Hawai'i Department of Education
K-12 Energy Systems Study
Part 1: Research and Planning
Contract #MA140034

Executive Summary: Tasks 1.1 to 1.6

March 2015

www.mkthink.com
415.288.0888 | office@mkthink.com

MKTHINK
1500 Sansome Street
San Francisco, CA 94111

PREPARED FOR:
Richard E. Rocheleau
Director, Hawaii Natural
Energy Institute
1680 East West Road, POST 109
Honolulu, HI 96822
(808) 956-8346
rochelea@hawaii.edu

PREPARED BY:
Nate Goore
Principal, MKTHINK
Roundhouse One
1500 Sansome Street
San Francisco, CA 94111
(415) 288-3393
goore@mkthink.com

THIS PAGE INTENTIONALLY LEFT BLANK.

1 Overview

Context

In support of the Hawai'i Department of Education (HIDOE) and the Hawai'i Natural Energy Institute (HNEI), MKThink was commissioned to study various aspects of thermal comfort using the Campbell complex facilities at Ewa Beach, O'ahu as a pilot project. The scientific data collected there could be used as guidance for policies regarding thermal comfort and classroom conditions at schools statewide.

Increasing costs and dependence on imported energy led to State of Hawai'i (SOH) initiatives to reduce energy demand and reliance on conventionally produced electricity. Additionally, aging, uncomfortable school infrastructure produced public pressure to improve the quality of learning environments.

Goals

The aim of this project is to assess the Asset, Resource, and Cultural (ARC) conditions that are currently affecting thermal comfort levels at the Campbell School complex on O'ahu. The main project objective is to maintain natural ventilation at the schools while supporting HIDOE's overall strategic objectives. The main goals of this study can be summarized as follows:

- Collect data pertaining to building assets and thermal comfort from project sites through field-installed instrumentation and on-site observation
- Analyze asset, environmental, energy, and cultural data to assess the impacts of specific building conditions on indoor environmental conditions
- Identify opportunities for improvements in energy consumption, comfort levels, and overall economics associated with comfortable learning environments
- Develop various scenarios and options to create a strategic plan to guide future physical building modifications

Project Phases

The phases and tasks for this project are broken down follows:

Task 1: Discovery
- Preliminary collection and assessment of available data
- Develop field data collection and monitoring plan
- Project kickoff
- Define criteria for database, analytic, and modeling software
- Field data collection
- Develop criteria for future decision making

Task 2: Testing (future phase)
- Implement strategies at targeted classrooms
- Monitor and evaluate effects of each strategy
- Determine technical and cost effectiveness for various strategies

Task 3: System-Wide Evaluation (future phase)
- Develop plan to monitor and evaluate schools sites in specific climate zones
- Collect and assess environmental data from targeted school sites
- Collect asset data for all school facilities
- Develop a system-wide assessment of thermal comfort strategies for district facilities

Recommendations

As a result of the work undertaken to date, the following strategies are recommended and presented in detail in this document:

Recommendation 1: Reduce Solar Gain
- 1.1. Lighter Roof Colors
- 1.2. Additional Roof Insulation
- 1.3. Replan Paved Areas
- 1.4. Shading Asphalt Surfaces Adjacent to Rooms
- 1.5. Natural Shading

Recommendation 2: Increase Natural Ventilation
- 2.1. Fenestration Configuration
- 2.2. Unpartitioned Rooms
- 2.3. Thermal (Nocturnal) Flushing

Recommendation 3: Mechanical Conditioning
- 3.1. Fans
- 3.2. PV Air Conditioning Units
- 3.3. Optimize Air Conditioning Usage

2 Analysis

Thermal Comfort

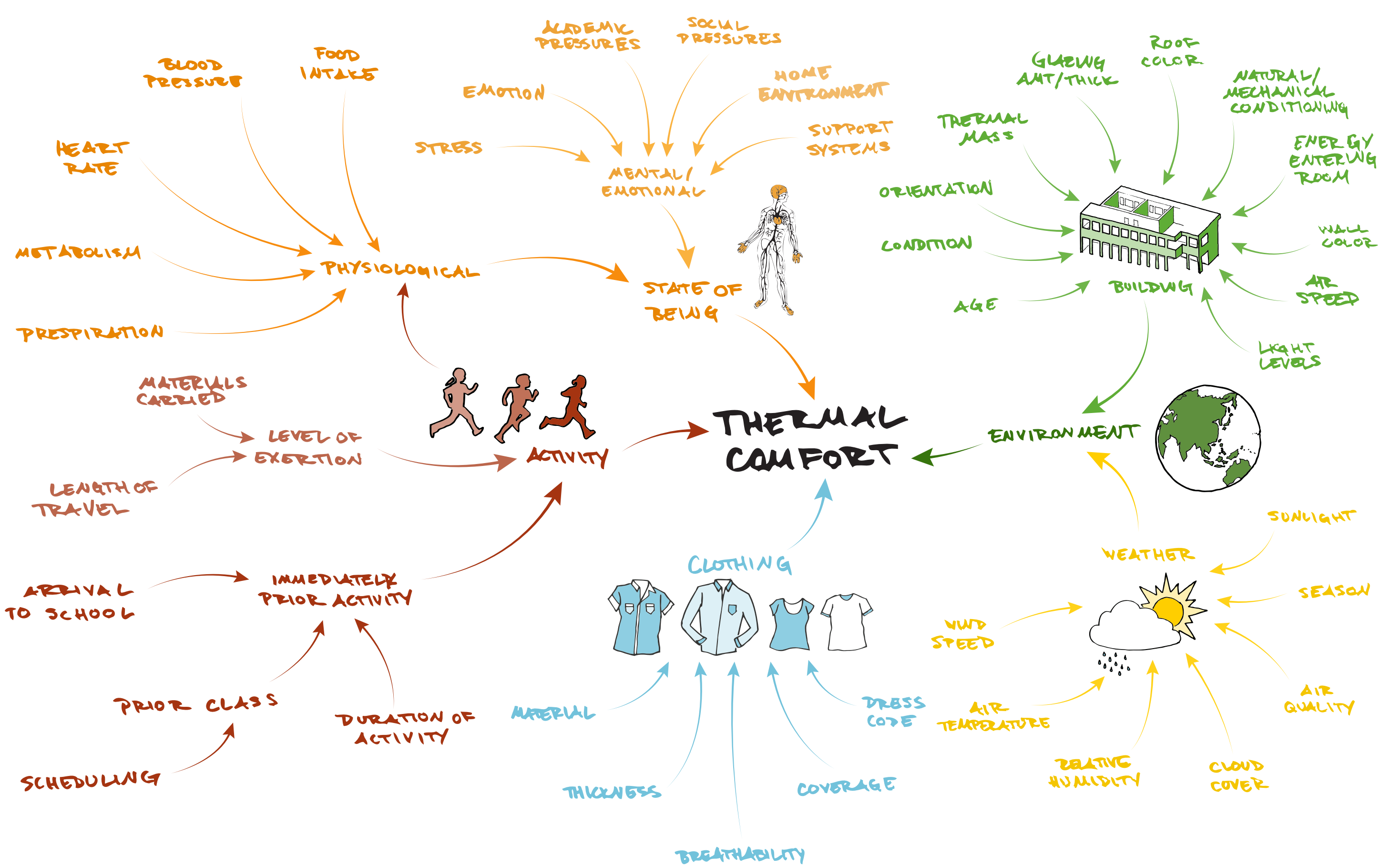
Comfort is a result of thermal, visual, and acoustic conditions. Thermal Comfort is the condition of mind that expresses satisfaction with the thermal environment.

Attributes

There are many factors that affect an individual's perception of thermal comfort. These factors have been grouped into three over arching categories: Asset, Resource, and Culture. Attributes associated with buildings (Assets) such as operability of windows, construction materials, and building overhang can affect the interior environmental conditions, thereby affecting thermal comfort. Environmental (Resource) conditions such as temperature, relative humidity, and wind speed create the external conditions to which the human body must adapt to achieve thermal comfort. Cultural attributes such as clothing affect thermal comfort by providing a level of insulation for the human body. As part of this, the body's physiological conditions are affected by the types and intensities of activities engaged in by individuals.

The over arching categories of Asset, Resource, and Culture including the attributes as shown in the system diagram below:

- *Asset* - Site / Building / Classroom
- *Resource* - Environment / Weather
- *Culture* - Clothing / Activity / Physiological / State of Being



Asset Attribute Data

Asset attributes include information related to the condition, quality, and design of buildings. Asset data was collected through on-site field observations in June 2014 and a field test period in October 2014. The table on page 6 shows the data collection observation schedule and tasks for the Asset, Resource, and Culture categories.

The following Asset attributes were collected:

Site Attributes

- Surrounding Ground Material
  - % Grass
  - % Dirt
  - % Paving: Concrete
  - % Paving: Asphalt
  - % Shaded by Trees
  - % Shaded by Other

Building Attributes

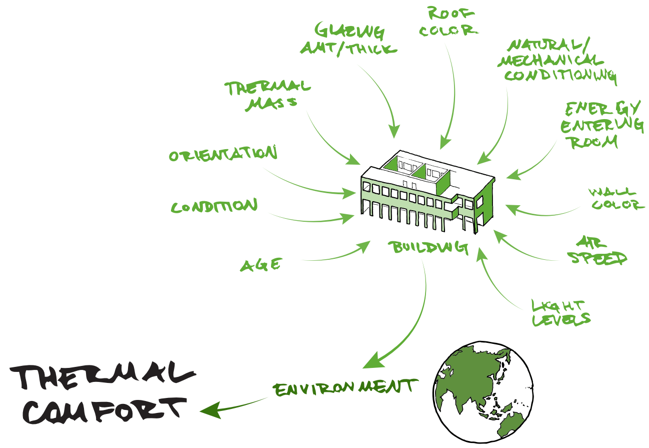
- Building Orientation
- Roof Color
- Façade Orientation
- Floor Level
- Construction Material
- Building Color

Façade Attributes

- % of Fenestration
  - % Operable
  - % Glazing
  - % Louver
  - % Other
- Window Type
- Location of Windows
- Depth of Overhang

A summary of the findings for monitored classrooms for the Asset category is as follows:

- 71 Classrooms monitored at 4 school sites
- 20 Air-conditioned classrooms
- 51 Naturally-conditioned rooms



Average Classroom Size for Monitored Classrooms

- Kaimiloa: *888 sq ft*
- Pohakea: *930 sq ft*
- Ilima: *1,352 sq ft*
- Campbell: *1,076 sq ft*

Windows

- *27%* of all monitored classrooms had glazed windows
- *73%* of all monitored classrooms had louver windows

Mechanical Conditioning

- Average number of fans in Air-conditioned rooms: *2.2*
- Average number of fans in Naturally-conditioned rooms: *3.1*

Seating Configuration for Monitored Classrooms

- Lecture Configuration: *49%*
- Cluster Configuration: *37%*
- Free Configuration: *14%*

Sensor Map of Campbell School Complex

Data Collection Schedule

OCTOBER 14, 2014 (TUESDAY)	
TASK	**LOCATIONS**
Retrieve Classroom Temp/RH/Illum Data	Kaimiloa, Pohakea, Ilima
Observe Classrooms/Take Infrared Images	Kaimiloa, Pohakea, Ilima

OCTOBER 15, 2014 (WEDNESDAY)	
TASK	**LOCATIONS**
Record Building Asset Data	Kaimiloa, Pohakea, Ilima

OCTOBER 16, 2014 (THURSDAY)	
TASK	**LOCATIONS**
Retrieve Classroom Temp/RH/Illum Data	Campbell
Record Building Asset Data	Campbell
Observe Classrooms/Take Infrared Images	Campbell

Resource Attribute Data

Resource attributes include information related to:

- Temperature
- Relative Humidity
- Illuminance
- Solar Radiation
- Wind Speed/Direction

Data was collected from July 2013 to the present day via weather stations, high detail (HD) monitoring sensors, and temperature/illuminance/relative humidity sensors to measure these interior and exterior attributes. The map on the facing page shows where the different types of sensors were installed and for how long they were collecting data. Sensors are still in place and collecting data for future analysis. The table on page 6 shows the data collection observation schedule and tasks for the Asset, Resource, and Culture categories.

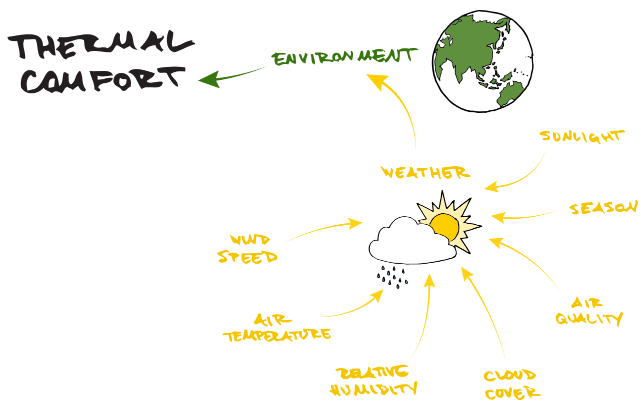
High level findings from the Resource data collected are as follows:

Temperature

- Temperatures in naturally-conditioned rooms ranged from 59.4°F (Kaimiloa P10) to 102.4°F (Ilima D202).
- Temperature in air-conditioned rooms ranged from 60.0°F (Ilima J102) to 87.8°F (Campbell F102).
- Six rooms had a higher maximum temperature. than the maximum outdoor temperature of 93.1°F (four rooms in Ilima, two rooms in Kaimiloa).
- With the exception of Kaimiloa P5 and Campbell F102, air-conditioned classrooms were significantly cooler than other classrooms.
- Half of the classrooms at Ilima were warmer than the outside temperature for most or all of the day
- Naturally conditioned classrooms saw an average peak temperature lag of 85-87 minutes from the outside temperature.

Relative Humidity

- Relative Humidity levels were consistently at upper range of ASHRAE recommended levels, which doesn't account for local climate expectations



- Most air conditioned rooms have similar humidity-levels as unconditioned rooms.
- Humidity levels in naturally-conditioned spaces at Kaimiloa and Ilima were 1.2% higher than outside humidity levels (on average), whereas humidity levels in naturally-conditioned spaces at Campbell were 3.6% higher than outside levels.
- On average, humidity levels in air-conditioned spaces at Kaimiloa, Pohakea, and Ilima were 0.5% higher than outside humidity levels, whereas humidity levels in air-conditioned spaces at Campbell were 13.7% lower than outside levels.
- For naturally-conditioned rooms, the average lag time between max indoor humidity and max outdoor was only 5 minutes. In air-conditioned rooms, max indoor humidity levels were reached 97 minutes before max outdoor humidity levels (on average).

Solar Radiation

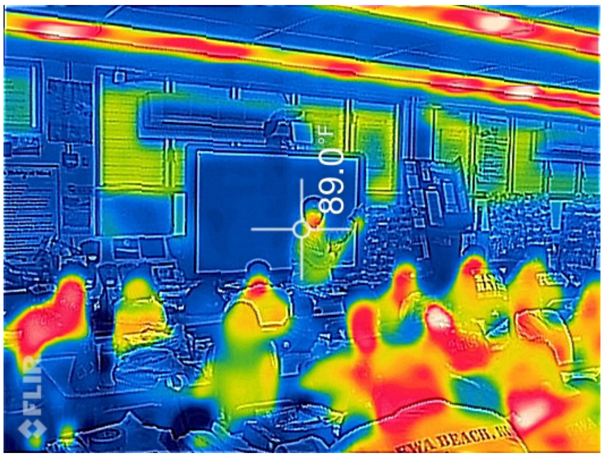
- Analysis shows the variation in solar radiation that rooms receive depending on their orientation and position within the building.
- Solar gain is the single most important contributor to interior temperature.

Wind Speed/Direction

- Winds are primarily out of the east and northeast
- Wind speeds are slowest in the mornings (between .5 and 1.1 mph at 6AM) and increase steadily throughout the day (between 3.8 and 4.3 mph at 6PM)

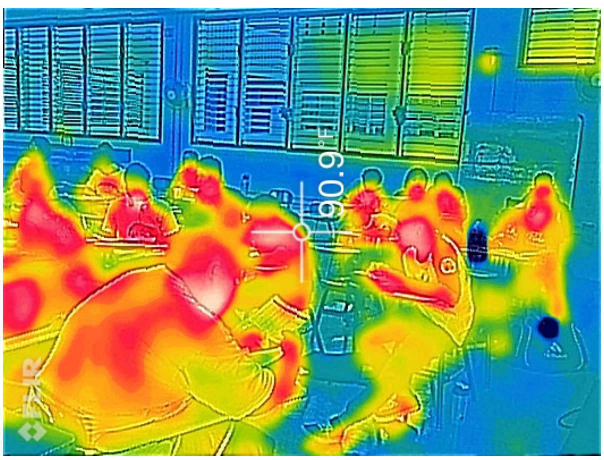
ANALYSIS: CULTURE ATTRIBUTE DATA

Infrared images were used to collect qualitative data to better understand how various Asset, Resource, and Culture attributes are affecting temperature and thermal comfort.



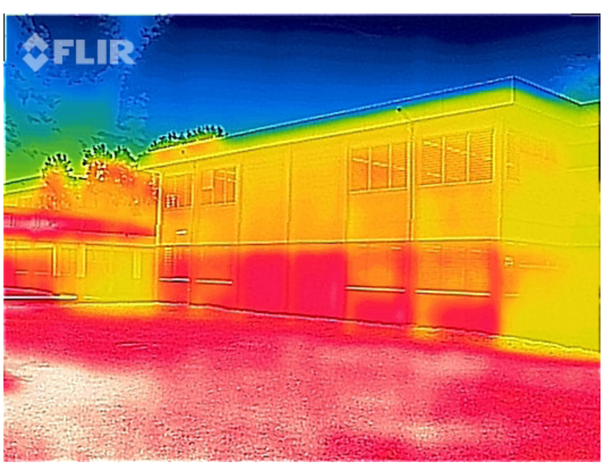
INFRARED IMAGE OF CLASS IN SESSION

This image shows that the closed louver windows (Asset) are warmer than the room generally. This is most likely due to sun hitting the closed windows from the outside. Closed louver windows may mitigate some heat gain, but they decrease the amount of air flow for natural ventilation.



INFRARED IMAGE OF CLASS IN SESSION

This image illustrates Culture attributes contributing to thermal comfort. The dark blue shapes are frozen water bottles (one on a desk and one in a backpack on the right side of the image), which demonstrate human behavior being used to keep cool and change thermal comfort levels.



INFRARED IMAGE OF CLASSROOM BUILDING

This image shows a much warmer external first floor (red) than second floor (yellow). This could be because of the heat radiating off of the ground surface and affecting the external temperature of the first floor. One solution could be to shade the ground cover outside the first floor with trees or a canopy to prevent this heat radiation.

Culture Attribute Data

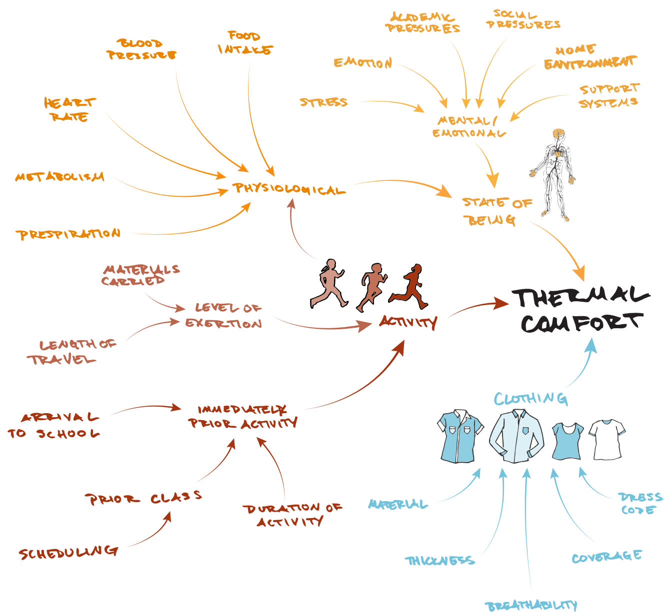
Culture data was collected via observation by the project team over a three-day period (October 14-16, 2014). Infrared images were taken in order to analyze culture attributes from a qualitative perspective. These images were also used to evaluate Asset and Resource attributes. Culture data includes information related to the following:

- Number of students in room
- Duration and frequency of room use
- Time of day for room use
- Seating configurations
- Activity levels
- Types of activities
- Type of clothing worn
- Clothing insulation levels

High-level findings for the Culture observation includes the following:

Apparel

- Average clothing insulation levels for unconditioned rooms was .29 as compared to .31 for conditioned rooms
- Students in unconditioned classrooms were more likely to weare shorts (80.4%) and t shirts (94.3%) than students in air conditioned classrooms (75.9% and 88.4% respectively)
- 12% of students at Pohakea wore sweatshirts or sweaters, as opposed to 0%, 3%, and 6% of students at Kaimiloa, Ilima, and Campbell.



Activity Levels

- Most students were seated at their desks, but students were occasionally observed standing, walking, and working in small groups.
- Metabolic rates were relatively consistent across all schools and between conditioned and unconditioned spaces at 1.2 met units on average
- Activity levels during recess were fairly low. Most students standing around talking instead of running and playing. Activity levels were highest during gym classes.
- Most students were seated desks during classroom observations, and thus metabolic rates may not be a large contributing factor to thermal comfort inside the classroom setting.

3 Results

Condition Analysis

A condition analysis was done to isolate and compare different factors that had an impact on classroom temperature and thermal comfort. For each condition, the project team chose classrooms with similar Asset attributes to isolate the selected condition as much as possible. This was done in order to determine the impact of that specific condition on temperature, with all other factors being equal.

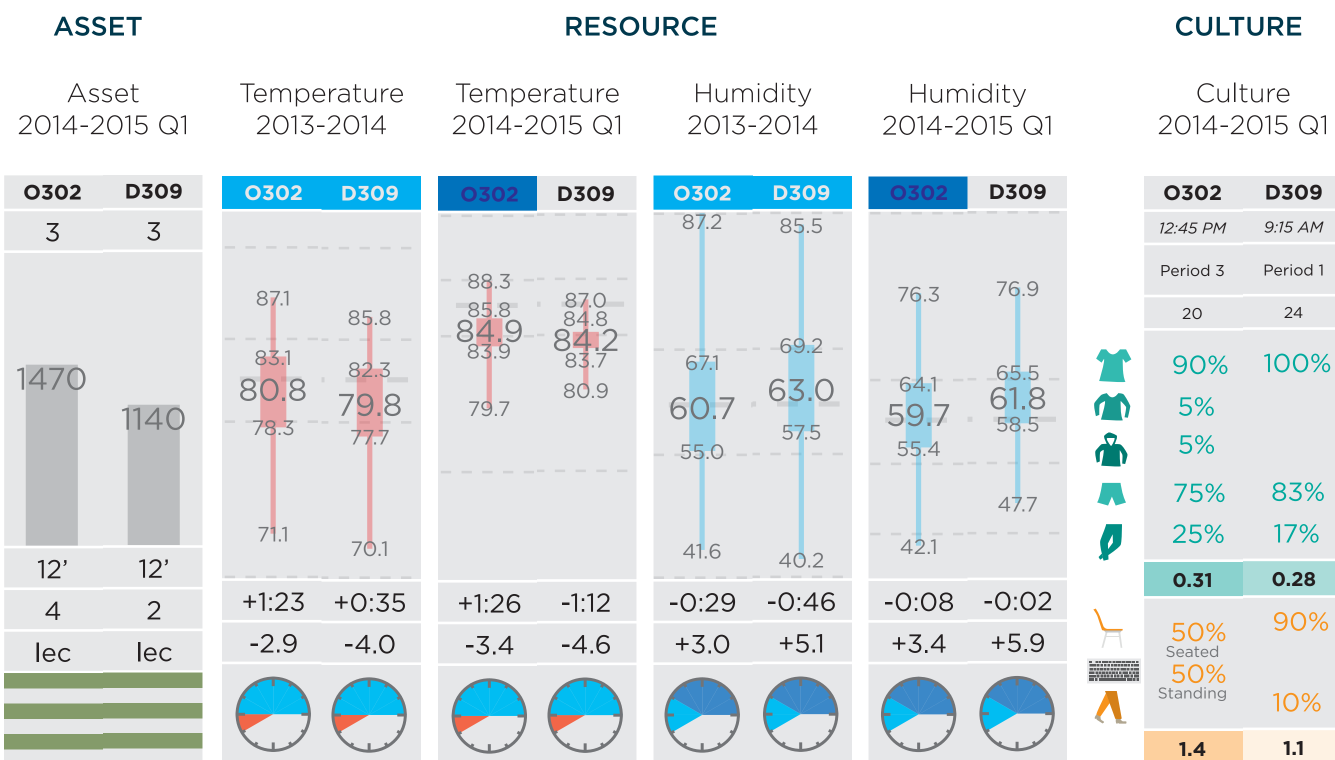
An overview of the following conditions and classrooms studied are presented in this section:

- *Condition 1:* Windows (Glazing versus Louvers) - Ilima D201 and C207
- *Condition 2:* Depth of Overhang - Campbell O202 and O205
- *Condition 3:* Floor Level - Campbell O102, O202, and O302
- *Condition 4:* Roof Color - Campbell O302 and D309
- *Condition 5:* Asphalt Paving - Ilima I101 and D101
- *Condition 6:* Air Conditioning Usage - Pohakea P25 and Campbell P1

For each set of classrooms, the project team analyzed the Asset, Resource (Temperature and Relative Humidity), and Culture data collected to compare the baseline conditions for each room. Below is a sample of the information that was collected and analyzed for each set of classrooms.

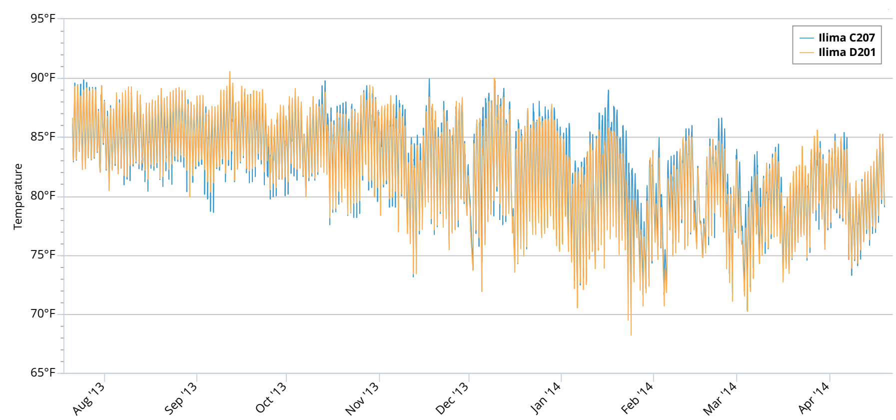
The team then graphed a range of comparative temperature data for each set of classrooms. Temperature profiles (actual and averages) for the 2013-2014 school year, first quarter (Q1) of the 2014-2015 school year, and specific months were analyzed in detail. This was done in order to determine the temperature trends for each set of classrooms, and to see if these trends were consistently throughout the school year and in specific months. The data presented in this section summarizes these findings by condition.

Each temperature profile chart shows temperature data from August 2013 to April 2014 (roughly the 2013-2014 school year) in order to compare the classrooms across a significant period of time. Additional charts were created, but are not presented in this Executive Summary.



Condition 1: Windows (Glazing versus Louvers)

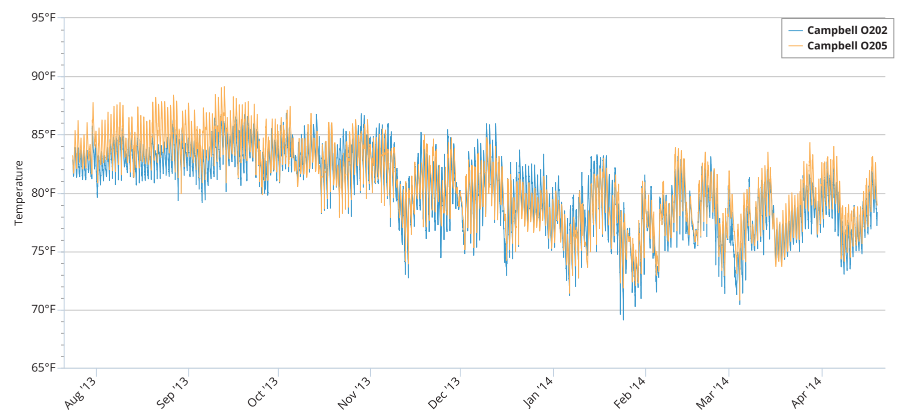
Two classrooms in Ilima were used to compare the relationship between fenestration type on temperature. Room D201 has all louvers while Room C207 has all glazed windows. Over the 2013-14 school year, fenestration type did not have a significant impact on room temperature as shown in the chart to the right. On average, D201 (louvers) was slightly (approximately 0.5-1°F) warmer than C207 (glazing). This is potentially due to the glazed rooms cooling down faster once the windows were open because air was able to flow into the rooms faster than with louver windows.



TEMPERATURE PROFILES (AUGUST 2013 - APRIL 2014)
ILIMA C207 AND D201

Condition 2: Depth of Overhang

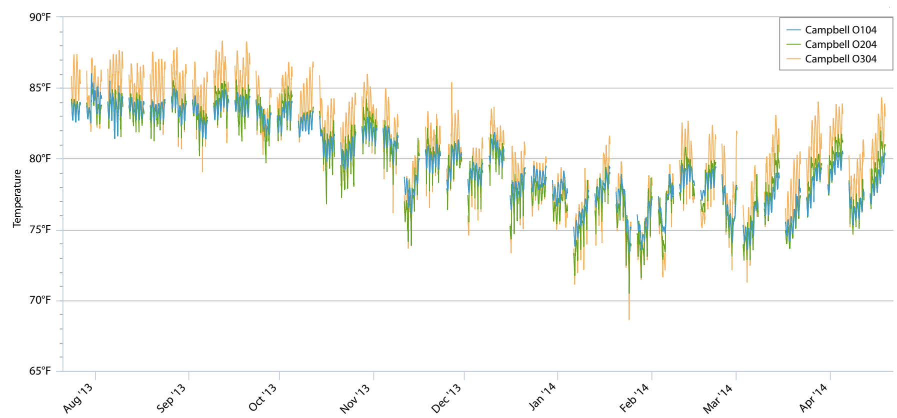
Two classrooms in building O (a donut-shaped or courtyard layout building) at Campbell were used to compare the impact of overhang depth. The analysis shows that Room O202 (overhang) was warmer than Room O205 (no overhang) in December and January, but in August and September there is a 3°F+ temperature differential between the two rooms, with O205 (no overhang) being warmer than O202 (overhang). This seasonal effect is likely due to the changing angle of the sun throughout the course of the year. When the sun is high in the sky during the summer months, the room with no overhang was warmer than the room with an overhang, which provided shade from the sun. When the sun was lower in the sky during the winter months, the building cast a shadow on itself and the room with no overhang received less direct sunlight and was therefore cooler.



TEMPERATURE PROFILES (AUGUST 2013 - APRIL 2014)
CAMPBELL D202 AND D205

Condition 3: Floor Level

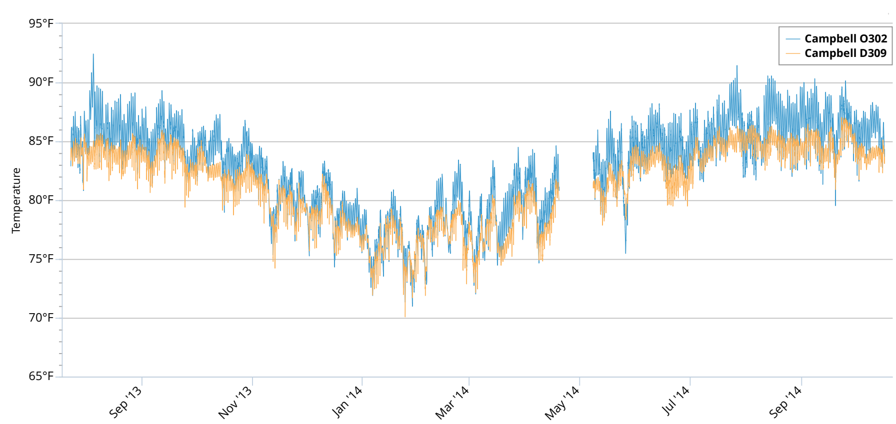
Three stacked rooms in Campbell building O were used to compare the effects of floor level on interior temperature. Room O304 (on the third floor) was consistently 3-5°F warmer than the lower level rooms (Rooms O104 and O204, on the first and second floors, respectively) throughout the school year. As shown in the chart, rooms O104 and O204 had similar temperature profiles to one another throughout the school year with narrower temperature ranges than Room O304. This effect is not necessarily attributable to floor level, but is more likely due to the roof color and insulation level.



TEMPERATURE PROFILES (AUGUST 2013 - APRIL 2014)
CAMPBELL O104, O204, AND O304

Condition 4: Roof Color

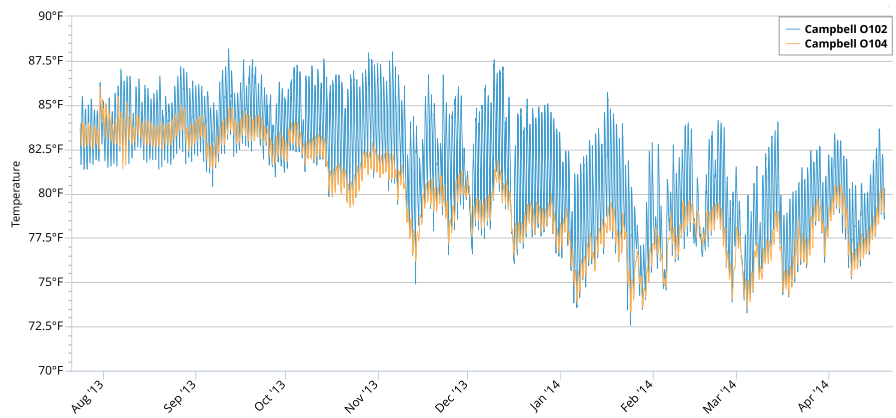
Roof color had a significant and consistent impact on room temperature. Two rooms at Campbell were used to compare this condition, Room O302 (black roof) and Room D309 (grey roof). Predictably, as darker roofs absorb greater amounts of solar radiation, Room O302 was consistently 3-5°F warmer than Room D309 throughout the school year. Room O302 also had a wider range of temperatures than D309.



TEMPERATURE PROFILES (AUGUST 2013 - APRIL 2014)
CAMPBELL O302 AND D309

Condition 5: Asphalt Paving

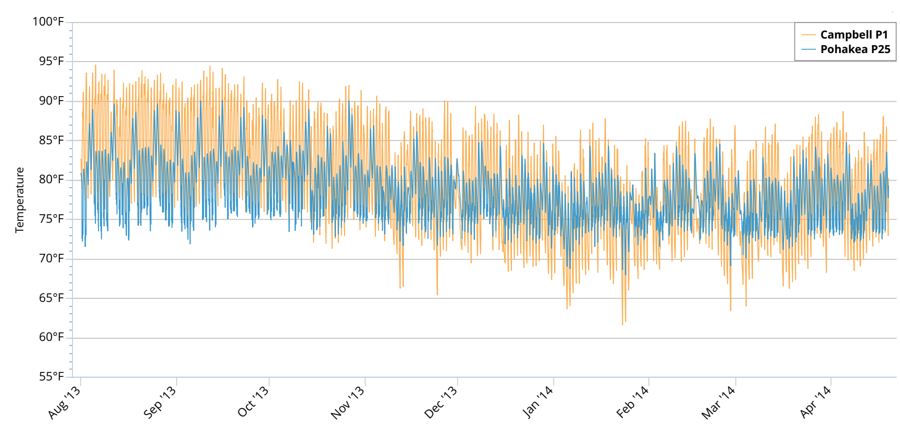
Two rooms in Campbell Building O were used to compare ground surface conditions. Room O102 is adjacent to asphalt paving while Room O104 is adjacent to grass ground cover. Room O102 was consistently up to approximately 6°F warmer than Room O104, the grass-adjacent room. This is a significant temperature differential between the two rooms. The temperature range for Room O102 is also much wider than the range for Room O104. Room O102 dips down to low temperatures similar to Room O104, but increases to temperatures up to 6°F higher.



TEMPERATURE PROFILES (AUGUST 2013 - APRIL 2014)
CAMPBELL O102 AND O104

Condition 6: Air Conditioning Usage

Two portables were used to compare air conditioning usage: Portable P25 at Pohakea (air conditioned) and Portable P1 at Campbell (un-air conditioned). Predictably, P25 was consistently cooler than P1 throughout the school year and had a narrower range than P1 (shown in the top chart). Looking at only the month of August 2013, P25 and P1 show a similar pattern to the profiles in the top chart. P25 has a narrower range and its maximum temperatures never reaching as high as P1 (un-air conditioned).



TEMPERATURE PROFILES (AUGUST 2013 - APRIL 2014)
POHAKEA P25 AND CAMPBELL P1

4 Recommendation

Recommendation Overview

The recommendations that will be summarized in this section are shown in the table below. These interventions can be combined based on specific site/building characteristics to yield optimal results relative to investment. These strategies are purely theoretical at this stage and would require future field testing to validate their effectiveness.

The table outlines the strategies presented in this section, the accompanying rooms/buildings studied, and the possible rooms/buildings where they could potentially be implemented.

The table also includes an 'Ease of Deployment' column. Each strategy is assigned a category based on the level of investment (time, money, labor, etc.) it would take to implement on the following scale of intensity:

- Least Intensive
- Minor Intensity
- Intensive
- Most Intensive

There is also a column in the table measuring 'Potential Effectiveness', which assesses the degree of impact that each strategy could have on temperature and thermal comfort. Each strategy is rated on the following scale of effectiveness:

- Least Effective
- Minor Effectiveness
- Effective
- Most Effective

The above criteria are hypotheses at this stage and would require further testing to determine the actual effectiveness of each strategy in practice.

By far the most promising strategy is 'nocturnal flushing' (using nighttime air to cool classrooms), which could theoretically be applied to all buildings as it only requires classrooms to be in multi-story buildings and to have windows for it to be effective. The other strategies presented are more specific to classroom types, such as fenestration configuration and shading asphalt surfaces adjacent to rooms.

In addition, a portable air conditioned classroom was studied to analyze any unexpected concerns caused by air conditioning usage. This helped to inform the Mechanical Conditioning strategies related to air conditioning.

Recommendations Summary Table

NO.	TYPE	STRATEGY	ROOMS/BUILDINGS STUDIED
1.1	Reduce Solar Gain	Lighter Roof Colors	Campbell Building O
1.2	Reduce Solar Gain	Additional Roof Insulation	Campbell Building O
1.3	Reduce Solar Gain	Replan Paved Areas	Entire Campbell School complex
1.4	Reduce Solar Gain	Shading Asphalt Surfaces Adjacent to Rooms	Ilima I101
1.5	Reduce Solar Gain	Natural Shading	Entire Campbell School complex
2.1	Increase Natural Ventilation	Fenestration Configuration	Kaimiloa Building E (or any rooms with windows on three sides)
2.2	Increase Natural Ventilation	Unpartitioned Rooms	Kaimiloa F105/F106 and F213/F214
2.3	Increase Natural Ventilation	Thermal (Nocturnal) Flushing	All multi-story buildings
3.1	Mechanical Conditioning	Fans	All classrooms using fans
3.2	Mechanical Conditioning	PV Air Conditioning Units	Not Applicable
3.3	Mechanical Conditioning	Optimize Air Conditioning Usage	Pohakea P25

RECOMMENDATION

Recommendation 1: Reduce Solar Gain

Solar gain can be reduced in a number of ways, through roof color, paving, and shading.

1.1 Lighter Roof Colors
Roof color appears to have an impact on room temperature (see top chart). Changing dark roofs to a lighter color could reduce room temperatures.

1.2 Additional Roof Insulation
Roof insulation could be used to reduce the indoor temperature impacts from rooftop solar gain. This could be applied to buildings with darker roofs for maximum effectiveness.

1.3 Replan Paved Areas
Paved surfaces act as thermal masses and absorb and retain heat throughout the day. This heat can radiate to nearby buildings, causing their interior temperatures to rise. Darker paving materials absorb and retain more heat than lighter paving materials. Therefore, light colored paving materials should be used when possible. Ideally, natural landscaping or unpaved areas are preferable to surface paving (see 1.3 below).

1.4 Shading Asphalt Surfaces Adjacent to Rooms
Ilima I101 was the hottest room out of all 71 studied. Room I101 was directly next to an asphalt parking lot and has a roll-up door that opens onto the parking lot. This set of conditions potentially caused hot air radiating from the parking lot to enter the room and cause temperatures to rise greatly (as seen in the data collected). If the asphalt parking lot surface is in fact the reason for the exceedingly high temperatures in I101, possible mitigation strategies could include putting a shade over the parking lot, or replacing the asphalt parking lot surface with a lighter colored paved surface.

1.5 Increasing Shading
Shade from canopies and other landscaping elements can reduce ground temperatures. Increasing the amount of paved area shaded by trees, canopies, arbors, or overhangs can decrease the amount of heat absorbed and radiated by asphalt, concrete, and other paving materials. Architectural canopies should be designed to provide maximum shading in addition to providing cover from the rain.

POSSIBLE APPLICATIONS	EASE OF DEPLOYMENT	POTENTIAL EFFECTIVENESS
Buildings with black roofs	Least Intensive	Most Effective
Buildings with darker roofs	Intensive	Minor Effectiveness
Rooms directly adjacent asphalt surfaces	Most Intensive	Minor Effectiveness
Rooms with doors open to adjacent asphalt surfaces	Intensive	Effective
Rooms directly adjacent asphalt surfaces	Minor Intensity	Minor Effectiveness
Rooms with windows on three sides	Intensive	Effective
Kaimiloa F105/F106 and F213/F214 / Other partitioned rooms	Intensive	Effective
All rooms (emphasis on upper level floors due to security concerns)	Minor Intensity	Most Effective
All rooms	Least Intensive	Least Effective
Rooms currently air conditioned	Most Intensive	Most Effective
Air conditioned rooms	Minor Intensity	Effective

Recommendation 2: Increase Natural Ventilation

Natural air flow and ventilation could be increased and maximized in a number of ways.

2.1 Fenestration Configuration
Many of the rooms in the Campbell school complex have louver windows. Opened louvers (jalousies) can increase thermal comfort by allowing natural ventilation to occur. Closed jalousies will not only block air flow, but will also increase heat gain. Jalousies are often not opened because they are difficult to operate, broken/inoperable, or there is the need to use the jalousies as wall/display space.

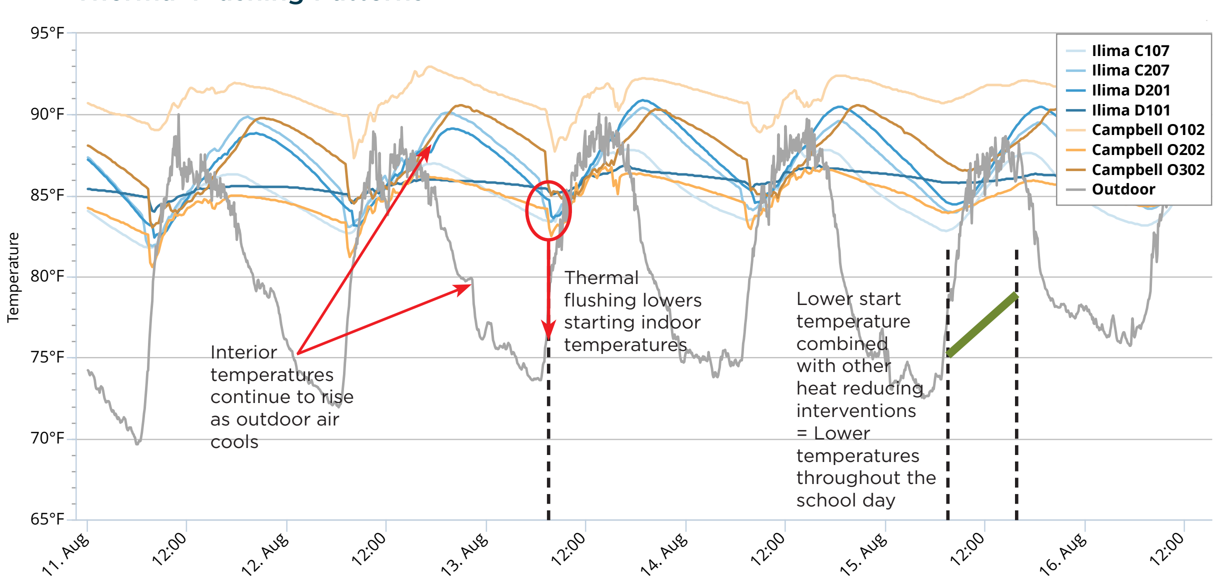
2.2 Unpartitioned Rooms
The classrooms at Kaimiloa were designed for cross ventilation but the installation of a partition decreases air flow. While these rooms were designed with windows on both sides, the partition creates a barrier to air flow with only small openings (doors) on the side, thereby decreasing ventilation. Removing the partitions in these rooms or replanning the classroom layout could increase air flow and take advantage of the cross-ventilation that the windows could provide.

2.3 Thermal (Nocturnal) Flushing
Thermal or nocturnal flushing presents a significant opportunity for indoor temperature reduction. The nighttime outdoor air temperature often much cooler than the indoor room temperature, with the differential sometimes exceeding 15°F. The benefit of thermal flushing benefit is twofold:

- Lower starting temperature
- Increase lag time between exterior and interior temperature peaks (i.e. interiors warm more slowly than exterior temperature)

Passive flushing (opening windows and jalousies) should be tested, in addition to active flushing (assisted by fans or centralized system), which can accelerate interior cooling (see Recommendation 3).

Thermal Flushing Patterns



Recommendation 3: Mechanical Conditioning

Mechanical systems can be added where needed to supplement passive cooling.

3.1 Fans

Some combination of ceiling fans, box fans, wall-mounted fans, and floor fans, were observed in nearly all unconditioned classrooms .Fans on top of buckets of ice were also observed being used as mechanical cooling devices. Fans can be used to increase air movement inside classroom spaces. The presence of moving air can increase an occupant's perception of thermal comfort.

3.2 PV Air Conditioning Units

PV air conditioning units can be a more energy-efficient way of providing air conditioning. PV air conditioning units use solar energy collected in solar thermal panels to cool indoor spaces.

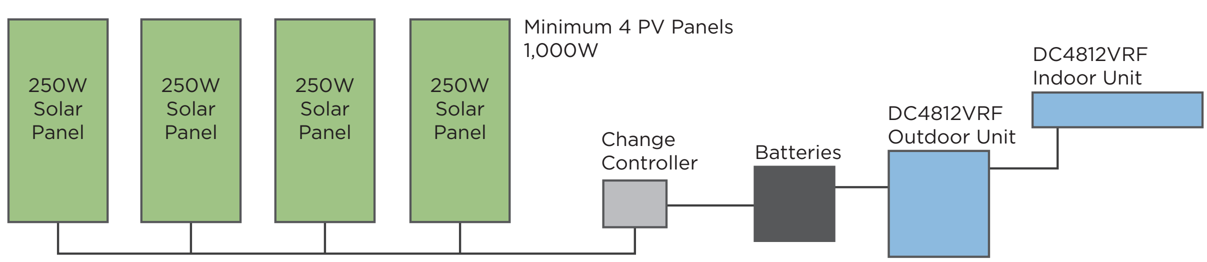
3.3 Optimize Air Conditioning Usage

Pohakea Room P25 was the only air conditioned portable room where thermal comfort, carbon dioxide, and sound were measured. The comfort levels during school hours (calculated assuming that students wear T-shirts and shorts) are excessively cool. The carbon dioxide levels reach levels nearing benchmarks for poor ventilation and moderate decision-making impairment (caused by ambient carbon dioxide concentrations greater than 1,000 ppm).

While the sound data for Room P25 is from non-school days, the measured sound level still hovers around the EPA benchmark for indoor background noise. Since the air conditioner wasn't on during this period, the background noise level would be expected to be quieter than the background noise level during school hours when the air conditioner is on. The analysis of Pohakea P25 suggests that air conditioning in classrooms could lead to unintended consequences, including:

- Indoor temperatures that make classrooms feel uncomfortably cool
- Increased energy costs due to excessive AC usage
- Background noise levels exceeding the EPA threshold

PV Air Conditioning Process



MKTHINK

the IDEAS company for the built environment