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PHOTOVOLTAIC ROOFING SYSTEMS

INTRODUCTION

Photovoltaic roofing systems are becoming more common in both residential and commercial applications. The technology has received increased acceptance from facility managers and residential homeowners. Private developers have also begun to see the benefits of this technology as a way to make their product stand out in a competitive market. While most of the focus has been placed on new construction integration there is also a direct application for upgrade/renovation projects. The contents of this paper will focus on the feasibility of replacing an existing roof surface with a photovoltaic system.

The feasibility of this application will focus on a traditional residence hall complex located on the UC Davis campus. The Regan Complex was built in 1964 and is comprised of four 3-story buildings, three 2-story buildings and one community building. The Regan Complex is part of the larger residential area referred to as the Segundo Area. The seven residence hall buildings each have an occupancy capacity of 60 bed spaces in a traditional double-loaded corridor format with a community bathroom on each floor. Each residential building within the complex has a laundry room, kitchenette, TV lounge, and guest bathroom. The buildings are wood framed construction with stucco exterior, wood trim and clay tile sloped roofs. The central community building provides an apartment for the live-in staff member, 2 offices, 2 large study rooms, a TV area, mail room, guest bathrooms, kitchenette, and a maintenance shop.

During the summer of 2006 the Regan complex underwent a 5 million dollar infrastructure project which included replacement of all fan coil units, site hydronic piping, building hydronic piping, domestic water piping and installation of site fire sprinkler supply lines. This project has increased energy efficiency within the heating/cooling system by maintaining a two pipe system with upgraded fan coil units and controls. The two pipe system is fed from a mechanical room on-site. Eventually, this mechanical room will be taken off-line and the system will be connected to the campus steam/chilled water loop. This will bring additional energy efficiency as this “campus loop” system is very energy efficient and cost effective. During the summer of 2007 the complex will undergo another 5 million dollar project which will renovate all bathrooms and install the interior fire sprinkler system. With these two large investments, this 40 year old complex will have long life ahead.

Regan Complex Summary:

- Built 1964, wood frame construction
- Sloped roof with clay tile
- 4-3 story buildings, 3-2 story buildings, 1 community building, 1 mechanical room
- 86,166 gross square feet
- 420 resident occupancy
- Site map & Regan Main (Community Building), ***see attachment A***
- Building pictures with optimal exposures, ***see attachments B-E***

WHAT ARE THE SUSTAINABILITY CONNECTIONS?

Removing the existing roof surfaces on these buildings and replacing them with photovoltaic systems would be a sustainable practice. The roofs are old and in need of replacement. The moisture barriers are vulnerable and we have experienced water intrusions. We would be removing an existing product which has reached the end of its lifespan. A commitment to properly discarding, re-using and/or recycling the existing roof tiles would be initiated. The choice of replacement product would be driven by quality, anticipated lifespan, production process and potential integration of a photovoltaic energy system. If it is feasible to integrate an energy generating system into the roof we will be reducing the need for energy generated by traditional methods which increase air pollution and impact global warming. This practice would not only replace old roofs but it would add value in the form of energy and it would limit the negative environmental impacts resulting from using energy derived from fossil fuel.

If this technology is integrated into these facilities we would also look for ways to integrate it into the living communities. These communities are comprised of 18 year old freshman. This means we have a prime educational opportunity with future leaders. Integration of educational opportunities centered on this technology would enhance the "Place Making" which is already a part of this community. We have an existing community which is highly active, social, diverse and comfortable with easy walking and biking access to the campus and city. Photovoltaic energy supply could be the platform from which many other existing sustainable practices are high-lighted. This could literally and figuratively re-energize a 40 year old complex.

WHAT IS PHOTOVOLTAIC ROOFING?

It is important to first note the obvious; Photovoltaic energy systems are designed to convert natural sunlight into electricity. This is achieved by the capturing of photons from sunlight, converting the photons to DC power and then transforming this DC power to 120 volt AC power. In the most typical application this 120 volt AC power is then connected to the facilities' electrical system and also to the electrical grid providing service to the area. Some applications which may not be connected to the local electrical grid will require connection to batteries for power storage and back-up. Generators may also be in place for systems which are off of the electrical grid.

There continues to be on-going research and development within the science of photovoltaics. The most commonly used typologies are single crystal and multicrystalline silicon cells. It is estimated that 90% of the solar market is comprised of these typologies. Efficiency for these photovoltaics is measured by the ratio of the cell's actual electrical energy output to the available sun energy received by the panel. Commercially available solar cells typically range from 5 to 20 percent efficiency ratings. This low percent demonstrates two points. The first point is this technology even with such low efficiency rates, has an incredible impact and great ability to provide energy. The second point is there is much room for continued development and increased efficiency. As technology advances greater efficiency is expected. For sake of comparison a typical fossil fuel generator has an efficiency rate of ~28%. [2] It is possible that photovoltaics will some day be more efficient than fossil fuel generators. These two points as well as the overlying need to find alternative energy sources has provided continued growth to the development of photovoltaic technologies.

Research and factors such as manufacturer costs and aesthetics have pushed forward thin film technologies. Amorphous silicon is used in many thin film products such as United Solar Ovonics' UniSolar. [1] These thin film products are more easily manufactured and integrated into a great diversity of building materiel. Additional research is proceeding with nanocrystalline technologies, copper indium diselenide and cadmium telluride. [1] Some of these technologies have not yet produced products for the marketplace but it is anticipated that these future products will offer increased efficiency. It is important to also note that research is being done to determine if photovoltaic cells may be comprised of organic elements. Researchers believe organic photovoltaic products may be in the marketplace within the next 10-15 years. The concept of organic photovoltaics is based on the use of organic molecules which are described as "hair like". Researchers hope to adjust the electrons in an organic element resulting in the intended outcome of energy. Organic photovoltaics may offer designs such as fabric structures or any surface that can withstand a printing process. The potential benefits or organic photovoltaics would be lower cost, increased building integration, increased design flexibility and decreased thickness.

An example of thin film solar building integrated photovoltaic (BIPV) may be found in roofing shingles. These photovoltaic roofing shingles incorporate polycrystalline silicon which integrates with the roof shingle system. Another example of BIPV is the flexible solar roof panels which are amorphous silicon material. This product may be easily installed into a roof system. The advantages of using BIPV are cost may be offset as part of a roof replacement project; it is architecturally appealing and compatible with slate or masonry roofs. Concerns about BIPV systems which need to be assessed are roof load, shingle interconnection reliability and efficiency strains due to high temperature operation.

Aside from the solar power cells, another key component to a photovoltaic system is the solar power inverter. The inverter converts the power generated by the solar cells from DC power to AC power. The inverter also will match the converted AC power to the voltage and frequency of the electrical network. The inverter is also critical for the protection of the panel and allowing for safety during repairs and maintenance.

WHAT IS THE FEASIBILITY OF THIS PROJECT?

The research conducted for this paper has demonstrated enough initial feasibility for this project to warrant a formal feasibility study by either campus engineers or an outside consultant. The main issues or questions which need to be resolved are:

- Do these buildings provide appropriate roof square footage to house a PV system? I believe the buildings have enough square footage and are positioned with a strong enough southern exposure to warrant further investigation. Assessment of square footage and estimated kW production will allow for setting a percent goal for how much power can be provided to supplement the existing system. I also believe that the structures are strong enough to hold a variety of PV system options. These roofs currently hold the weight of clay roofing tiles. It may be engineered to replace these tiles with a lighter weight tile thus maintaining structural integrity.

- What would the best product be to use for this application? While it is my assumption that this would be a good application for a Building Integrated Photovoltaic (BIP) shingle system, I am not an expert and would want to seek an expert's recommendation. I am assuming that since the moisture barrier and tiles need replacement, a BIP shingle system may be cost effective and an architecturally pleasing option.

- How could this system be integrated into the entire Regan complex? It would be operational effective to connect all PV roof systems into the main mechanical room serving the Regan Complex. This would present easier tracking of the system and connection to the main grid. This would also allow for the buildings with better exposure to supplement those buildings with less than desirable exposure. This also would allow us to place photovoltaics on the Regan Main Community building which has good southern exposure. Energy generated at this location would supplement the entire complex.

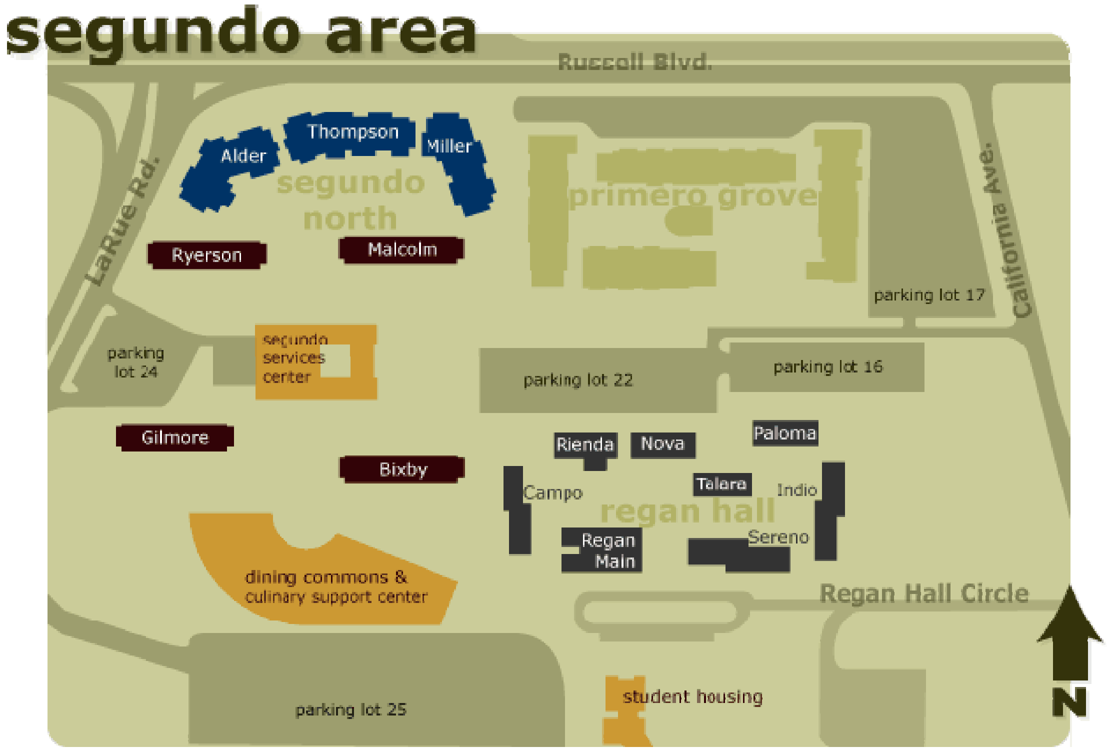
- What would the financial payback be? This would be evaluated along with consult from the campus' Utilities division. Utilities and Student Housing track kilowatt usage and cost so, this data is readily available. Currently, UC-Davis has an agreement with the Western Area Power Administration (WAPA) for 100% of its electrical supply. The current rate is .074 per kilowatt hour. This is a very competitive rate, in comparison the PG&E baseline rate is ~.119 per kilowatt hour. The current competitive rate agreement may make the financial decision a difficult one. This financial information would also allow us to assess the potential payback on the investment. The usage information would allow us to assess the amount of kilowatts needed to be generated from a photovoltaic system.

In conclusion, Student Housing will continue to evaluate the operational use of photovoltaic technology within a residence hall application. Currently, Student Housing has in operation solar pre-heating technology for domestic hot water. This is being used in Orchard and Solano Parks which are our family housing apartments. It is also being used to serve the Malcolm, Ryerson, Bixby and Gilmore residence halls. Student Housing has a photovoltaic operation in place which is serving a small group living community called the Co-ops. This is designed as a residential application. This has been in place for two years. It is the department's desire to further implement photovoltaics where it is operational feasible and financial prudent. The next step will be to more formally assess a photovoltaic application for the Regan complex by engaging professionals from the campus' Utilities Division.

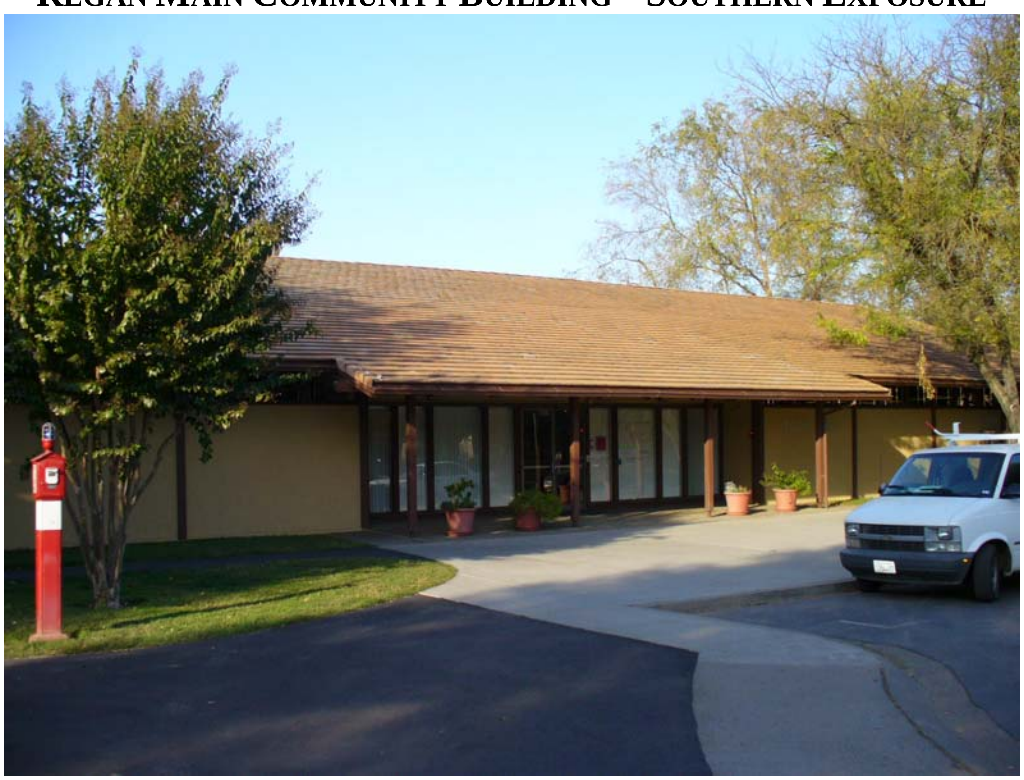
REFERENCES

1. Fortmeyer, Russell, (September 2006): *Selling the Light of Day*, **Architectural Record**.
2. U.S. Department of Energy Website, (October 2006), *Energy Efficiency and Renewable Energy*.
3. California Energy Commission, (March 2003), *Buying a Photovoltaic Solar Electric System: A Consumer Guide*, 2003 Edition/Handbook.
   Web access at http://www.energy.ca.gov/reports/2003-03-11_500-03-014F.PDF
4. http://www.smud.org/
5. http://www.pge.com/

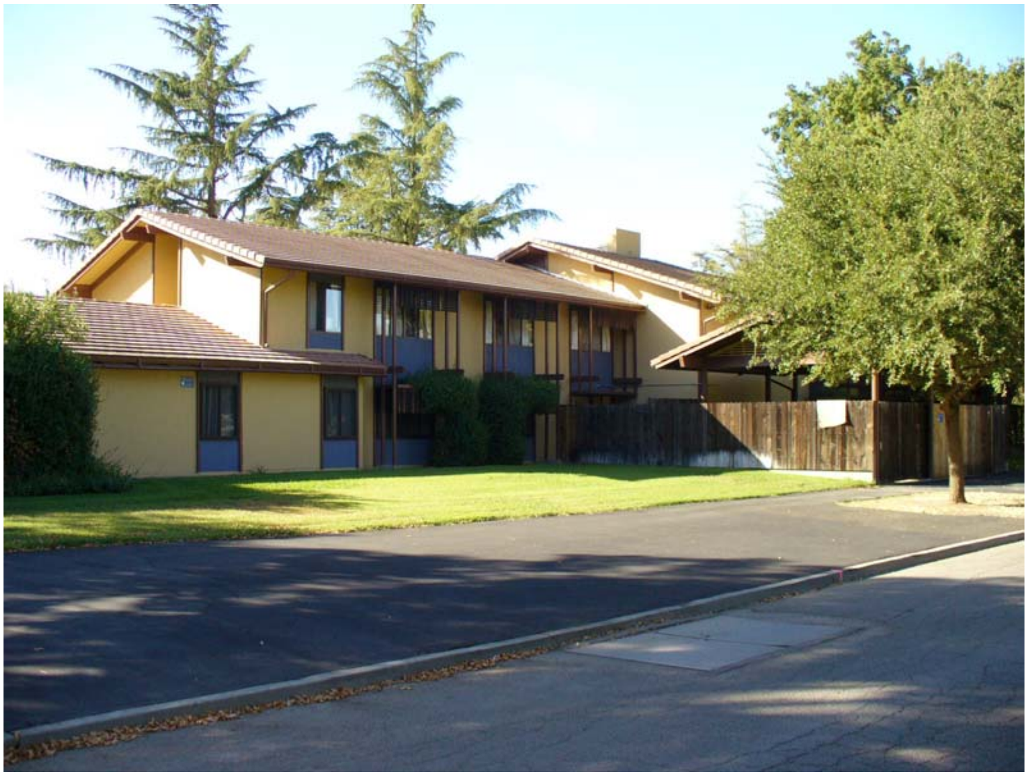
RESIDENTIAL AREA MAP – SEGUNDO AREA



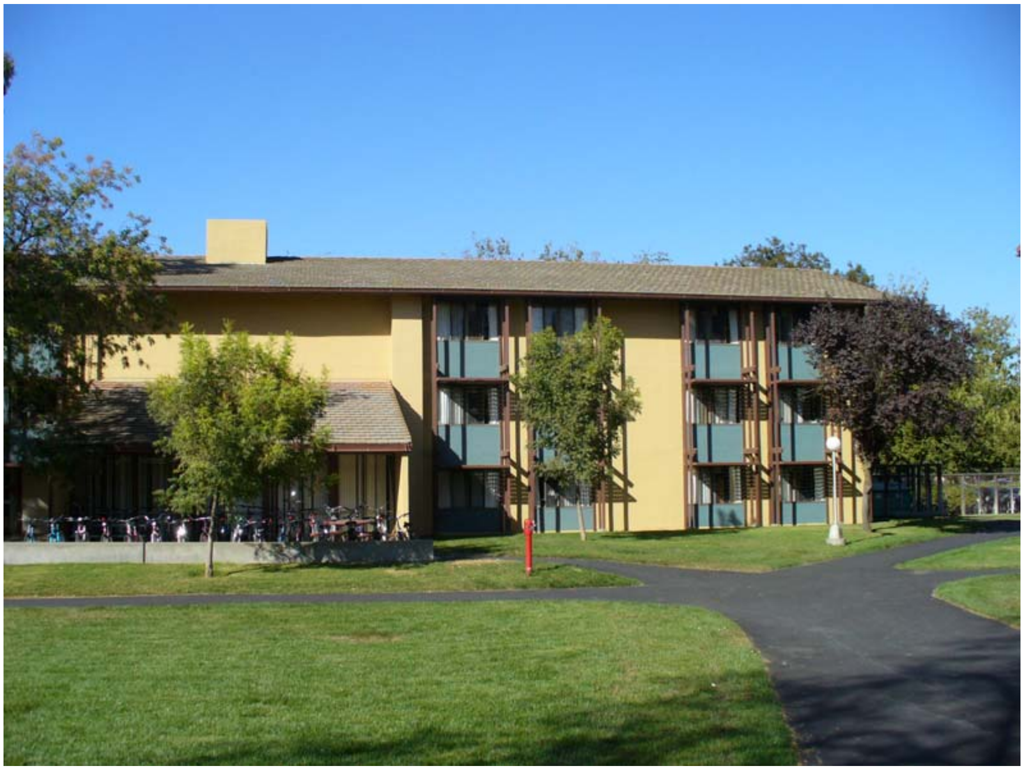
REGAN MAIN COMMUNITY BUILDING – SOUTHERN EXPOSURE



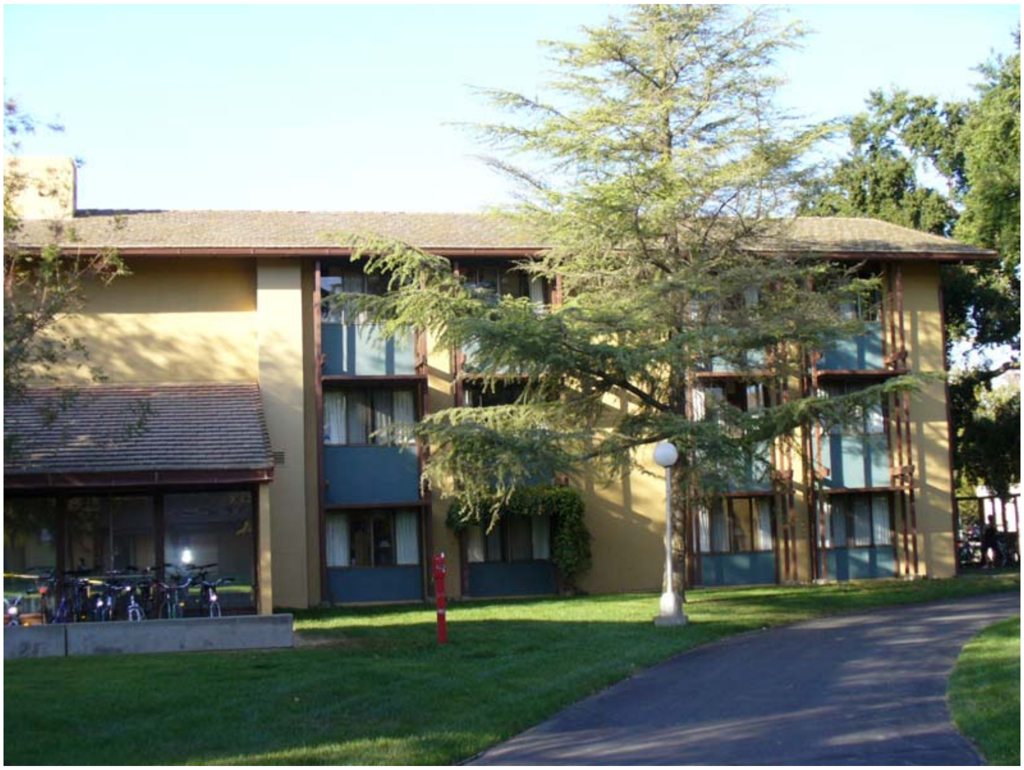
INDIO – EASTERN EXPOSURE



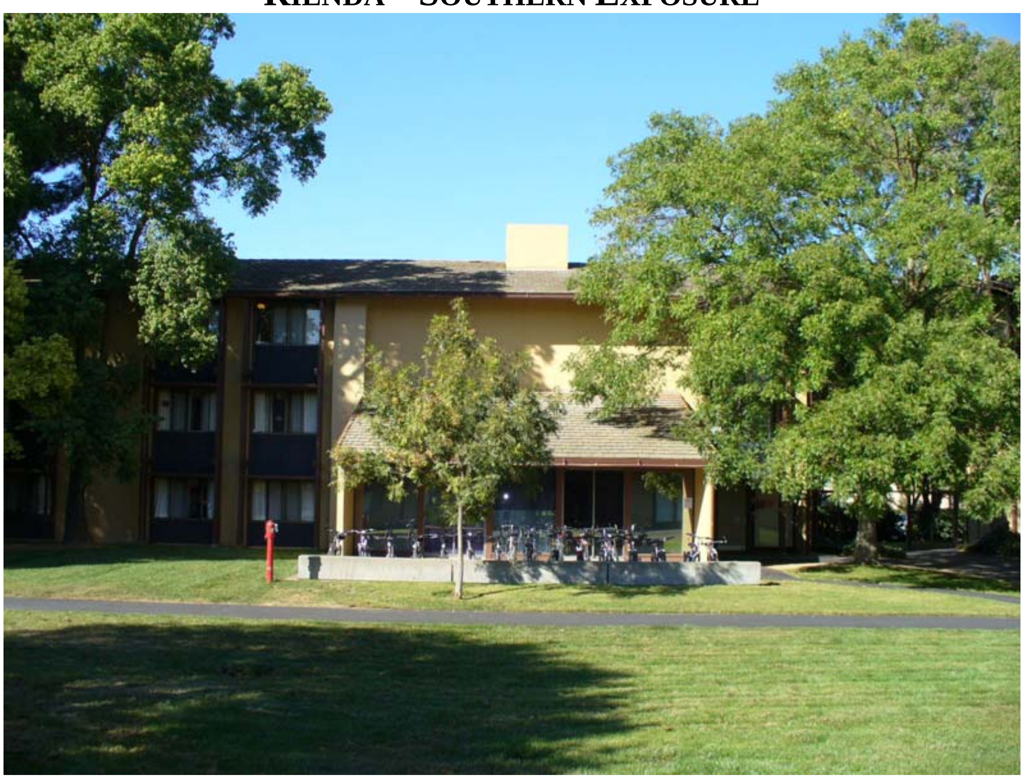
NOVA – SOUTHERN EXPOSURE



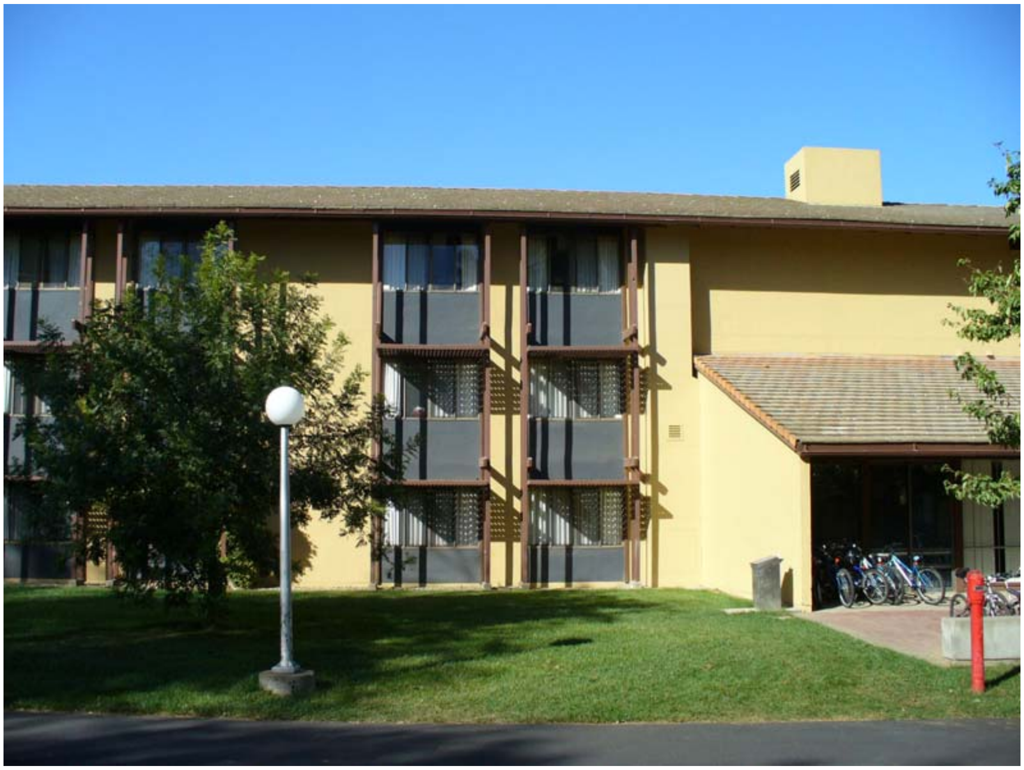
PALOMA – SOUTHERN EXPOSURE



RIENDA – SOUTHERN EXPOSURE



TALARA – SOUTHERN EXPOSURE



SERENO – SOUTHERN EXPOSURE

CAMPO – WESTERN EXPOSURE