0. Introduction

We are pleased to submit the following Draft Report of findings for our review of retrofit potential for the Kaua’i Police Facility (KPF). This report builds upon site visit observations taken between June 6 and June 10, as well as building performance data collected for June 11–July 31. This report constitutes Deliverable 3 in the Agreement for Services dated April 17, 2014.
The scope of this study is limited in terms of its time and effort but is also ambitious in that it addresses multiple aspects of building performance. This report thus collects a set of observations and evidence that may be indicative of building performance. Further study would be necessary to fully diagnose performance issues and to rank potential retrofits in terms of their economic pay back period.

This report includes four sections that present our findings. The first section provides an overview of the research plan. The second section summarizes observations made during an initial site visit to the facility at the time when the monitoring equipment was installed. The third section summarizes data collected for energy use and thermal comfort. The fourth section discusses potential building retrofit opportunities that make sense given the observations, measured data and our knowledge of the building relative to contemporary best practice. An appendix provides detailed plots of daily profiles for individual temperature, humidity, and energy monitoring points.
1. Research Plan

In order to make an informed set of recommendations for improving energy performance, we established a research plan to study the performance of the building in its current state. The plan incorporates a number of methods in order to achieve a breadth and depth of research within a limited budget. First, a site visit was conducted in order to observe characteristics of the building envelope and program, to speak with occupants and building operators regarding indicators of performance, and to take spot measurements to understand a snapshot of performance at the time of the visit.

To complement the information gathered during the site visit, we established a monitoring plan to measure performance over time in order to understand the daily and weekly variations and patterns exhibited by the building and its operation. We monitored the major energy end uses: HVAC energy, lighting energy, and other (receptacle) energy. In addition, we monitored air temperature and relative humidity components of thermal comfort, temperature indicators of system performance, and occupancy.

The Kaua'i police facility is a challenging building to study as a whole since it has a variety of use patterns and intensities associated with it. In recognition of a limited time and equipment budget, we focused the monitoring efforts on the East wing of the building and designed the plan to help reveal specific aspects of building behavior. For energy, this meant that we did not monitor panels or circuits feeding the west wing of the building (with the exception of chiller energy, which we monitored at the whole building level). While we are not able to quantify specific lighting or equipment energy use in the west wing, the difference between utility bill data and energy use data as monitored gives a ballpark indication of the combined magnitudes of these missing values.

For comfort and occupancy, we focused on a smaller subset of spaces in the east wing. The systematic measurement of two similar office spaces gives a cross section of the building that helps reveal aspects of the envelope and HVAC system thermal performance. While other spaces may have drastically different occupancy patterns and use intensities, the envelope and the HVAC system is consistent across most spaces, so the lessons learned in the study spaces can provide context for studying performance in other spaces as well.

Energy Monitoring

HVAC energy, lighting energy, and other (receptacle) energy were measured at a variety of electrical panels using current transformers connected to one of three power monitoring meters which transmitted data to data gateways installed on the local area network (LAN). The data gateways were configured to gather and upload data to a cloud-based server at a 5-minute interval.

<table>
<thead>
<tr>
<th>sensors:</th>
<th>Continental Control Systems ACT Series Split-Core Current Transformers</th>
</tr>
</thead>
<tbody>
<tr>
<td>power meter:</td>
<td>Dent Powerscout 24</td>
</tr>
<tr>
<td>data gateway:</td>
<td>Obvius Data Acquisition Server</td>
</tr>
<tr>
<td>data hosting:</td>
<td>L+U Monitoring</td>
</tr>
</tbody>
</table>
Each of these energy end uses was calculated as a combination of energy monitored on at least two circuits, since no one circuit supplies any particular end use exclusively. The following circuits were measured. See Appendix for detailed profiles of these measurement points.

<table>
<thead>
<tr>
<th>label</th>
<th>description</th>
<th>end use(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH1</td>
<td>chiller 1 feed</td>
<td>whole building HVAC</td>
</tr>
<tr>
<td>CH2</td>
<td>chiller 2 feed</td>
<td>whole building HVAC</td>
</tr>
<tr>
<td>4E1EA</td>
<td>panel feed</td>
<td>lights, HVAC</td>
</tr>
<tr>
<td>EOC Lights CCT1</td>
<td>lights circuit 1</td>
<td>lights</td>
</tr>
<tr>
<td>EOC Lights CCT2</td>
<td>lights circuit 2</td>
<td>lights</td>
</tr>
<tr>
<td>EOC Lights CCT3</td>
<td>lights circuit 3</td>
<td>lights</td>
</tr>
<tr>
<td>EOC Lights CCT4</td>
<td>lights circuit 4</td>
<td>lights</td>
</tr>
<tr>
<td>EOC Lights CCT5</td>
<td>lights circuit 5</td>
<td>lights</td>
</tr>
<tr>
<td>EOC Lights CCT6</td>
<td>lights circuit 6</td>
<td>lights</td>
</tr>
<tr>
<td>EOC Lights CCT7</td>
<td>lights circuit 7</td>
<td>lights</td>
</tr>
<tr>
<td>CRAC E1</td>
<td>computer room air conditioner</td>
<td>HVAC</td>
</tr>
<tr>
<td>CRAC E2</td>
<td>computer room air conditioner</td>
<td>HVAC</td>
</tr>
<tr>
<td>SF 11</td>
<td>supply fan</td>
<td>HVAC</td>
</tr>
<tr>
<td>EF E11</td>
<td>exhaust fan</td>
<td>HVAC</td>
</tr>
<tr>
<td>VAHU E12</td>
<td>variable air handling unit</td>
<td>HVAC</td>
</tr>
<tr>
<td>4E1NA</td>
<td>panel feed</td>
<td>lights</td>
</tr>
<tr>
<td>4E2NA</td>
<td>[all circuits are monitored, so feed is not]</td>
<td></td>
</tr>
<tr>
<td>Lights 2E3 CCT1</td>
<td>lights circuit 1</td>
<td>lights</td>
</tr>
<tr>
<td>Lights 2E3 CCT2</td>
<td>lights circuit 2</td>
<td>lights</td>
</tr>
<tr>
<td>Lights 2E3 CCT3</td>
<td>lights circuit 3</td>
<td>lights</td>
</tr>
<tr>
<td>Lights 2E3 CCT4</td>
<td>lights circuit 4</td>
<td>lights</td>
</tr>
<tr>
<td>Lights 2E3 CCT5</td>
<td>lights circuit 5</td>
<td>lights</td>
</tr>
<tr>
<td>Lights 2E3 CCT6</td>
<td>lights circuit 6</td>
<td>lights</td>
</tr>
<tr>
<td>EF 21</td>
<td>exhaust fan</td>
<td>HVAC</td>
</tr>
<tr>
<td>VAHU E21</td>
<td>variable air handling unit</td>
<td>HVAC</td>
</tr>
<tr>
<td>VAHU E22</td>
<td>variable air handling unit</td>
<td>HVAC</td>
</tr>
<tr>
<td>XFMR E1 2E1NDP</td>
<td>East normal 240V distribution panel</td>
<td>equipment</td>
</tr>
<tr>
<td>XFMR E2 2E1EDP</td>
<td>East emergency 240V distribution panel</td>
<td>equipment and server (HVAC)</td>
</tr>
</tbody>
</table>

Space Monitoring

The following sensors were used to monitor thermal conditions and occupancy:

- **temperature probes**: Onset HOBO TMC6-HD
- **temperature and humidity loggers**: Onset HOBO U12
- **occupancy sensor and loggers**: Onset HOBO UX90
Temperature and occupancy were monitored in spaces on the north and south sides of the second floor of the east wing. These spaces were selected to capture building behavior from north to south (including perimeter and core conditions), while minimizing differences due to space configuration and program. The spaces selected are open offices with cubicles. Sensor locations are noted in Figure 1.

Figure 1: Floor plan intentionally removed for public report
2. Site Visit Observations

During the site visit, we noted a number of observations that indicate potential issues with building performance. We summarize these here.

Envelope

We found multiple indicators that the building envelope is performing poorly. These indicators include:

- Occupants reported that the interior conditions of the building track seasonal changes in weather. This is quite surprising given that the building is fully enclosed and contains no natural ventilation in regularly occupied areas. We found no evidence to suggest seasonal changes in HVAC operation. This suggests that the building envelope is fairly conductive if occupants are aware of seasonal change in the mild Kaua’i climate.

- Occupants in the northeast side of the east wing complained about Monday mornings being particularly uncomfortable as a result of the building being warm throughout the weekend. At the time they complain about the overheated conditions, the unshaded east facade would also be exposed to direct sun.

- Infrared (IR) images showed a very warm interior surface temperature for glazing. For instance, one IR image shows a window surface temperature of about 82°F, compared with a room temperature of about 68°F. Windows are thus both a major source of conductive heat gain as well as a potential source of thermal discomfort for occupants.

- IR images also showed thermal bridging through wall framing elements, but this effect appeared to be smaller than thermal conduction through windows.

- While extensive exploration of roof insulation was not possible, we did note that the insulation in the central attic space was compacted and had a number of gaps. Thermal gains through the roof are potentially exacerbating cooling loads.

HVAC

- Occupants have a particularly wide range of thermal comfort criteria. Some occupants are civilians (ie, they wear typical clothing, often including short sleeves and open sandals) who tend to stay seated at a desk (ie, they have a low metabolic rate) for much of the work day. Other occupants are police officers in uniform (long sleeves, slacks, an armored vest, and shoes with socks) who are fairly active throughout a work day (higher metabolic rate). The result is that there may not be any set of thermal conditions under which both groups could be comfortable. We noted that this manifested itself in a variety of thermostat settings and measures taken to keep thermostats set to particular settings.

- Occupants in the first floor commented that the spaces are uncomfortably cool during the vast majority of the time, with temperatures becoming comfortable only occasionally, when spaces approached peak loading.
- We observed thermostat settings that ranged from 60F to 75F, and with some thermostats taped to prevent occupants from changing them. These are not likely desired temperatures, but rather are an expression of being too hot or too cold and a desire for cooling now or heating now.

- We noted that the condition of the rooftop chiller units was poor, with exterior surfaces of various components (especially the evaporators and pumps) exhibiting corrosion. The condenser appeared to be in newer condition and may have been upgraded recently, so heat rejection does not seem to be impacted.

- The evidence storage and processing area in the west wing presents a number of challenges. This area of the building was initially unconditioned, with the exception of walk-in cold storage, an air conditioned storage room, and a lab with continuously-running fume hood exhaust. Due to a mold issue on the interior walls between the air conditioned room and unconditioned areas, dehumidifiers were installed and air conditioning setpoints were adjusted. While there are no ongoing complaints regarding these issues in this space, it is likely that the solution carries a high operational cost.

**Lighting**

Electrical lighting design is typical of 1990s era, with more than enough light available with all the lights on. As an experiment, we turned off half of the lights in the War Room, and found that the light levels were more than adequate for office work. Generally, the electric lighting strategy in the facility is to use overhead fixtures to provide light levels that exceed the minimum illumination for most office tasks by a safety factor of as much as 100%. The Illuminating Engineering Society of North America (IESNA) guidelines indicate that 30 fc is sufficient illumination for all but the most demanding office tasks (e.g., reading 6 pt. font). In some areas, such as conference rooms, we found lighting levels higher than 100 fc. Spot measurements were taken throughout office areas at desks and in circulation spaces. We found light levels of 40-59 fc at desk height, with the highest levels in circulation spaces and with the lowest levels at desk surfaces since partitions partially obscure the view from desktops to ceiling fixtures. This is a very inefficient lighting strategy since the result is the inverse of what would be desired: rather than lighting each space appropriate to its task, more light ends up being provided to those areas that require the least amount of light. A much more efficient strategy would be to provide a lower level of ambient lighting and to also provide task lights so that individual occupants have control over how much light they have for a particular task.

<table>
<thead>
<tr>
<th></th>
<th>Circulation</th>
<th>Desktops</th>
</tr>
</thead>
<tbody>
<tr>
<td>spot measurements of existing</td>
<td>50-59 fc</td>
<td>40-50 fc</td>
</tr>
<tr>
<td>desirable (IESNA)</td>
<td>10-20 fc</td>
<td>10-50 fc*</td>
</tr>
</tbody>
</table>

*adjustable using task lighting

**Equipment**

The building contains some equipment that is essential to be powered on all the time, but there is also equipment that could be turned off when not in use.
<table>
<thead>
<tr>
<th>Continuous Use</th>
<th>Occasional Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>servers</td>
<td>most desktop cpu’s and monitors</td>
</tr>
<tr>
<td>radio electronics</td>
<td>printers and copiers</td>
</tr>
<tr>
<td>phone system</td>
<td>monitors, televisions, and projectors</td>
</tr>
<tr>
<td>dispatch electronics</td>
<td>microwave ovens, toasters, hot pots</td>
</tr>
<tr>
<td>high priority desktop cpu’s</td>
<td></td>
</tr>
<tr>
<td>ATM</td>
<td></td>
</tr>
<tr>
<td>refrigerators</td>
<td></td>
</tr>
</tbody>
</table>

We also discovered use of personal heaters with some of them (4 in the areas we observed) being on continuously. Old equipment (especially refrigerators) is present in the building for which newer and much more energy efficient replacements are available. We also observed the use of old, inefficient personal refrigerators.
3. Measured Performance

Energy

In addition to data collected by the monitoring system installed in the facility, historical data were available for whole-facility energy use from the utility. This historical utility data consists of 15-minute interval data for approximately the last month, hourly data for approximately the last two months, and daily data for just over a year.

These data allow us to identify how much variation appears in the facility, and thus the degree to which the monitoring period may be different from performance at other times of the year. While the monitoring period was 50 days long, yearly utility data show that the building’s energy use remains fairly consistent all year. Average weekday energy use varies from 4,000 to just under 6,000 kWh per day, with an average around 4,800 kWh during the monitoring period (see Figure 2).

The utility data allows the facility’s yearly energy use intensity to be calculated as follows.  [approximate Portfolio Manager Use category noted in brackets]:

East 1st : $145 \times 88 \approx 12760$ sf
East 2nd : $145 \times 88 \approx 12760$ sf
East Total $\approx 25500$ sf

West 1st : $81.5 \times 224 \approx 18256$ sf
West 2nd : $81.5 \times 189 \approx 15403$ sf
West Total $\approx 33700$ sf
Facility Total $\approx 59200$ sf

Facility EUI = 1,690,000 kWh/yr / 59200 sf = 28.5 kWh/sf/yr
Projected Facility EUI from monitoring period =
4495 kWh/dy * 365 dy / 59200 sf = 27.7 kWh/sf/yr
Monitored data begins to reveal how this energy is used in the building. First, we total all energy by end use logged during the monitoring period. We then compute a daily average energy use for comparison to the annual daily average energy use recorded by the utility (see Figure 3). This shows that chillers are the largest energy use among those uses monitored, and use nearly half of the daily averages recorded by the utility during this time period. Equipment is also a significant user of energy, with the equipment in the east wing alone totaling about 40% of the energy used by chillers.

In order to understand energy end use and its behavior in a more detailed way, we graph the daily power profiles for the monitoring period (see Figures 4, 5, and 43–83).
Figure 4. Weekday Power Profile.
*energy cost of one grid cell is kW × 2 hr/day × $0.39/kWh × 250 work days

Figure 5. Weekend Power Profile.
*energy cost of one grid cell is kW × 2 hr/day × $0.39/kWh × 115 non-work days
These profiles show average monitored hourly power per end use (thin red lines), average hourly total facility power use according to the utility (thick red line), and the hourly average power use according to the utility for each day during the monitoring period (blue lines) for weekdays (see Figure 4) and weekends (see Figure 5). Note that area in this graph represents energy use (power × time). Yearly energy cost can be calculated directly from this area (eg, this graph shows grid cells that represent 50 kW × 2 hr/day × $0.39/kWh × 250 work days per year = $9750 per year for work days). Currently, all grid cells equal the same yearly cost of energy; if a time of use (TOU) rate were to be implemented for the island, the yearly cost of energy within each grid cell would change depending on time of day.

The monitored total profile (ie, the line labeled ‘chillers’) matches the utility profile closely. The difference between these profiles is the power used by lighting, equipment, and fans in the west wing. To begin to characterize the load profile of this building, we can compare performance during occupied and unoccupied hours. The profiles show that the building has a base electrical load of around 150 kW, with an additional 100 kW added during occupied hours. The remarkable feature of this graph is the size of the chiller load compared with all other loads, particularly during occupied hours when chiller power use is about half of total power use.

<table>
<thead>
<tr>
<th>HVAC Projected Energy Use:</th>
<th>2003 kWh/day * 365 / 59200 = 12.3 kWh/sf/yr (at least) East</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fans Projected Energy Use:</td>
<td>70 kWh/day * 365 / 25500 = 1.0 kWh/sf/yr (at least)</td>
</tr>
</tbody>
</table>

Equipment comprises a significant portion of energy use, with a load profile that consists of mostly base load (notice how there is very little difference in the east equipment between day or night, and between weekday and weekend). Translated, this means that the vast majority of equipment in the building is powered fully whether the building is occupied or not.

<table>
<thead>
<tr>
<th>East Equipment Power Density:</th>
<th>42kW -&gt; 1.6 W/sf (at least)</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Equipment Projected Energy Use:</td>
<td>850 kWh/day * 365 / 25500 = 12.2 kWh/sf/yr</td>
</tr>
</tbody>
</table>

Electric lighting, both interior and exterior, show a much stronger relationship to schedule. The lights in occupied spaces show a reduction in power use during unoccupied times at night and on the weekends, while the parking lot lights operate at night when expected. While these end uses are relatively small compared with chiller energy use, the energy impact of interior electric lighting is actually greater since the chiller needs to use more energy to remove the heat generated by the lighting.

<table>
<thead>
<tr>
<th>East Lights Power Density:</th>
<th>19kW -&gt; 0.75 W/sf (at least)</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Lights Projected Energy Use:</td>
<td>330 kWh/day * 365 / 25500 = 4.7 kWh/sf/yr</td>
</tr>
</tbody>
</table>

Energy Benchmarking

The KPF presents benchmarking challenges due to its use and its location. The process of benchmarking would ideally compare the energy use of the study building.
to a fictional building that is constructed using the average performance of a large number of buildings similar in use and characteristics to the study building. The KPF is challenging in this regard because its combination of uses is particular. While much of the building is likely comparable to office buildings, the EOC, server room, radio room, dispatch center, and police facilities are not typical of a generic office. In addition, its location reduces the number of buildings that could be considered peers because it is located in a climate that covers a relatively small area of the United States, the region for which benchmarking data were readily available.

Two sources for benchmarking in this study include a 2005 energy benchmarking study (EBS) of Oahu state-owned facilities (*State of Hawaii Facilities on Oahu Energy Benchmarking Study, The State of Hawaii, July, 2005*), and the US EPA Portfolio Manager benchmarking tool. The EBS is helpful because it describes a comparable regional building stock and because it includes an estimation of end uses. Portfolio Manager is helpful because it is a widely used benchmarking tool that can benchmark specific space uses. It is important to note that neither source represents good performance. Rather, these sources describe typical performance in the existing building stock.

We can calculate a rough estimate of the energy end uses for the facility by comparing the projected energy uses above and using extrapolation:

- Total Energy Use : 27.7 kWh/sf/yr (utility)
- HVAC : 12.3 kWh/sf/yr (measured)
- Fans : 1 kWh/sf/yr (measured; assumes west wing is similar)
- Lights : 4.7 kWh/sf/yr (measured; assumes west wing is similar)
- Equipment : 9.7 kWh/sf/yr (remainder)*

*This includes server room HVAC and fan energy

Finally, we can compare the projected KPF energy use and end uses to the data available from the two sources identified above (see Figure 6). Each of these sources is limited in its ability to be an accurate benchmark for the KPF due to the issues described above; the comparison is presented in order to gain a better relative understanding of KPF energy performance. The KPF uses more total energy per square foot than any of the benchmarks identified. This difference is likely due primarily to unusually high equipment energy use as well as higher HVAC energy use. This may be due to specialized equipment and use patterns for this facility in particular, or due to poor performance, or more likely a combination of both.
Occupancy

Occupancy patterns demonstrate an overall pattern that is typical of office use, with maximum occupancy between around 7:30AM and 4:30PM (see Figure 7). The spaces were generally unoccupied between 10PM and 5AM, with occupancy ramping up from 5AM to 7:30AM, and ramping down from 4:30PM to 10PM. The spaces were generally unoccupied during weekends (see Figure 8).

The occupancy patterns do show occasional use during times that are generally unoccupied, which include daytime during weekends and throughout the night on weekdays. This is expected for a facility that responds to events that could occur at any time.
Comfort

The temperature profiles for each space show that the spaces are cooled well below their free-floating temperature as demonstrated by the difference between weekday and weekend behavior. On weekends, the thermostat has been set to a wider deadband, allowing the space to “float” at higher temperatures that result from heat gains and losses without the mechanical system removing heat from the space. There is a notable difference between locations near the core and locations near the perimeter in each space monitored. Figures 9 and 10 show the weekday temperature profiles for the Vice Core and Vice Perimeter, respectively. Figure 11 shows the weekend
temperature profile for the Vice perimeter, for comparison. Note that in 2E18 (Vice), the room operates as a single system zone, whereas in 2E41 (Detective), the core is a separate zone from the perimeter.

The thermal behavior in the Vice room shows further evidence that the envelope is playing a significant role in building performance. The thermostat is located near the sensors logging the space temperature closer to the core of the building (ie, farther away from the façade). Occupants in this space are primarily located near the exterior wall, or in a perimeter location. Since the thermostat is located closer to the core, we see that the system generally maintains the core area temperature consistently regardless of exterior temperature. On the other hand, the temperature near the perimeter is less consistent during occupied hours. One possible explanation for this variation in temperature could be a poor envelope. To test this hypothesis, we checked to see if the perimeter temperature is correlated to exterior temperature during occupied hours (see Figure 12). We found that it is indeed warmer when the exterior temperature is warmer, and cooler when the exterior temperature is cooler. If occupants in such zones are controlling the thermostat based on their comfort, they will tend to over-cool the core areas to compensate for perimeter areas that are too warm.
HVAC loads are the lion’s share of energy use in the building. The building has a number of thermal challenges. First, its envelope appears to be fairly conductive, making it more difficult for the system to maintain interior conditions at a setpoint. Second, its HVAC zones may not be laid out optimally, with some zones comprising disparate thermal requirements (eg, the Vice zone contains perimeter and core areas). Third, the occupant population consists of people with a wide range of thermal comfort requirements. Finally, the building has a high intensity of equipment loads and an electric lighting system that uses more energy compared with state-of-the-art. Equipment and lighting not only use energy, but they also generate heat which the HVAC system must remove from the building.

Considering the observations made during the site visit and the data collected during the monitoring period, we have identified a number of potential retrofit projects.

**HVAC**

It is unlikely that envelope, equipment, and lighting retrofits will render mechanical loads insignificant, so we recommend taking steps to make sure that machines used are highly efficient and that they operate minimally. Minimizing system energy use should include both optimizing control of system components and also ensuring that zone temperatures are set to appropriate levels given programmatic needs. Next steps include:

- Find out what HVAC equipment has been recently replaced and if there are any other scheduled capital upgrades on the horizon. Use currently installed equipment specs, monitored data, and specs of state of the art highly efficient equipment to estimate potential savings from equipment upgrade.

- In general, raising the cooling setpoint temperature even a few degrees will have a significant impact on cooling energy use, since the efficiency response to a change in setpoint is non-linear (ie, the savings raising the setpoint from 70F to 75F would be more than half what would be saved raising the setpoint from 70F to 80F). This setpoint is quite low for at least two reasons. First, the building envelope is conductive, so that in some zones, the setpoint may need to be lower in order to compensate...
for thermal asymmetry within zones (see Envelope section below). Second, occupants have a wide range of thermal comfort needs. The current strategy is to lower the space temperature to satisfy the most active and clothed occupant and then to use space heaters for those who are cold. This is a very inefficient way to meet thermal comfort needs. A much more efficient way would be to meet the needs of the less clothed and active occupants with the HVAC system, and then provide additional cooling for occupants who are still too warm. This can be done by introducing individualized cooling solutions such as desk fans, grouping these individuals into zones conditioned to a lower setpoint, reviewing clothing related policies to see if less clothing can be required, etc.

- Confirm scheduling of zone temperature setpoints and operational condition of VAV boxes associated with the EOC. This zone appears to not be throttling appropriately, with over cooling at times when cooling demand is low. The HVAC system should be able to handle this variation in loading without causing the kinds of complaints currently voiced by occupants.

- Regarding the evidence storage and processing space, we strongly recommend that a comprehensive mechanical design with the addition of envelope improvements be performed. While the current condition is working, it is likely doing so at a high cost of energy and at a high risk of failure. In addition, a review of the cold storage equipment should be carried out.

- Install 3rd party optimization software. The Trane controls software is not set up to be user-friendly. Rather than undertake expensive training or fly a Trane engineer to Hawaii, an increasingly viable option is to identify a third party optimization platform that can interface with the Trane system and help it make control decisions that are more optimized for patterns of use and for weather. We recommend more research to identify which solutions will meet the particular needs of this facility.

Since quantifying cost and benefit of the above potential actions is beyond the scope of this report, we recommend waiting until such an analysis is complete before significant expenditure on capital improvement or full-scale retro-commissioning.

Lastly, please note that we advise mechanical rooms should not be used as storage. These rooms should be kept clean in order for equipment to be inspected and maintained properly. This is also a potential fire hazard. In addition, these rooms have the potential for leaks, which makes them a poor choice to archive files.

Envelope

The nature of occupant complaints and the observed conductive losses indicate a building that is, in a sense, fighting with itself. Despite what is generally considered a mild climate, Kaua‘i presents a complex thermal comfort problem with its relatively high humidity and high solar radiation environment. This is why traditional open buildings work well, as do many residential buildings that exist with no air conditioning whatsoever; sealed buildings are harder to control. In this case, the
construction of this building further exacerbates this issue, since the limited thermal insulation (particularly in the walls) allows the heat from solar radiation striking the exterior to easily conduct through the wall. The result is that when sun is on a given exterior wall, it becomes the equivalent of a large radiator. Anyone in direct exposure to that wall experiences an elevated thermal sensation despite the fact that the dry bulb temperature (what a thermostat uses) stays within the comfort range. Occupants in turn demand a lower temperature setting on the thermostat which will feel too cool when the solar radiation is no longer on that particular wall or for occupants who are not right by the wall.

The temperature zones also do not take this localized condition in account, with the result that at a given temperature setting, some occupants report being cold and others hot at the same temperature setting. Occupants wear a wide range of clothing, from light, to medium casual, to heavy body armor. With the reported disparity in clothing, and it becomes clear that maintaining a comfortable setting is quite a complex task.

The walls and windows make for a building that is thermally unstable. What this means is that to provide comfort one needs to exercise continuous nuanced temperature control. The opposite would be a building that provided the conditions where a wide variety of comfort conditions can be acceptable, like a shaded façade with some building mass. Another way to think about it is that the police facility is like a large metal container attached to a powerful air-conditioner. Despite the power of the AC, one will never be completely comfortable in that space.

Unfortunately, it is unlikely that envelope improvements will provide a short payback, but such improvements would have significant comfort benefits, while also producing energy savings.

- Windows in the building are single pane. A window and frame retrofit will dramatically reduce conducted heat transfer through window assemblies. Windows should be replaced with double-pane, low solar gain low-e windows with glass such as Solarban-70XL.

- The building is always either in cooling mode or it is warmer than comfortable when the system is standing by; adding exterior shading has the potential to lower solar gains on walls, windows and roof. One way to achieve this and also shorten the pay back period is to install a canopy of PV panels to provide shade over the entire roof and to provide a source of renewable energy generation during peak demand hours. PVs can also be used to shade the walls on the south, west and east sides, which will improve comfort as well.

**Lighting Retrofit**

While lighting energy use in this building is smaller than other end uses, the potential energy savings of a lighting retrofit project includes savings in HVAC energy as well, since a reduction in heat gain from lighting will also reduce cooling loads. As a result, the percent reduction can be quite large, and if it is done well, the improvements in visual comfort can be equally dramatic. There are three potential approaches to a lighting retrofit that vary in their scope, cost, and potential for energy savings.
• Lamp replacement is simple but is also limited with respect to potential energy savings. This would be a one for one replacement of lamps and ballasts with newer technology. This will have measurable energy savings and zero to negative impact in visual quality.

• A retrofit to replace the lighting technology (i.e., the fixtures and controls) but to retain the same lighting design has potential to save more energy. For instance, the fluorescent fixtures could be replaced with more efficient LED fixtures. This will improve payback and will have a minor increase in visual quality.

• The largest savings and performance gains would be realized from a retrofit involving redesigning the lighting as fewer fixtures can be used, and highly efficient fixtures can be specified. The current electric lighting design lights all spaces intensely and evenly, but all spaces do not need this much light. In addition, we observed many task areas that did not receive appropriate light levels. A redesign can provide electric lighting more judiciously, and a controls system can be selected which takes advantage of available daylight where possible. This can not only dramatically increase energy efficiency (75% reduction is not uncommon), but it can also produce large improvements in visual quality and general appearance.

The choice of lighting retrofit is a choice between performance, time and cost. The first choice is relatively simple; an energy services company can easily perform this. The second and third choice require a lighting designer, requiring somewhat more time and will cost more as a retrofit project. The benefits, however are likely to be impressive. We estimate that a rough order of magnitude savings for electrical lighting retrofit is as follows:

- Simple technology retrofit, replace current lamps and ballasts but retain luminaires: 20 -35%.
- Luminaire retrofit, replace luminaires with modern fixtures: 40 – 50%
- Comprehensive retrofit, replace luminaires with modern fixtures and design a task ambient lighting system: 50 – 75%

The parking and exterior lighting is also normative to 1980’s and 1990’s design with pole lighting. Introduction of dark sky design standards would not only save energy, but would also have ecological and human benefits. In particular, modern LED parking lighting should be adapted with a control system to allow the following:

- Astronomical timer to activate lighting during occupied times that occur past twilight.
- Each pole should be activated only by an occupancy sensor. In addition to saving significant energy, this strategy also enhances safety as it broadcasts to any pedestrian if others are in the vicinity.

Equipment
- To estimate potential energy savings from cycling off desktop computers, obtain a plug meter (such as a kill-a-watt) to estimate power use for an
individual machine, and then multiply by the number of machines that could be powered down during unoccupied hours.

- Replace the refrigerator in the detective area with a current energy efficient model. A plug meter could be used to estimate savings, although the savings are likely to be dramatic enough that one should not waste any time and go ahead and replace it immediately. There is a false economy in accepting a donated older refrigerator. The difference in energy use between an older model and a new EnergStar-rated model can easily exceed $500 per year at Kaua‘i electricity rates, yielding short simple payback. In addition to cooling food inefficiently and potentially unevenly, the less efficient refrigerators generate much larger heat gains to the building, which increases cooling energy use and reduces thermal comfort.

- We observed two large copiers in the space. Currently we have observed a reduced use of copying as digital media is being used more and more. Despite that copiers are still necessary, however large volume copying for reports and memos seem to be required less. We would encourage the Station to look into how much copying is actually needed and if this can be accomplished with a smaller, modern copier that will be more efficient. Other than significant energy savings there are health benefits from less outgassing from modern equipment.

- Over a longer time frame, virtualization of computational tasks to be accessed via a thin client can make IT infrastructure more efficient since optimization could be more easily managed and desktop infrastructure would be much lighter and less energy intensive.
Appendix: Detailed Monitoring Profiles

Occupancy Profiles :: Weekdays

Detective Core/Cubicles Occupancy, Weekdays

![Figure A1. Detective core/cubicles occupancy, weekdays](image)

Detective Perimeter/Entry Occupancy, Weekdays

![Figure A2. Detective perimeter/entry occupancy, weekdays](image)

Vice Occupancy, Weekdays

![Figure A3. Vice occupancy, weekdays](image)
Occupancy Profiles :: Weekends

**Detective Core/Cubicles Occupancy, Weekends**

![Graph showing detective core/cubicles occupancy on weekends](image)

Figure A4. Detective core/cubicles occupancy, weekends

**Detective Perimeter/Entry Occupancy, Weekends**

![Graph showing detective perimeter/entry occupancy on weekends](image)

Figure A5. Detective perimeter/entry occupancy, weekends

**Vice Occupancy, Weekends**

![Graph showing vice occupancy on weekends](image)

Figure A6. Vice occupancy, weekends
Temperature Profiles :: Detective Core

Figure A7. Detective core cube 1 vs outdoor, weekdays

Figure A8. Detective core cube 10 vs outdoor, weekdays

Figure A9. Detective core return vs outdoor, weekdays
Temperature Profiles :: Detective Core

Figure A9. Detective core return vs outdoor, weekdays
Figure A10. Detective core cube 1 vs outdoor, weekends
Figure A11. Detective core cube 10 vs outdoor, weekends
Temperature Profiles :: Detective Core

Figure A12. Detective core return vs outdoor, weekends
Figure A13. Detective core supply vs outdoor, weekdays

Figure A14. Detective core supply vs outdoor, weekends
Temperature Profiles :: Detective Perimeter

Figure A15. Detective perimeter vs outdoor, weekdays

Figure A16. Detective perimeter return vs outdoor, weekdays

Figure A17. Detective perimeter supply vs outdoor, weekdays
Temperature Profiles :: Detective Perimeter

Figure A18. Detective perimeter vs outdoor, weekends

Figure A19. Detective perimeter return vs outdoor, weekends

Figure A20. Detective perimeter supply vs outdoor, weekends
Temperature Profiles :: Vice Core

Figure A21. Vice core cube 1 vs outdoor, weekdays

Figure A22. Vice core cube 12 vs outdoor, weekdays

Temperature Profiles :: Vice Core
Figure A23. Vice core cube 1 vs outdoor, weekends

Temperature Profiles :: Vice Perimeter

Figure A24. Vice core cube 12 vs outdoor, weekends

Figure A25. Vice perimeter vs outdoor, weekdays

Figure A26. Vice perimeter vs outdoor, weekends
Temperature Profiles :: Vice System

Figure A26. Vice perimeter vs outdoor, weekends

Figure A27. Vice supply vs outdoor, weekdays

Figure A28. Vice return vs outdoor, weekdays
Figure A29. Vice supply vs outdoor, weekends

Figure A30. Vice return vs outdoor, weekends
Load Profiles :: Detailed by End Use

Figure A31. Chillers power profile, weekday, weekend and average weekday

Figure A32. East equipment power profile, weekday, weekend and average weekday

Figure A33. East HVAC fans power profile, weekday, weekend and average weekday
Load Profiles :: Detailed by End Use

**Figure A34.** East lights power profile, weekday, weekend and average weekday

**Figure A35.** Parking lights power profile, weekday, weekend and average weekday
Load Profiles :: Chillers

CH1 ave power

Figure A36. Chiller 1 power profile (whole building HVAC)

CH2 ave power

Figure A37. Chiller 2 power profile (whole building HVAC)
Load Profiles :: East 480V Panel Feeds

Figure A38. Panel 4E1EA power profile (east lights, HVAC fans)

Figure A39. Panel 4E1NA power profile (east lights)
Load Profiles :: East Equipment Panel Feeds

Figure A40. Panel 2E1NDP power profile (east equipment)

Figure A41. Panel 2E1EDP power profile (east equipment and server room HVAC)
Load Profiles :: East Lights, Floor 1 :: Individual Circuits

Figure A42. EOC lights circuit 1 power profile (east lights)

Figure A43. EOC lights circuit 2 power profile (east lights)

Figure A44. EOC lights circuit 3 power profile (east lights)
Load Profiles :: East Lights, Floor 1 :: Individual Circuits

Figure A44. EOC lights circuit 3 power profile (east lights)
Load Profiles :: East Lights, Floor 1 :: Individual Circuits

Figure A45. EOC lights circuit 4 power profile (east lights)

Figure A46. EOC lights circuit 5 power profile (east lights)
Load Profiles :: East Lights, Floor 1 :: Individual Circuits

Figure A47. EOC lights circuit 6 power profile (east lights)
Figure A48. EOC lights circuit 7 power profile (east lights)
Load Profiles :: East Lights, Floor 2 :: Individual Circuits

Figure A49. Lights 2E3 circuit 1 power profile (east lights)

Figure A50. Lights 2E3 circuit 2 power profile (east lights)

Figure A51. Lights 2E3 circuit 3 power profile (east lights)
Load Profiles :: East Lights :: Individual Circuits

Lights Panel 2E3 CCT4 PH L2 power

Figure A52. Lights 2E3 circuit 4 power profile (east lights)

Lights Panel 2E3 CCT5 PH L3 power

Figure A53. Lights 2E3 circuit 5 power profile (east lights)

Lights Panel 2E3 CCT6 PH L3 power

Figure A54. Lights 2E3 circuit 6 power profile (east lights)
Load Profiles :: East HVAC :: Individual Phases

* represents only a portion of energy use since only one phase is monitored

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**Figure A55.** Computer room air conditioner E1 power profile (east HVAC)

**Figure A56.** Computer room air conditioner E2 power profile (east HVAC)

**Figure A57.** Supply fan 11 power profile (east HVAC fans)

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Load Profiles :: East HVAC :: Individual Phases

* represents only a portion of energy use since only one phase is monitored

Figure A58. Variable air handling unit E12 power profile (east HVAC fans)

Figure A59. Variable air handling unit E12 power profile (east HVAC fans)
**Load Profiles :: East HVAC :: Individual Phases**

* represents only a portion of energy use since only one phase is monitored.

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**EF E21 Panel 2E3 CCT9 PH L2 power**

![Graph showing power profile](image1)

Figure A60. Exhaust fan E21 power profile (east HVAC fans)

**VAHU E21 Panel 2E3 CCT12 PH L3 power**

![Graph showing power profile](image2)

Figure A61. Variable air handling unit E21 power profile (east HVAC fans)

**VAHU E22 Panel 2E3 CCT16 PH L2 power**

![Graph showing power profile](image3)
Figure A62. Variable air handling unit E22 power profile (east HVAC fans)
Load Profiles :: East HVAC :: Individual Phases
* represents only a portion of energy use since only one phase is monitored

Load Profiles :: East 480V Panel Feeds :: Detailed Per Phase

Figure A63. Panel 4E1EA line 1 power profile (lights, HVAC fans)

Figure A64. Panel 4E1EA line 2 power profile (lights, HVAC fans)

Figure A65. Panel 4E1EA line 3 power profile (lights, HVAC fans)
Figure A66. Panel 2E1NDP line 1 power profile (east equipment)

Figure A67. Panel 2E1NDP line 2 power profile (east equipment)

Figure A68. Panel 2E1NDP line 3 power profile (east equipment)
Load Profiles :: East Equipment Panel Feeds :: Detailed Per Phase

Figure A71. Panel 2E1EDP line 3 power profile (east equipment, server room HVAC)

Figure A69. Panel 2E1EDP line 1 power profile (east equipment, server room HVAC)

Figure A70. Panel 2E1EDP line 2 power profile (east equipment, server room HVAC)

Figure A71. Panel 2E1EDP line 3 power profile (east equipment, server room HVAC)