a survey of renewable technology such as solar PV and solar thermal being used at similar buildings will be presented. Then these strategies will be assessed to determine their applicability to Ghausi Hall. A layout of each strategy along with their cost and feasibility will be provided at the end.

One challenge with reducing the energy usage of laboratory building is their base load. Even at night (12 am) the power is more than 120 KW for a typical weekday/weekend in May).

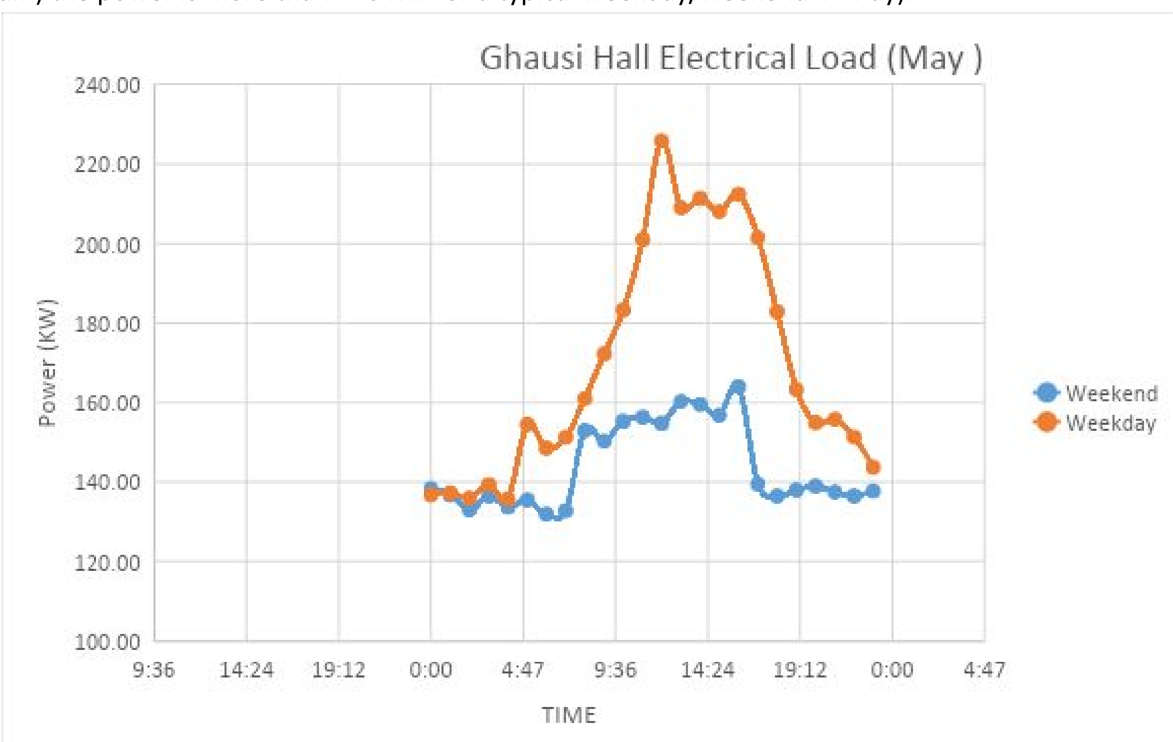



*Figure 1- Electrical Load for a typical weekday and weekend in May*

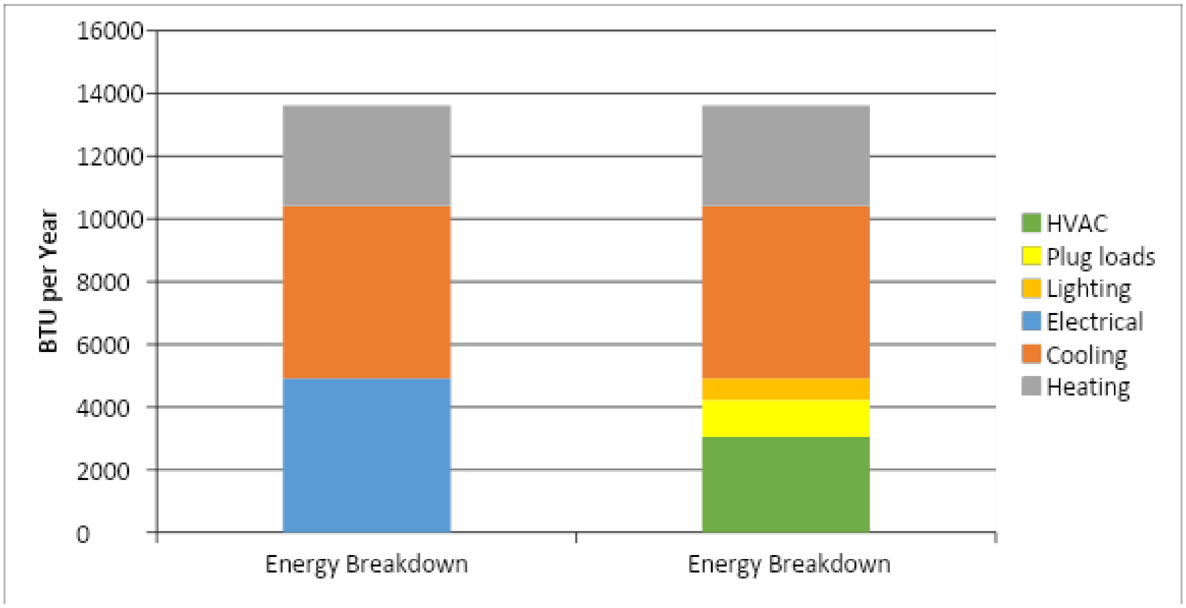



*Figure 2- Energy Breakdowns ( in terms of BTUs)*

# III. METHODOLOGY

## A. Metrics

The following metrics are considered in determining the appropriate strategies for this project

- Load Reduction Percentage is percentage of energy load saving per year of the total energy load per year. The total energy load include electrical, heating and cooling load. Reduction of energy load can be done through optimizations of HVAC systems and understanding and changing occupants' behaviors.
- Savings/ year is the $ amount corresponding to the load reduction. This is calculated using simple approximations which will be given in the appendix.
- Net present cost is the total annualized cost divided by the capital recovery factor. Total annualized cost include capital cost, replacement cost and operating and maintenance cost of the PV system. Capital recovery factor depends on interest rate and project lifetime. Detailed formula can be found in [1]
- Project cost per year is the net present cost divided by project life time.
- Percent Renewable (% ZNE ) is the amount Renewable Electrical Production /(Total Electrical) x 100%

## B. Energy Retrofit

### 1. Reducing Airflow

| Annual Cost of Energy | | |
|---|---|---|
| Electrcity (kWh) | Building Gas (therms) | Chilled Water (ton-hrs) |
| $103,794.87 per year | $28,158.38 per year | $32,469.22 per year |

| Energy Cost | | | | |
|---|---|---|---|---|
| Vet Med 3B | Alt #1 = Traditional 6 ACH CAV system | Alt #2 = Vet Med 3B with unoccupied reset during the day | Alt #3 = full VAV with Aircuity | Alt #4 = full VAV with Aircuity |
| $1.25/sf | $1.81/sf | $1.16/sf | $1.10/sf | $0.61/sf |

| Original Energy Consumption | | | | |
|---|---|---|---|---|
| | Electrical Load | Cooling Load | Heating Load | Total |
| Energy (MBtu) | 4912.11 | 5487.76 | 3218.10 | 13617.97 |
| Dollars per year ($) | 103794.87 | 32469.22 | 28158.375 | 164422.47 |

| Reducing Airflow by Half | | | | |
|---|---|---|---|---|
| | Electrical Load | Cooling Load | Heating Load | Total |
| Energy (MBtu) | 2247.30 | 2743.88 | 1609.10 | 6600.22875 |
| Dollars per year ($) | 47486.38 | 16234.62 | 18880.5 | 82601.50 |

The approach used to reduce the baseline load of Ghausi Hall was to first reduce the airflow in the building. Reducing the airflow by half would allow Ghausi Hall to experience energy savings found in the Vet Med 3B building. If the airflow is reduced by half that means that the HVAC portion of the electrical load would be reduced by $(1/2)^3$ based on the fan laws that state that power is proportional to the cube of the fan speed. We are assuming that air flow is proportional to fan speed. The cooling and heating loads would be reduced by half based on the assumption of reducing the air flow by half, since the air flow is what mainly contributes to the generation of heating and cooling in the building. Reducing the air flow by half contributes to a total savings of $81,820.97 a year. This is estimated to be 50.24% reduction in dollars per year. The new total energy cost per year would be $82,601.50 instead of $164,422.47 from using the original airflow. The total energy would be reduced by approximately 48.47% by using this measure. The energy cost for Ghausi Hall would be $1.43 per square foot by adapting this air flow reduction. This is comparable to the energy cost in dollars per square foot for the Vet Med 3B building which currently stands at $1.25 per square foot. Additional measures can be taken to reduce the total energy consumption further. The smart lighting initiative phase 2 program is promising to reduce interior lighting of campus buildings in UC Davis by 50-60%.

Reference [6]-[13] are examples of active control of the HVAC systems and lighting based on occupancy. In some cases, they have reported up to 30% of saving in energy by implementing these control systems.

## 2. Eco-Analytics

A survey on the occupants' comfort levels and rooms' usage were conducted. Interesting result included

- About 50% of occupants report their rooms were either too hot or too cold at some point
- Room 1114 is primarily storage, occasionally researchers working on PCR stations for only an hour

- Room 3163 is too dusty. This results in most occupants working mostly from home.

The survey gives us an idea on the thermal comfort level of occupants not being met. It also shows that there are unutilized space in the building. Studies have been done by UC Berkeley on energy dashboards and incentive programs. This has proved to have some savings in some cases (reference [14]). Our current display of the electricity usage is static and not interactive. Future work will include more interactive sessions and give incentives for users to be engaged in saving energy for their building.

## C. Renewable Technology

### 1. Solar PV

Homer is used by our team to take into account of the loads, costs, onsite energy generation and other factors to study the feasibility of a path to ZNE for Ghausi hall using solar PVs. The grid rate, PV cost, project lifetime and other factors are taken into consideration. They are summarized in Table 1. Day by day electrical energy usage is provided by Josh Morejohn and is used as an input for our Homer model. The physical location (latitude and longitude) of Ghausi hall is also taken into account to provide the precise solar radiation intensity. The following data are used as the baseline case. A sensitivity analysis will be performed to see how any changes in these values will affect the project's feasibility.

On campus solar PV is done through PPA, which means we will provide space for solar PVs owned by a contractor. UC Davis will pay a fixed rate for the amount of energy generated onsite. Feasible onsite location for PV arrays are the nearby parking lots (P46 and P44). Net metering is assumed, thus any excess electricity will provide for other buildings on campus. This will result in a reduction in the total energy bill for UC Davis as a whole.

Net Present Cost and % ZNE are two metrics that are considered in selecting the size of the PV. Even though we assume the project is done through PPA, Net Present Cost reflects total project cost over the project life time that the contractor would have to pay. Thus it quantifies the feasibility of the project. The higher net present cost will make the project less feasible to pursue. Note that no tax credits are subtracted from this cost in our study. % ZNE in our Homer's model reflects the percentage of the electrical energy being produced onsite in the total electrical energy being consumed. Since we know the percentage of electrical load (36.1%) of the total load, this % ZNE can be converted to percentage of the total loads (electrical, cooling and heating). Thus it gives us an idea of how close we can get to 100% ZNE and at what cost we can achieve it.

| | Rate | Sellback Rate | Sources | | |
|---|---|---|---|---|---|
| Grid | $ 0.072 / KWh | Net metering | [2] | | |
| | | | | | |
| | Capital | Replacement Cost | O&M | Life Time (years) | Sources |
| PV | $4 / W | $4/W | $0.2 /W | 25 | [3], [4], [5] |
| Converter | $ 0.50 /W | $ 0.50 /W | 0 | 5 | [3], [4] , [5] |
| | | | | | |

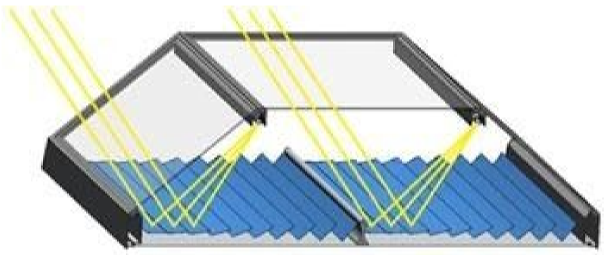
| | Interest Rate | Life Time (years) | Sources |
|---|---|---|---|
| Project Economics | 6% | 30 | Josh Morejohn |

*Table 1- Homer's Input*

## 2. Solar Thermal

An alternative technology worth pursuing in the future would be solar thermal. The use of solar thermal would be ideal since cooling and heating loads are large contributors to energy consumption and contribute to rising energy costs. This technology could possibly offset thermal building load of Ghausi Hall directly and more efficiently. Micro-concentrators from the company Chromasun are high temperature solar panels that can be easily integrated with thermal chillers and heat pumps. The Chromasun Micro-Concentrator is a high performance solar collector that can produce higher temperatures and efficiencies than a normal flat plate collector. The receiver of this collector has a coated stainless steel pipe that absorbs concentrated sunlight and does not lose heat. The receiver pipe allows for a heat transfer liquid to be circulated and heated. The pipe can receive up to 20 times concentrated sunlight and achieves a working temperature of up to 400 degrees Fahrenheit. There are currently some heat pump designs that can produce heating hot water and domestic hot water at 160% efficiency and at the same time output chilled water at 60% efficiency. The efficiency seen using solar-enhanced heat pumps is almost double the efficiency of tradition boilers. This combined heating and cooling system can have an efficiency of 220%, which can bring large savings on natural gas. These heat pumps can be supplemented with solar energy from the micro-concentrator solar collector to attain better performance. The benefit of using these heat pumps with either solar or natural gas means that the heating and cooling loads can be satisfied with solar during the day and natural gas during the night.

A current heat pump that is out on the market is the Helisorber absorption heat pump. The Helisorber's water heating efficiency is 65% higher than existing solar heating products. The free chilling that the Helisorber produces is a byproduct of the heating. Based on a study done in California, a 25-ton Helisorber can save 3.6 billion BTU per year on natural gas, and 148,750 kWh per year on electricity.



The use of Micro-Concentrators was highlighted in a case study featuring Santa Clara University. Sixty Micro-Concentrators were installed at the Benson Center, which features dining services and is similar to the Memorial Union in UC Davis. The panels that were installed should provide around 6,727 therms annually and heat water to 200 degrees Fahrenheit. The water-heating bills of the building are estimated to be reduced by around 70% by just heating water with solar energy instead of natural gas

# IV. RESULTS

Running Homer simulation produces the optimized size of solar PV arrays and their respective costs. Homer results are collected and plotted to represent project feasibility in terms of money for each PVs size. Each of the below plots can be used to study the feasibility of our project. Each plot corresponds to a fixed PV size. The blue curve represents the dollars money being saved per year by applying load reduction via energy retrofits. Load reductions of 10%, 20%, 30%, 40% and 50% are looked at. These reductions are feasible as described in energy retrofit section. The orange curve represents the project cost per year and the gray curve represents the % ZNE being achieved by solar PV arrays and load reductions.

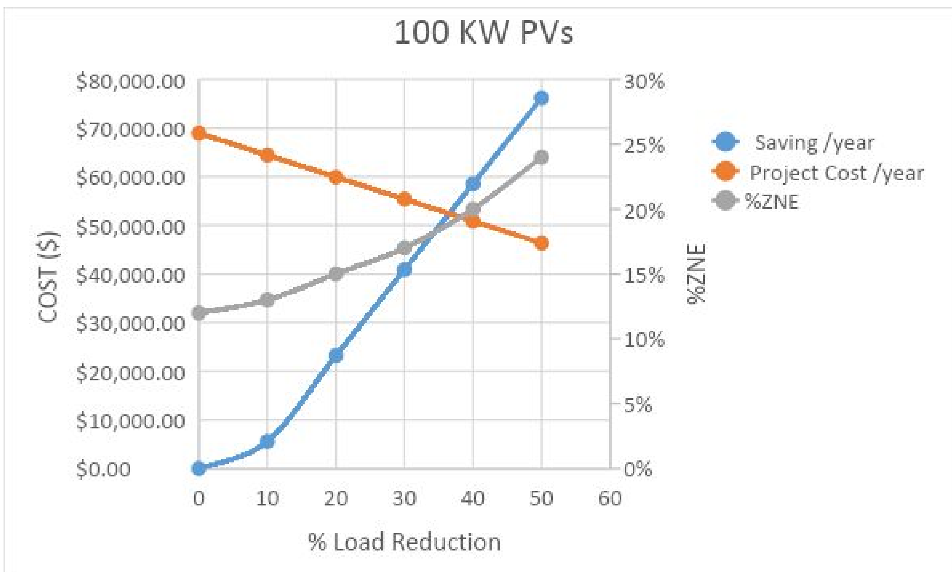



*Figure 3- 100 KW PVs*


*Figure 4- 200 KW PVs*

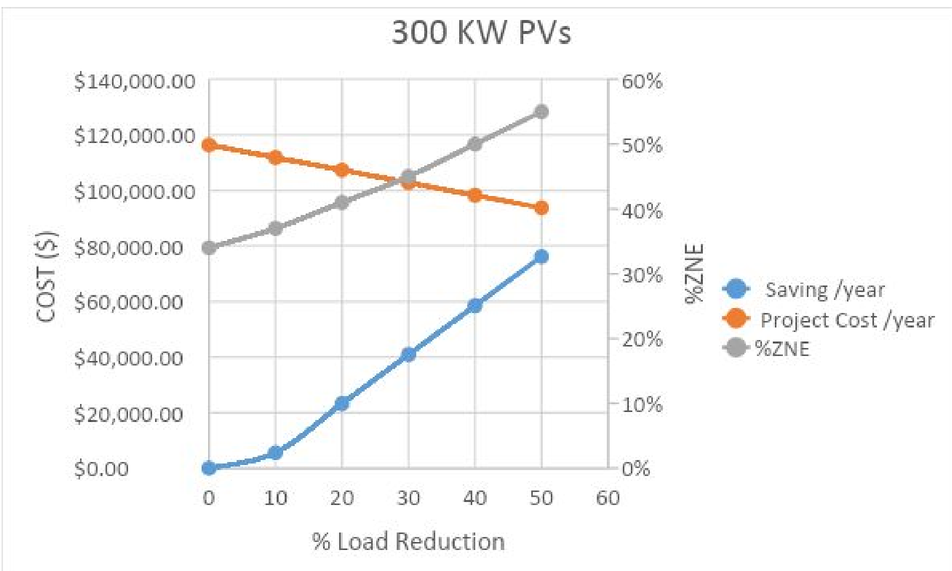



*Figure 5- 300 KWs PV*

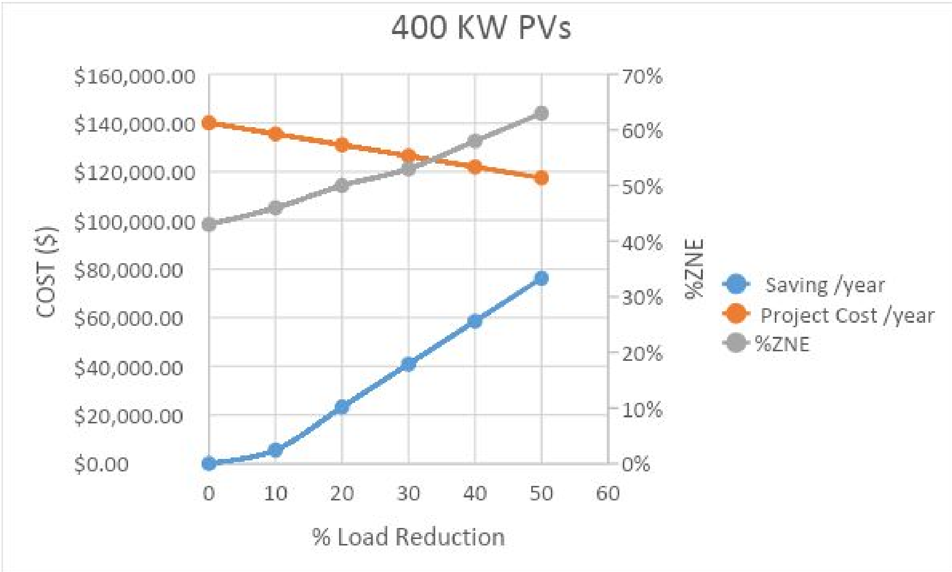



*Figure 6 - 400 KW PVs*

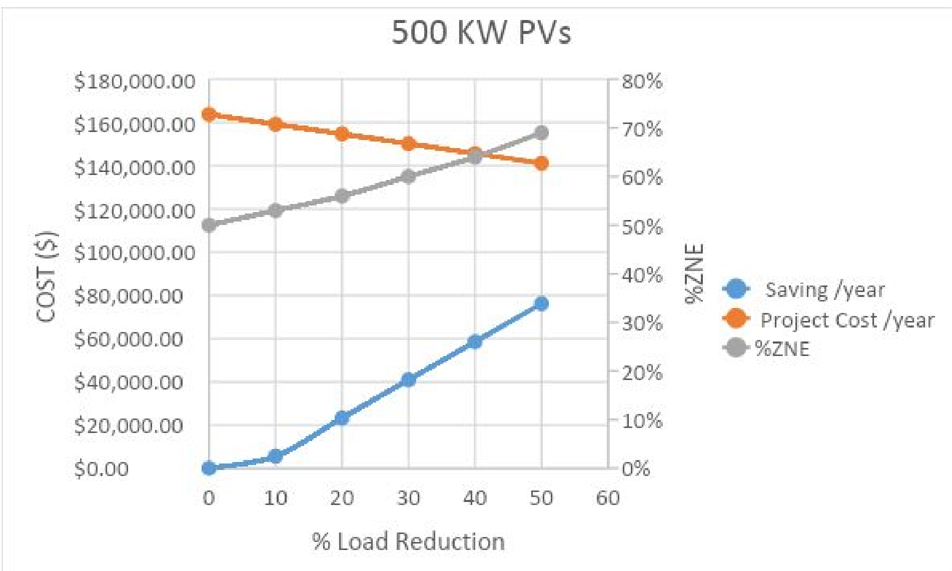



*Figure 7 - 500 KW PVs*

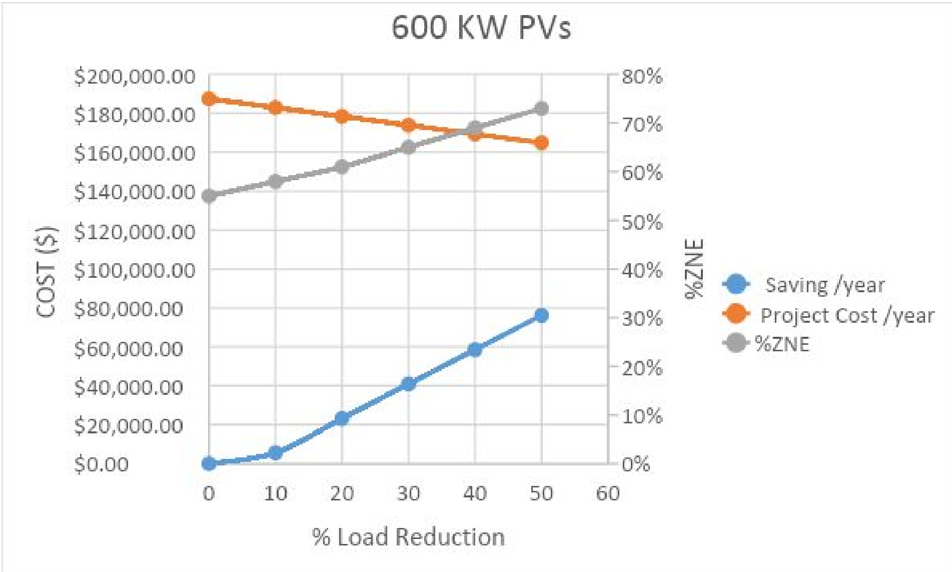



*Figure 8 - 600 KW PVs*

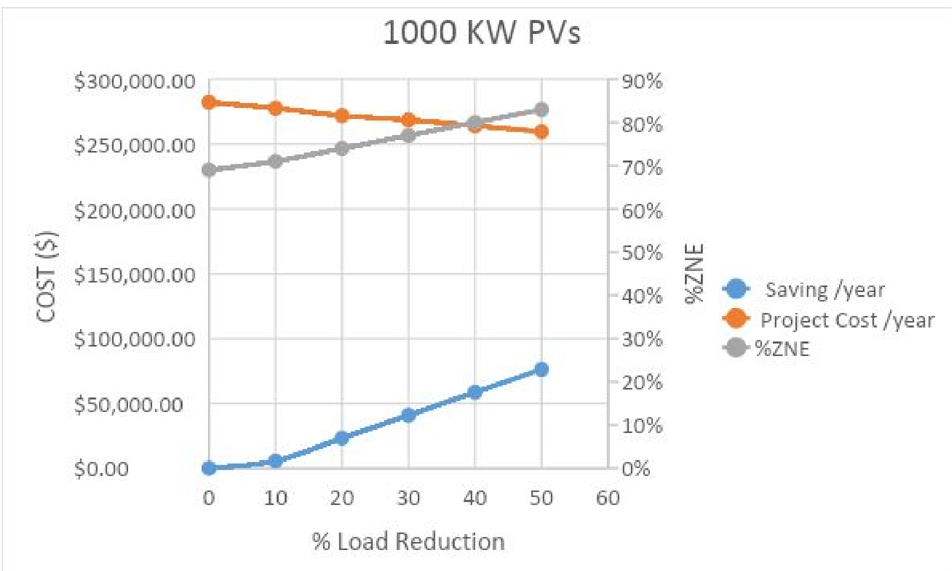



*Figure 9- 1000 KW PVs*

# V. DISCUSSION

The orange and blue curves' intersection are a point at which the annual saving by load reduction equals to the project. By implementing the energy retrofit up to that amount of load reduction, we will have enough money from the saving to implement solar PVs arrays that will provide up to a certain ZNE percentage.

Figure 2 gives the most feasible situation. At 50% load reduction, the saving is sufficient to cover the project cost to provide up to 45% ZNE using 200 KW solar PV. As the size of the PVs goes above 200 KW, the percent ZNE achievable increases. However, the project will require extra money because the blue curve and the orange curve never meets. The gap between these curves is the amount of extra money that the project will require. Figure 7 shows a potential amount of 85% ZNE for 1000 KW PV at a cost of about $150,000 a year. This is not a very feasible scenario because of such high cost. Unless more load reductions can be achieved and the prices of PV drop significantly, the path to ZNE for laboratory buildings will be a challenging one.

## VI. CONCLUSION / RECOMMENDATION

Our analysis is a rough approximation to study the feasibility of a path to ZNE for Ghausi hall. Net present cost and % ZNE are calculated by Homer. These values provide inputs to our spreadsheet to plot the feasibility curve in the result section. Since our load reductions calculation are roughly approximated, care must be taken when interpreting the results. The feasibility curve can be modified by changing inputs to the spreadsheet. The spreadsheet and the detailed process of running Homer will be emailed. Based on our assumptions and results, the path to ZNE for laboratory buildings will not be very feasible, at least at the mean time. Significant energy reduction and drops in PV prices will be needed to have a 100% ZNE building.

## VIII. Future Work

It would be beneficial to build a low cost occupancy sensor network in the future to understand the occupancy flow inside Ghausi Hall and change the temperature to a suitable temperature in real time. It is also important to make the building occupants aware of the energy use of the building and persuade them to use less energy as mentioned earlier. This can be done by improving on the energy dashboard interface that UC Davis currently has and making it more user friendly. Cooling and heating loads can be included in the interface instead of just electrical load data that is currently found on the energy dashboard. Furthermore, occupants could be required to take an energy training session that will allow them to become familiar in saving energy initiatives. Moreover, posters can be displayed around the interior of Ghuasi Hall in order to encourage occupants to save energy and not waste it.

## VIII. ACKNOWLEDGEMENT

We would like to thank Josh Morejohn and Kurt Kornbluth for providing us guidance on this project throughout the quarter.

## VI. REFERENCE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