**ABT 212 001:** A Path to Zero Net Energy

# Energy Efficiency at the University Retirement Community (URC)

By
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## 1. Project Background

Davis's University Retirement Community (URC) is one of many retirement communities styled to provide on-site medical services, a community similar to a university, and a quiet place to live. The URC was built in 2000 on five acres and has 277 full-service community units, serving around 600 meals a day. In addition, the URC has a 51-bed nursing center, a spa, indoor and outdoor swimming pools, and other amenities. The URC provides these amenities to over 400 residents ensuring their health and prosperity. To help them continue to offer their services at a stable price with the rising cost of energy and the ever-changing weather events, we will outline steps to achieve energy efficiency. Our goal is to complete an energy audit for the entire URC campus and recommend reducing energy consumption through energy efficiency upgrades and reducing unused load. We will also provide insights into options for adopting electric vehicle (EV) charging stations to prepare for the future demand for such.

### 1.1 Problem Description and Scope

The senior residents at the URC are quite vulnerable to increasing power demand and electricity prices due to their fixed incomes. The high variation in weather and car-friendly nature of Davis calls for radical changes in the energy efficiency sector of this senior community. The URC community has been working hard to meet their increasing power demand for running their day-to-day life while at the same time dealing with increasing utility prices. Their energy usage comes from heating, ventilation, and cooling (HVAC) systems, hot water and chilled water system, electric appliances, and current and future EV charging stations. Although several upgrades were made shortly after the URC was built, there are still many opportunities for the URC to reduce its power consumption. Our group will provide the URC with technologically and economically feasible options to better prepare for a lower energy footprint in the future while supporting California's energy goals, supporting tenants, and reducing costs. With a background in engineering, energy, physics, and environmental science, we have the tools to provide energy efficiency recommendations for a more efficient, reliable, and affordable retirement community.

### 1.2 Literature Review

Retirement homes have a constant demand for hot water, heating and cooling, and ventilation. They would benefit the most from energy-efficient technology to reduce the cost and greenhouse gas emissions for those demands (Mohammadpourkarbasi & Sharples, 2022). The two goals of our project are to increase the energy efficiency of the URC and to install EV chargers. EVs are associated with specified power demands whereas HVAC loads have unknown power demands which also contribute to ~50% of the energy consumption (Yu et. al, 2019).

To enhance the energy efficiency of a retirement community, certain cultural and economic challenges are put on residents that have a fixed income. A study by Xia et. al. suggests that satisfaction of people living in retirement housing is increased when sustainable practices are implemented and suggests that most residents recognize the need for sustainability in their lifestyle. However, affordability of both capital costs and maintenance costs. According to a survey conducted by Barker et. al. (2013), 54% of residents are concerned with the cost of energy supply, 92% think it is important to protect the environment, and 69% were worried about their building's impact on the environment.

## 2. Methodology

### 2.1 Energy Audit

We completed an energy audit for the entire URC complex specifically focusing on residence appliances, the HVAC system, hot water system, lighting, pumps, and generators. We sourced our information from photos and information we gathered during our two site visits. We then compiled them and individually researched each model number to find the specifications. We then assumed the hours per day each item was used to estimate the annual energy consumption. Our findings can be summarized in Table 1. Once the yearly energy consumption was calculated and the energy-saving recommendations were found, we calculated the simple payback time for the recommendations based on the cost of energy saved divided by the investment, without accounting for depreciation.

**Table 1:** Breakdown of the University Retirement Community's energy consumption

| Energy Source | Category | Total annual energy | % of total annual energy |
|---|---|---|---|
| Electricity | Lighting | 220,821 | 1.5% |
| Electricity | HVAC | 7,504,660 | 50.5% |
| Natural Gas | main kitchen and café (gas) | 157,607 | 1.1% |
| Electricity | Residence appliances | 4,244,630 | 28.6% |
| Electricity | Heat pump | 164,988 | 1.1% |
| Electricity | Generators/pumps | 60,600 | 0.4% |
| Electricity | EV chargers | 685 | 0.0% |
| Electricity | Pump | 1,395,483 | 9.4% |
| Natural Gas | Other | 462,056 | 3.1% |
| Electricity | main kitchen and café | 360,921 | 2.4% |
| Natural Gas | Water heater | 292,000 | 2.0% |

## 2.2 HVAC System: Existing Equipment Description and Analysis

The apartments make use of the water source heat pump systems for Heating, Ventilation, and Air Conditioning. In this system, water is circulated in a loop at $80^0$F. This water is heated by 3 Crest condensing boilers and cooled by a cooling tower to maintain the water entering and leaving the unit for optimal performance. Bell and Gosset pumps of 15 hp are used for circulating the water. Each floor is situated with 4 heat pumps, 2 in each wing, north, and south. The system also uses the Bosch FHP ES series and ADP water to air heat pumps for transferring the underground heat energy from hot water to the indoor air distributed through the building's ductwork. The Crest condensing boilers were installed in 2018 and are up to 96% efficient when programmed right. The cottages and garden units have the ACE split systems which include an outdoor unit or a compressor and an indoor natural gas furnace section. The outdoor unit is a 2-ton condensing unit by Carrier with a decent efficiency of 15 SEER.

Heat pumps can reverse airflow direction to transfer heat in or out of the home via a reverse valve built into the compressor. They move heat rather than generate heat, enabling stronger energy efficiency. The water source heat pump system is a better overall system than the split systems

## 2.3 Hot Water System

The URC has five main hot water draws, including hot water for the tenants, laundry, a restaurant, the 1,250 square foot swimming pool kept at $82^0$ F, and the spa kept at $100^0$ F (Figure 5). To maintain a hot water supply for the facility, the URC has a direct vent instantaneous water heater and two combined heat and power units.

The direct vent instantaneous water heater is located at the central plant and is heated by natural gas fuel combustion to serve domestic hot water. This type of heater enables lower water heating costs and provides a constant flow of hot water set at a preset temperature. Direct vent heaters bring air in from the outside and release combustion gases outside. When someone turns on a hot water tab, the heater immediately produces hot water. Although convenient, this water heater provides an easy way to increase energy efficiency while also keeping costs low. We will suggest a way to keep an instant supply of hot water in our recommendation section by using heat energy already present in the system and removing the water heater completely.

The community installed two combined heat and power units after the URC was built to reduce energy costs in 2000. They decided to install two in case of unscheduled maintenance that would require putting the URC load on the grid, resulting in the loss of significant energy savings all at once. They used Hess Microgen manufacturing for their CHPs to generate electricity with natural gas and heat water with the waste heat (Damberger, 2005). We believe the CHP units were installed to reduce the use of the gas boilers that heat the water when necessary. However, all other heating needs are compensated for by the direct vent instantaneous water heater.

## 2.4 Electric Vehicle (EV) Charging Infrastructure

California has begun aggressive targets for EVs in both personal and commercial sectors with Governor Newsom's Executive Order N-79-20 (Governor Newsom's, n.d.). N-79-20 mandates 100% of commercial and passenger vehicles to be electric by 2030. With the introduction of millions of EVs, infrastructure will become an unavoidable task.

To ensure that management has the time and resources to continue to provide their necessary amenities and attention to the residents, we considered partnering with a vendor to operate and manage the electric vehicle charging station. The vendor that was focused on was ChargePoint, as they have experience in multi-family and commercial dwellings and have infrastructure throughout California. The vendor is located on the PG&E-approved vendor webpage (Approved, n.d.).

The URC would be responsible for electrical upgrades and ensuring the site is installation ready. ChargePoint takes over with the installation of the charging stations and does the software and hardware installations onsite. The URC and a ChargePoint specialist will do an on-site walkthrough, make recommendations, and provide client-specific incentives information. The URC can choose two options: outright buy the charging stations for between $10-$14K and operate the stations themselves or utilize ChargePoint's full services and pay $2160 a year per station and pay $775 a year for Assure maintenance and management. The benefits of both are below in the results section. We also performed a cost-benefit analysis for installing two new level 2 charging stations at the URC with a minimum operating life of 10-years. We accounted for the cost of initial equipment, installation, regular maintenance, and electricity consumed during installation.

Level 2 charging stations provide a moderate charging speed, 4-8 hours for residential and commercial business purposes. Additionally, Level 2 is recommended for locations where people are parked for several hours, such as shopping malls, commuter lots, and downtown parking (Francfort & Brion Bennett, 2015). The station can be a smart meter that enables people to monitor electricity usage remotely and charge for fueling events, but it can lead to an additional $7000 cost. Although level 3 chargers provide a very fast charge, they are considerably more expensive and recommended for public spaces (Frades, 2014). Level 1 charging stations would not be adequate for a multifamily resident as they have charging times of up to 24 hours (Ai, 2016). The various charging stations and their total costs refer to in Table 2. However, this table does not account for a smart meter.

### 2.4.1 Assumptions and considerations

We assumed the newly installed 2 EV charging stations will be regularly used by the residents and their visitors. Another major assumption is that the electricity price would follow a trend of Levelized cost of electricity in Davis, California making it somewhat static for the 10 years of operation. It was also assumed that the maintenance costs and needs would be the same for 10 years and the charging points will operate throughout its lifetime.

### 2.4.2 Equipment and Procedures

A Basic parking lot charging station includes hardware equipment like a charging portal, weatherproof cables, and an electric meter. Smart metering that can enable people to monitor electricity usage remotely is optional and it can lead to an additional $7000 cost. Level 2 and Level 3 charging stations almost always require professional installation that may include demolition and adjustments of underground utilities or pouring concrete on the installed cables (May, 2009).

## 3. Results and Discussions

### 3.1 Energy Audit

Figure 1 represents the residential energy usage breakdown. We have found that the HVAC system and the residence appliances are the largest contributors to the URC's energy consumption. The residence appliances were largely estimated and there is likely error due to a lack of data on how many hours a day each of the 215 residents uses each appliance.

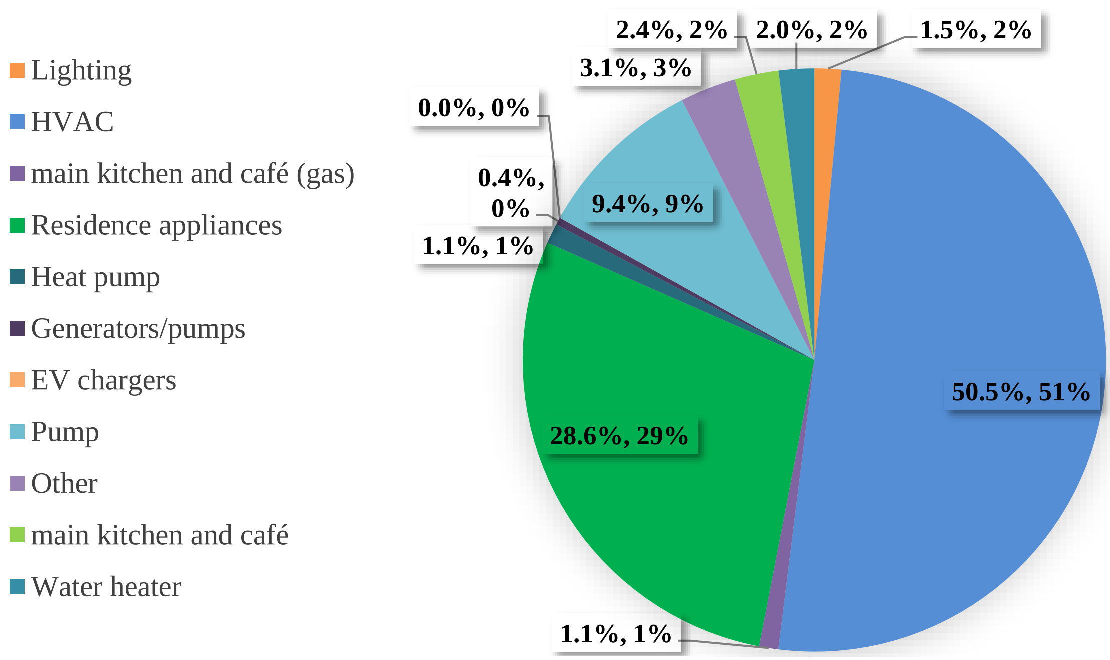


**Figure 1:** Breakdown of the University Retirement Community's energy consumption

However, there is a lot of room for improvement, especially in the HVAC system as discussed below. The HVAC system uses approximately 7,504,660 kBtu/year, accounting for 50.5% of the total load. The residence appliances use approximately 4,244,630 kBtu/year, or 28.6% (Figure 1). The smallest contributors to the load include the generators because they are only used when there is no access to other energy sources and the pumps which run at a low wattage. The current heat pump is also very efficient and uses very little energy.

We estimated that the main kitchen and café used the remaining energy unaccounted for in our audit because it was the main system. We did not have access to nameplates. This accounted for 2.4% of total energy or 360,921 kBtu/year. This estimate is likely less than the actual consumption, however, when looking at energy efficiency upgrades, the kitchen would not be in the top places to upgrade. The URC should consider performing a survey or speaking to residents about what appliances they currently use, which ones they think they could do without, and whether they are using them correctly. This could help save the URC money, potentially even reducing costs to residents without changing their lifestyles. This includes heat lamps that reside in many of the residents' homes that have not been removed yet.

### 3.2 Heating Ventilation and Air Conditioning (HVAC) System

The water source heat pump systems are an overall efficient system as compared to the split systems and we recommend keeping them. The other units in the system can be replaced at end of life. An investigation can be conducted to check whether all the units are running efficiently and if the current controls for the water loop are maintaining it at 80F. Heating and cooling at the same time can take up extra energy, which is not desirable. To avoid this, the boilers and the cooling tower need to be programmed correctly so that they are not running at the same time.

The natural gas boilers have been replaced recently around 3 years back. The new Crest condensing boilers are up to 96% efficient and they need not be replaced anytime soon. Once these boilers reach the end of life, they can be replaced with electric heat pumps. They provide three times more energy than they consume and they help reduce Carbon dioxide emissions thus providing better quality air to the residents and the neighborhood. However, they may incur a high installation cost of $13000 on an average which may cause a strain on some of the residents because of their fixed incomes. Various incentives can help address this issue. Defraying the cost of medium-efficiency heat pump technology can be achieved by industry training to reduce installation costs, research and development to lower technology costs, subsidies that prioritize higher-efficiency units, or rewards that incentivize net reductions in $CO_2$ emissions. Small reductions in capital costs and small efficiency gains can increase the acceptance rates among the residents.

The splits systems in the cottages and apartments can be replaced with ductless mini-split HVAC systems. These systems outperform the conventional system mainly due to smaller fan power consumption and they are more suited in hot climate regions like California. They can provide around 30 to 45 percent savings as compared to the conventional systems and their installation costs range from around $1800 to $7500. However, they are more suitable if there is no existing ductwork. If the original split system is ducted to multiple rooms, which it is in this case, we need to install multizone Ducted Heat pumps. Installing 4 Air handling units may cost up to $10000 for installation.

### 3.3 Hot Water System

The direct vent instantaneous water heater the URC currently uses consumes approximately 175,000 kBtu annually. This assumes the unit is on for three hours a day. We found that replacing this unit with an air-cooled heat pump would increase energy efficiency by approximately 30% and cut costs by almost half (Energy Saver, 2022). This switch would save money long-term with lower operating costs, and the upfront cost of replacement is similar to if they were to just replace their current water heater with a newer natural gas-powered one. In addition, heat pumps have a positive effect on the indoor environment by bypassing any indoor compassion emissions such as carbon monoxide, nitrogen dioxide, and fine particles. Our goal is to increase energy efficiency while also keeping up the standards of the retirement community. This replacement would increase indoor health, and reduce energy consumption while meeting hot water demand (Robbins, L., 2019).
An air-source heat pump is loud and when placing the unit, noise impacts on the residents need to be addressed as a potential for weather events that disrupt the proper function of the pump (such as strong winds which are common in Davis). The URC uses a cooling tower to release excess heat and uses a small pump to move the water through the system. This unit contributes little to the total energy demand at URC and it is not necessary to replace the pump or alter the cooling towers at this time.

### 3.4 EV Charging Infrastructure

The different types of costs and benefits associated with EV charging stations were obtained from (May, 2009) and they were adjusted to current costs. Tenant attraction, employee attraction, corporate branding, fleet cost savings that is resulted from avoiding commuting to a charging station located further away from the complex, advertising opportunities, etc. are a few of the benefits that we considered. Figure 3 and 4 in the Appendix shows that with the current investments associated with EVs and the Levelized Cost of electricity it will take about 5 years to reach the break-even point for 2 level 2 smart chargers. With an initial investment of around $15,000 and a payback period of five years, this solution is a good investment. However, these numbers are with the assumption that the stations are frequently used.

This payback period could be higher if the station is not used regularly, and with the current demand for charging stations being low, this possibility could be a reality and should be considered. Additionally, a smart charging station is vital to ensure that residents who do not own an electric vehicle are not burdened with the electricity fee of the charging events of the station.

The two charging points can be installed near the front entrance in guest parking spots (Figure 5) so that they can be available to the visitors.  Other benefits like LEED Certification, increased energy independence, etc. were excluded from this analysis.

Although we believe, that installing EV charging infrastructures can be beneficial and cost-effective for the URC community in the long run, we need to keep in mind the sources of uncertainties. Some of these uncertainties with EV charging infrastructure can be the price of electricity, maintenance, cost of maintenance, and cost of infrastructure upgrades needed. With the partnership, the cost of infrastructure is unknown. This includes the behind-the-meter infrastructure costs that may be needed for installation. After a site visit with the ChargePoint specialist, this uncertainty would become known.

## 4. Recommendations and Conclusion

### 4.1 Recommendations for Energy Audit

The cost and simple payback period can be seen in Figure 2. The variable frequency drive (VFD) has a simple payback of .44 years. This could be greater depending on if the pump or motor would need to be upgraded but the cost to savings is still significantly good and highly recommended. The simple payback period for the occupancy sensors for the common areas is .5 years. If more sensors were installed the payback period would increase but it would remain a very good simple payback and a good investment for reducing energy consumption. The simple payback period for replacing the natural gas boilers with electric heat pumps is 4 years.

### 4.2 Recommendations for the HVAC System

- **Replace boilers with electric heat pumps:** They can provide three times more heat energy than they consume and help reduce $CO_2$ emissions thus, providing better air quality. However, they may incur a high installation cost of $13,000 on average with a simple payback period of around 4 years.
- **Use of ductless mini-split HVAC systems,** as they outperform the conventional system mainly due to smaller fan power consumption and they are more suited in hot climate regions like California. These systems provide 30-45% energy savings compared to conventional systems and their installation costs range from $1800 to $7500. Multi-zone DHPs may cost up to $10,000 for installation.
- **Low-cost control strategies**
    - Investigate whether the current controls for the water loop are maintaining it at $80^0$F based on heating or cooling mode.
    - Heating and cooling at the same time take up extra energy. The boilers and cooling towers need to be programmed correctly and avoid running them at the same time.

- An investigation can be recommended to see if their sequence and setpoints need to be optimized for further efficiencies. Adjusting setpoints can help save up to 30% energy on an average.

**4.3 Recommendations for the Hot Water System**

- **Replace the direct vent instantaneous water heater** with an air-cooled heat pump when it reaches the end of life. An air-cooled heat pump can provide up to three times the amount of energy to your home as it consumes, requires less maintenance, and saves an average of around $412 a year per pump by energy conservation. Before switching, additional research is necessary to see which type of pump is best for the URC based on the ideal placement location, available space, and flow rate.

- **Source energy from the grid.** When microgenerators are at their end of life, the URC should instead source energy from the grid. This means that the URC can still keep their original split system and further reduce their energy footprint as the grid adds more renewable energy. The URC has a smaller risk in purchasing electricity from the grid as more renewables are put into place.

- **Replace boilers with electric boilers.** This change will push the URC in the right direction as California works to decarbonize and electricity buildings. By replacing the boilers now, the URC will already be prepared for necessary changes in the future and reduce their CO2 emissions by approximately 21% as seen in other studies (Jibran, M., 2021).

- **Install variable frequency drive on pool pumps.** Reducing the water circulation during non-occupancy would greatly reduce the pool's energy consumption and provide significant energy savings.

**4.4 Recommendations for the EV Charging Infrastructure**

Partnering with ChargePoint with the ChargePoint Assure maintenance and management warranty for one dual-port charging station with a 5-year term would provide the services of EV charging stations without the anxiety and stress of managing it. To ensure the charging stations run optimally, we would suggest placing them towards the entrance in the visitor parking to avoid invading a resident's assigned parking space. This also allows tiered charging fees, with different prices for residents and staff than for visitors. Having tiered charges eliminates an increase in utilities for residents, and those that do use the stations will be charged for their consumption, so those who do not will not be subsidizing them. Another recommendation would be to fully own and operate two smart level 2 charging stations in the visitor parking spaces that are grid-connected to optimize government subsidies and incentivize low-emission charging behavior. Providing residents with EV charging stations is a vital tool in the step towards California’s 100% EV on the road by 2035 and provides residents with a convenient location for charging their vehicles.

The benefits of partnering with a PG&E-approved vendor would allow for ease and the possibility of future expansion. ChargePoint offers a variety of charging stations. The station recommended for multi-family dwellings is their dual-port CT4000 charging station. If the Assure maintenance and management plan is chosen, some benefits include the following (Service-Support-BR-EN-US.Pdf | Powered by Box, n.d.).

Some of the benefits that are offered by ChargePoint are,

- Personalized pricing
- Accurate site qualifications, and quality preparation
- Hardware and software upgrades included
- Individualized plans
- Online access to control and performance reviews
- In-network technicians
- Unlimited software configuration changes
- Coverage of repairs for vandalism, abuse, and accidents
- The owner receives the revenue from the stations
- 24x7 proactive station health monitoring with remote troubleshooting and support

### 4.5 Conclusion

In conclusion, we believe, that emphasizing energy efficiency and improvement is crucial for ensuring the energy security and sustainability of the University Retirement community. Even though activities like replacing older equipment and installing EV charging infrastructure may be associated with a comparatively high initial investment, they have a smaller simple payback time and can improve the energy security immensely in the long run. We also have taken equity into consideration in our study and wanted to make sure all the recommendations that we have provided are feasible and economically viable. To sum this up, both the community’s and residents’ satisfactions are necessary. So, to improve the energy security and efficiency as a community, the University Retirement Community will be benefitted by looking more into the past and present issues they have been facing and focusing on adopting newer and more effective approaches like the ones proposed in this study.

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## 6. Appendices

**Table 2:** Estimation of EV charging station costs per EV Charging point in California

| Charger type | Time to fully charge | Equipment cost | Installation cost | Total Cost |
|---|---|---|---|---|
| **Level 1** | 8-24 hours | $450 – $950 | $0 – $500 | $450– $1,450 |
| **Level 2 (home)** | 4-8 hours | $490 – $1,200 | $300 – $2,000 | $790 – $3,200 |
| **Level 2 (Public)** | 4-8 hours | $1,875 – $4,500 | $1,000 – $10,000 | $2,875– $14,500 |
| **Level 3** | 30 minutes | $17,000 – $44,000 | $7,000 – $50,000 | $24,000 – $94,000 |

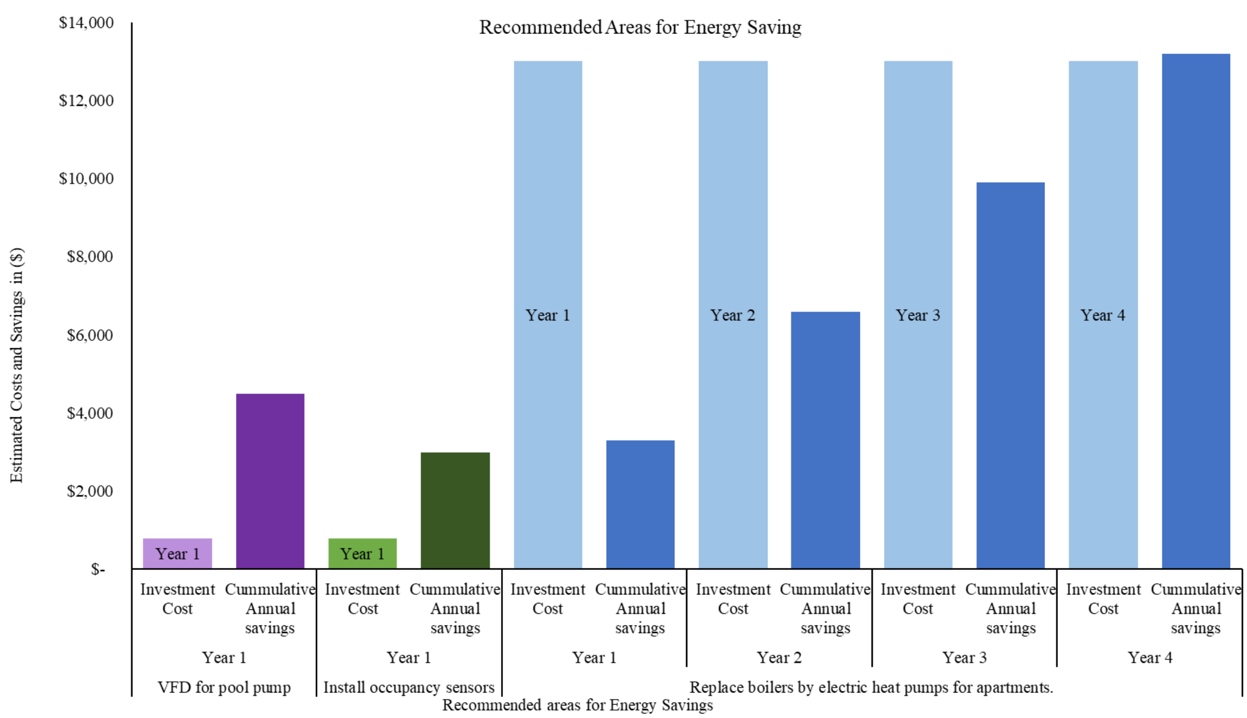


**Figure 2:** Recommended energy efficiency cost and annual savings.

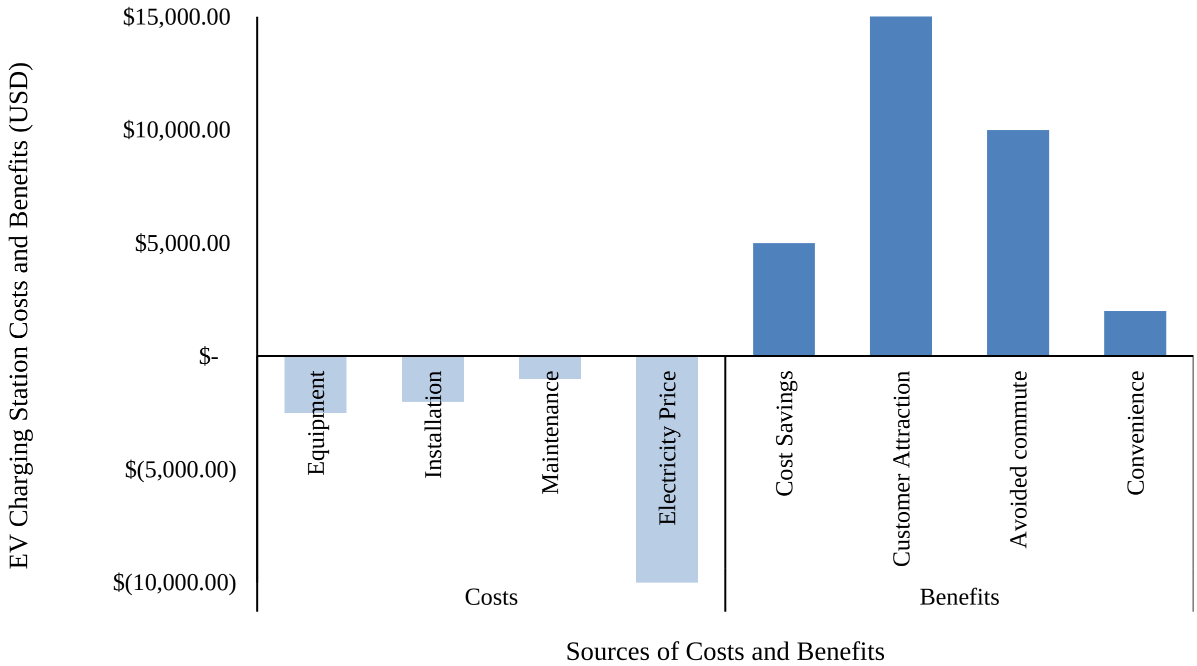


**Figure 3:** EV Charging station installation and operation in 10 years lifetime

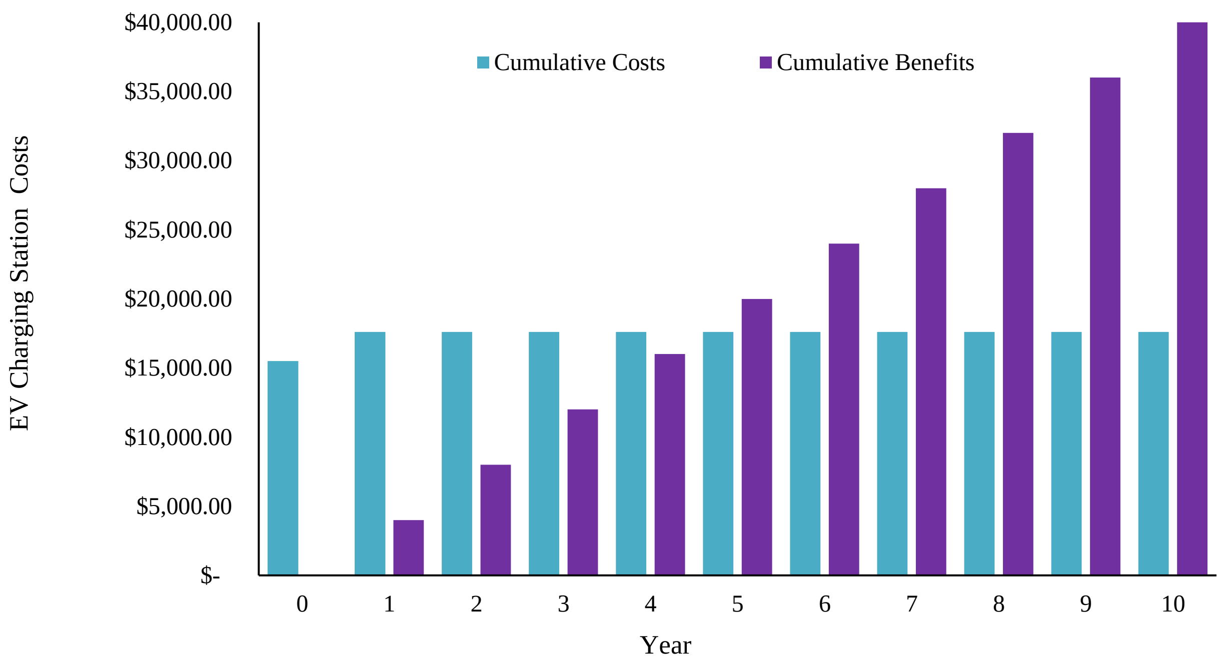


**Figure 4:** Cost-Benefit analysis of 2 smart EV charging station installations at URC parking structure with a Payback period of 5 years

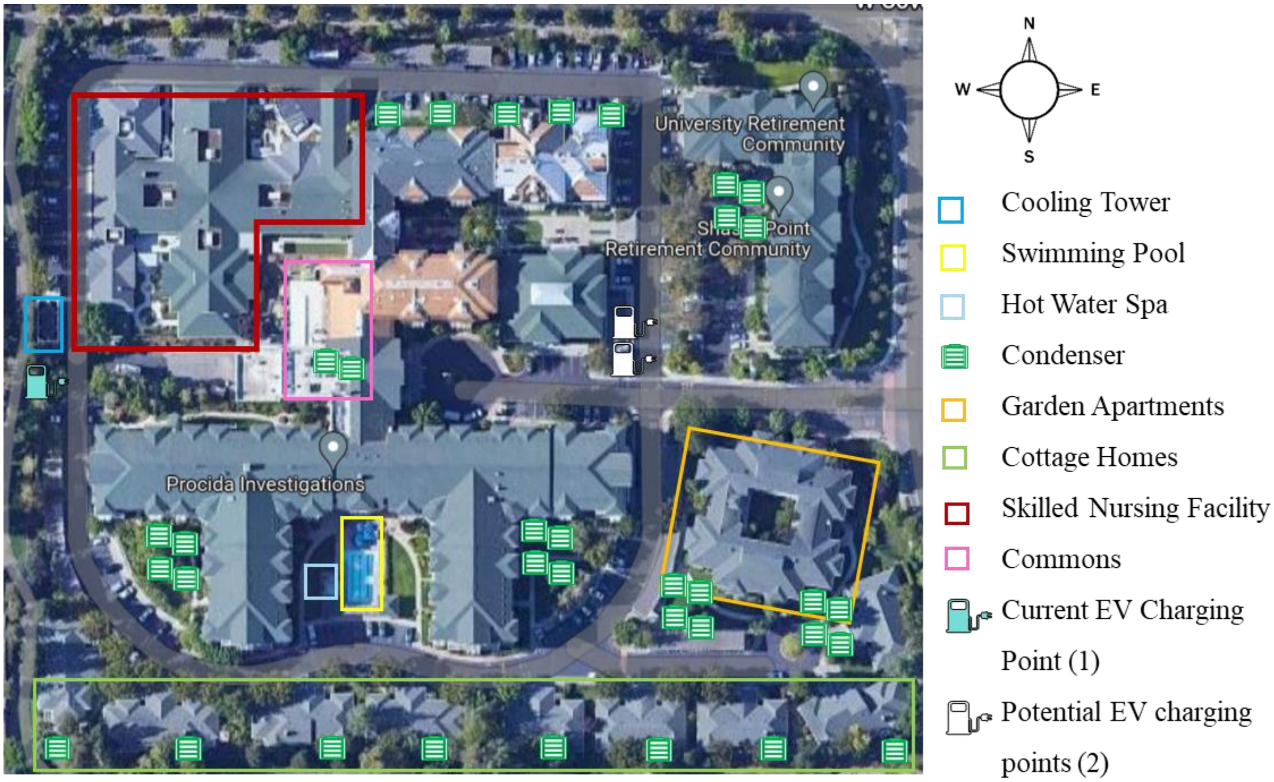


**Figure 5:** Layout of URC complex showing major infrastructural facilities