Impact of Energy Efficiency Initiatives

APEC Expert Group on New and Renewable Energy Technologies
Honolulu, Hawaii
March 20, 2018

Hawaii Natural Energy Institute

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School of Ocean and Earth Science and Technology
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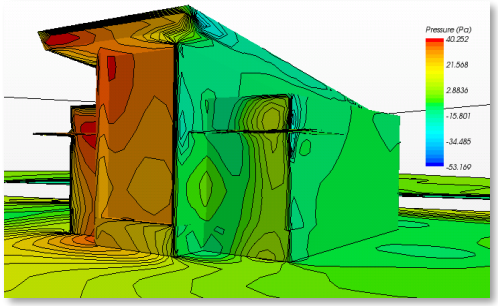

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1907
UA MAU KE EA O KA 'ĀINA I KA PONO

AGENDA

- Power of Policy and Programs
  - Evolution of Energy Efficiency
  - Direction over next 10 years
- Energy Efficiency in Buildings
  - Example Programs
  - Zero Net Energy Buildings
- HNEI Work in Energy Efficiency
- Future research

Power of EE Policy and Programs

- Power of Policy and Programs
  - Policy will drive future oriented savings
  - Programs drive current and future investments in energy savings
  - Programs drive Grid support and integration of renewable energy

Demand Side Management

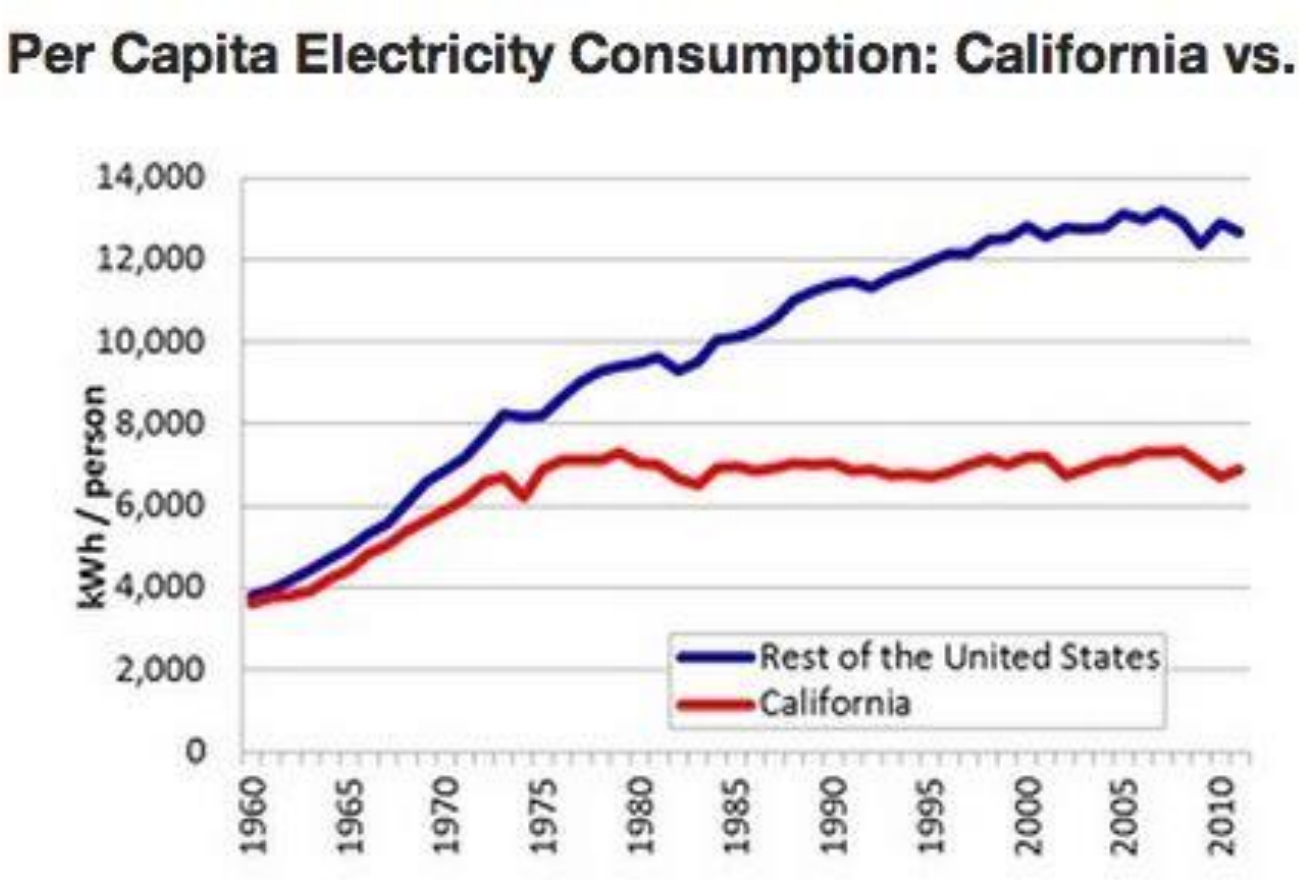
Demand-side management (DSM) is the planning and implementation of programs designed to influence electric and gas utility customer uses of energy in ways that will produce desired changes in a utility's or customer's energy profile.

Energy Efficiency bundled under DSM

California Energy Policy: Warren Ahlquist State Energy Resources Conservation and Development Act (1974)

- Calif Energy Commission Regulated all aspects of energy
  - Efficiency and Conservation
  - Electricity and Natural Gas
    - Generation / Power plants
    - Import of fuel
    - Transmission and Distribution
  - Transportation
  - Integrated Energy Policy

California Energy Policy: Warren Ahlquist State Energy Resources Conservation and Development Act (1974)



Source: Greentechmedia.com

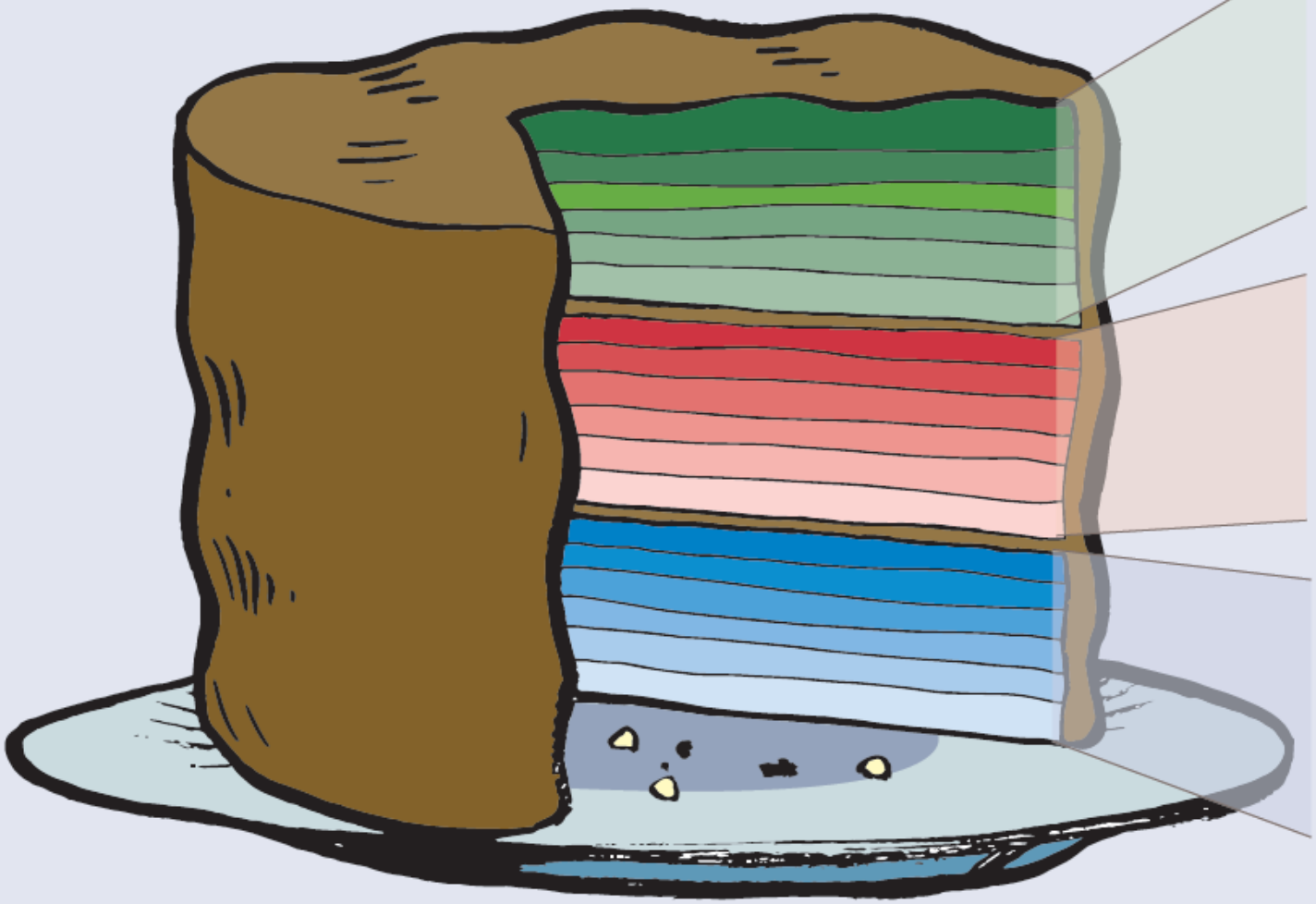
EU's "Efficiency First" model

In February 2015, the principle of Efficiency First was formally endorsed by the European Commission within the framework of the Energy Union.

- Help the Energy Union to deliver on the three goals of **competitiveness**, **energy security**, and **decarbonisation**
- Identifies Energy Union governance framework to make Efficiency First work in practice.
- Recommendations include:
  - Use consistent demand projections that assume all of the EU's existing energy and climate goals are met in energy plans and models;
  - Employ a societal perspective (use appropriate discount rates) when assessing the impact of efficiency policies;
  - Make *Efficiency First* a bedrock of national climate and energy plans under the Energy Union;
  - Set a binding 40 percent energy efficiency target for 2030;
  - Extend and tighten up energy efficiency obligations under the Energy Efficiency Directive;
  - Make efficiency a principle of energy system design;
  - Use Efficiency First to guide EU funds; and
  - Get local and regional governments involved.

Source: http://www.raponline.org/knowledge-center/efficiency-first-new-paradigm-european-energy-system/

A "Layer Cake" of Benefits from Electric Energy Efficiency



Utility System Benefits
- Power Supply
- T&D Capacity
- Environmental
- Losses and reserves
- Risk
- Credit and Collection

Participant Benefits
- Other Fuels
- Water, Sewer
- O&M Costs
- Health Impacts
- Employee Productivity
- Comfort

Societal Benefits
- Air Quality
- Water
- Solid Waste
- Energy Security
- Economic Development
- Health Impacts

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Source: Regulatory Assistance Project (RAP) http://www.raponline.org/knowledge-center/recognizing-the-full-value-of-energy-efficiency/

Integrated Demand Side Management

The integration/coordination of delivery for three or more of:

(1) Energy Efficiency,

(2) Demand Response,

(3) Distributed Generation,

(4) Storage,

(5) Electric Vehicle, and

(6) Time-Based Rate programs to residential and commercial electric utility customers.

Source: Lawrence Berkeley National Laboratory, *Barriers and Opportunities to Broader Adoption of Integrated Demand Side Management*, November, 2017




Barriers and Opportunities to Broader Adoption of Integrated Demand Side Management at Electric Utilities

March 8, 2018

Jennifer Potter[†], Elizabeth Stuart[‡], and Peter Cappers[‡]

† Hawaii Natural Energy Institute

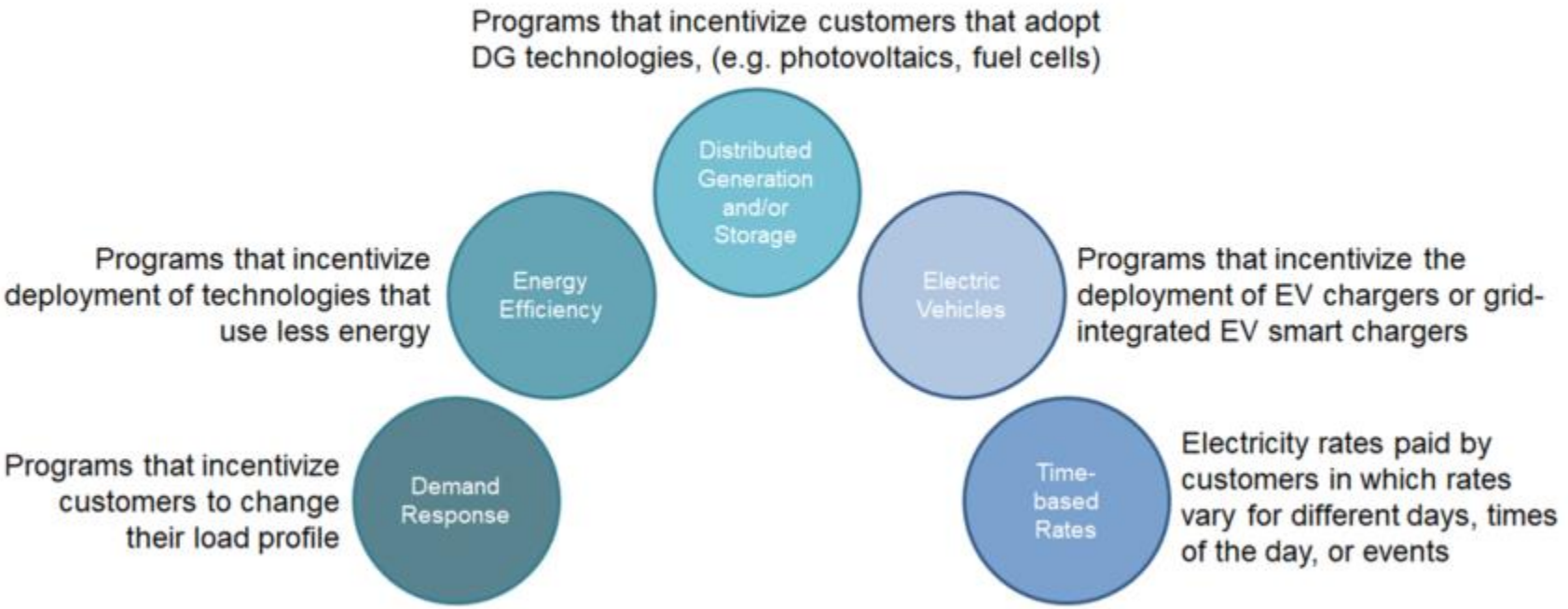
‡ Lawrence Berkeley National Laboratory

BERKELEY LAB

ENERGY TECHNOLOGIES AREA

Hawaii Natural Energy Institute

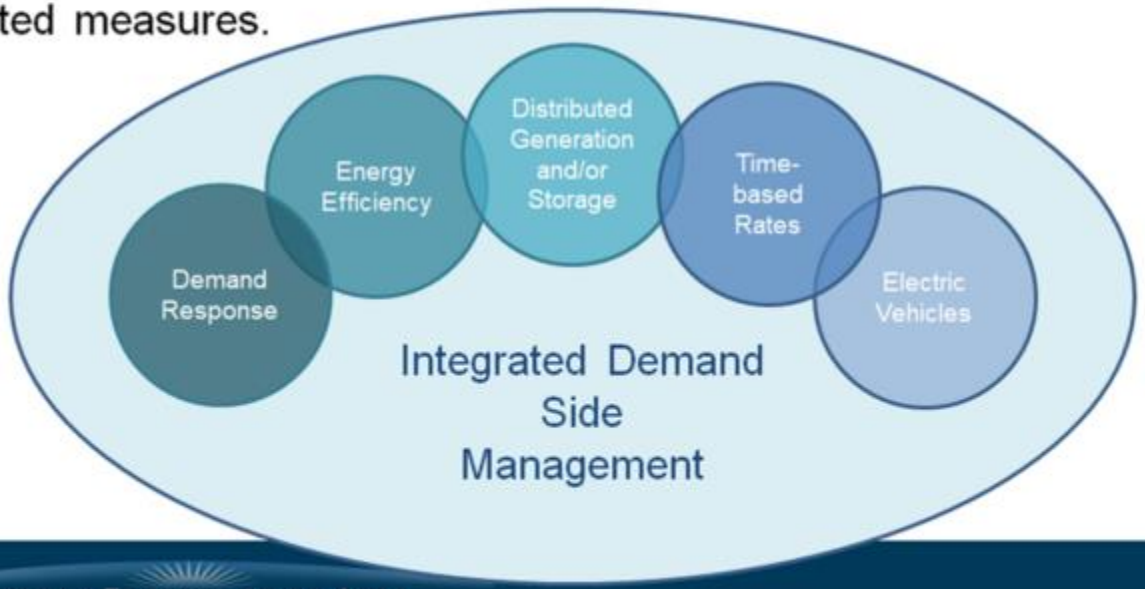
Current DSM Program Offerings



Source: Lawrence Berkeley National Laboratory, *Barriers and Opportunities to Broader Adoption of Integrated Demand Side Management*, November, 2017

Current IDSM Program Offerings

In an IDSM program, a customer is offered marketing materials, rebates and incentives, and/or financing for measures that integrate/coordinate with other measures that can be installed together as one package, simultaneously, or as interconnected measures.



Source: Lawrence Berkeley National Laboratory, *Barriers and Opportunities to Broader Adoption of Integrated Demand Side Management*, November, 2017

Objectives of Scoping Study by Lawrence Berkeley National Laboratory

- Identify barriers and opportunities for increasing implementation IDSM programs by:
  - Highlighting examples of programmatic mechanisms that have been or could be deployed for delivering IDSM technologies;
  - Identifying benefits reported by program administrators that IDSM has provided or may provide to the bulk power and distribution system;
  - Identifying a prioritized set of barriers that has been or could be experienced by program administrators to more fully implement IDSM; and
  - Discussing efforts that have been or could be undertaken to overcome these barriers.

Source: Lawrence Berkeley National Laboratory, *Barriers and Opportunities to Broader Adoption of Integrated Demand Side Management*, November, 2017

Respondents described significant barriers to implementing IDSM

- Separate/Distinct Program Budgets limit funding for IDSM projects
- Lack of Cost Effectiveness Metrics for valuing IDSM portfolios and measures limit implementation
- Separation of responsibilities within organizations for delivering DSM programs can limit or prohibit collaborative marketing, administration, and merging of resources that would improve delivery of IDSM

Source: Lawrence Berkeley National Laboratory, *Barriers and Opportunities to Broader Adoption of Integrated Demand Side Management*, November, 2017

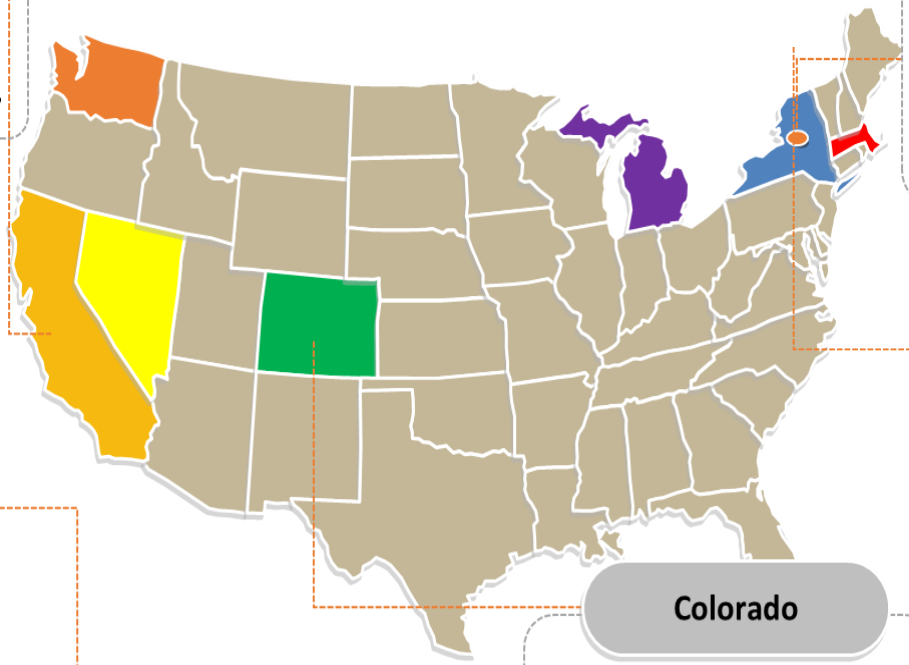
Limited Industry Experience with IDSM

California

- IDSM Proceeding began in 2009
- Focused on "duck curve"

New York

- Reforming the Energy Vision (REV)
- 40+ customer focused initiatives



Massachusetts

- Grid modernization
- Non-wires alternatives

Hawaii

- Current DR docket and DER initiatives
- 3rd party administered EE

Colorado

- Perf. based utility regulation (HB1250)
- AMI in progress

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Source: Lawrence Berkeley National Laboratory, *Barriers and Opportunities to Broader Adoption of Integrated Demand Side Management*, November, 2017

Utilities are pursuing IDSM because…

- Respondents stated that IDSM offers:
  - The ability to deliver broader range of demand side technology options
  - Services to optimize customers' end use energy consumption and increase customer engagement/satisfaction
  - Compliance with regulatory mandates to offer IDSM or EE and DR programs.
- Over 50% respondents indicated IDSM opportunities may help address distribution, and in some cases bulk power system, needs by providing **targeted, locational and temporal controllability** and/or energy reduction of end-uses.

Source: Lawrence Berkeley National Laboratory, *Barriers and Opportunities to Broader Adoption of Integrated Demand Side Management*, November, 2017

Residential DSM and IDSM Programs

	SMUD	SCE	PG&E	DTE Energy	Avan Grid	Con Edison	HECO	Hawai'i Energy
Residential								
Appliance Recycling	○	○	○	○	○	○		○
Behavior	●	●	○●	○	○			○
Education	○	○	○	○	○	○	○	○
Home Appliances	○	○	○	○		○		○
Home Retrofit	✚	○	○	○		✚ (targeted) ○ (general)		
HVAC	●✚	●✚	○●	○●	○✚	○✚	●✚	✚
Lighting	○	○	○	○	○	○		○
Multifamily	○	○	○	○		○		○
New Construction	✚	○	✚	○				
Water Heating	○	○	○	○		○	✚	○
Pool pumps	○	○	○					○
Electric Vehicles	○✚	○	○	○		○		

Key:

✚: IDSM Program offered

○: EE program only

●: DR program only

○●: A distinct EE program and a distinct DR program are offered

○✚: A distinct EE program and IDSM program are offered

●✚: A distinct DR program and IDSM program are offered

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Source: Lawrence Berkeley National Laboratory, *Barriers and Opportunities to Broader Adoption of Integrated Demand Side Management*, November, 2017

Commerical DSM and IDSM Programs

	SMUD	SCE	PG&E	DTE Energy	AvanGrid	Con Edison	HECO	Hawai'i Energy
Commercial								
Agriculture	○	○●	○					○
Efficient motors	○	○	○	○	○	○		○
HVAC	✚	○●	○●	○	○	○	●	○
Industrial custom	○	○●	○●	○	○	○		○
Business custom	○	○●	○●	○	○	○		○
Lighting	○	○	○	○	○	○		○
Lighting systems and controls	○	○	○	○	○	○		○
Retro-commissioning	○	○	○	○		✚(targeted) ○(general)		○
Small business custom	○	○●	○●	○	○	○		○
Energy Management Control Systems	✚	✚	○	○		○●		
New Construction	○	○	○✚	○				
Battery Storage	○	○	○✚			○		

Key:

✚: IDSM Program offered

○: EE program only

●: DR program only

○●: A distinct EE program and a distinct DR program are offered

○✚: A distinct EE program and IDSM program are offered

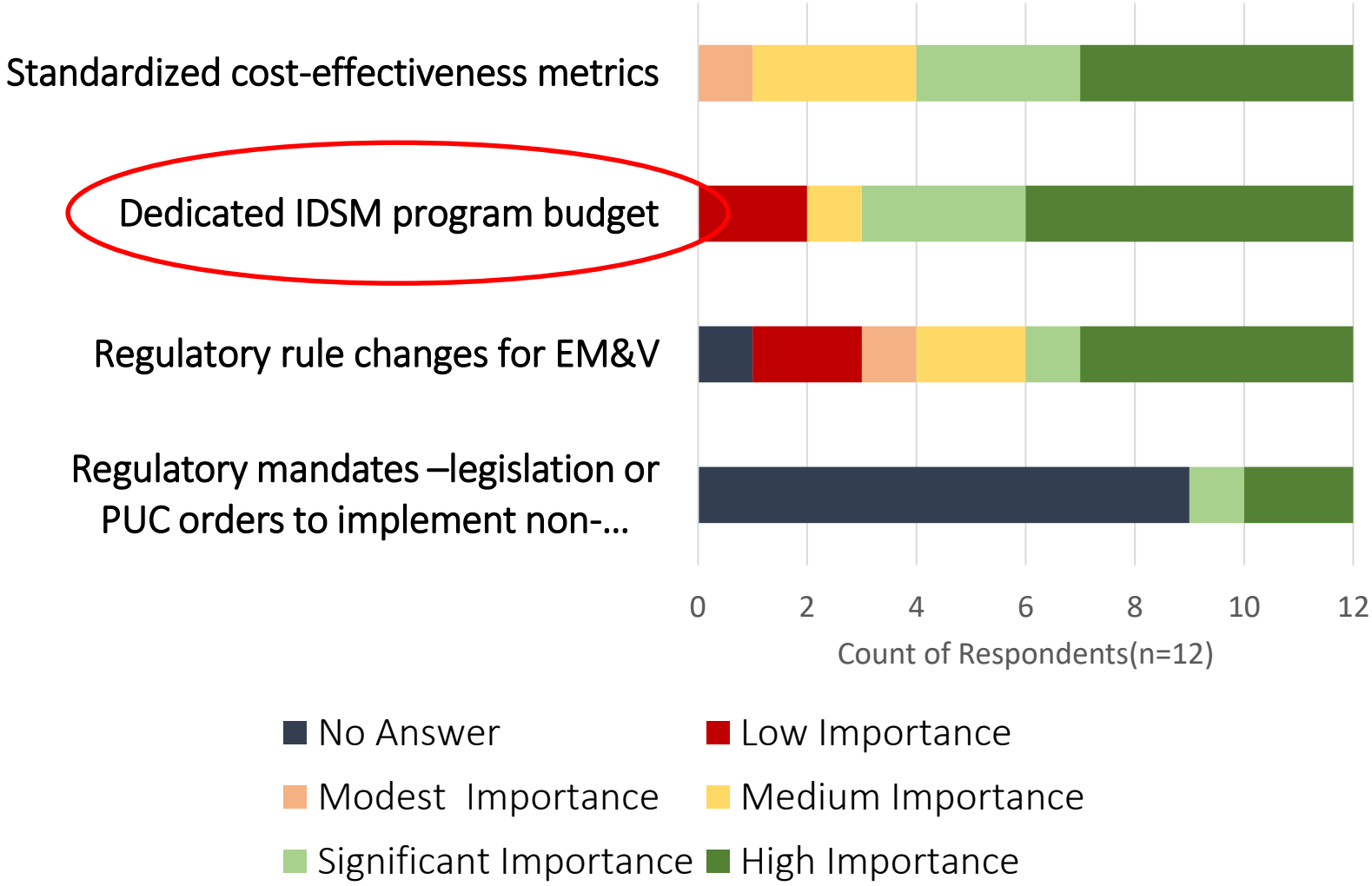
●✚: A distinct DR program and IDSM program are offered

Source: Lawrence Berkeley National Laboratory, *Barriers and Opportunities to Broader Adoption of Integrated Demand Side Management*, November, 2017

Key Takeaways

Source: Lawrence Berkeley National Laboratory, *Barriers and Opportunities to Broader Adoption of Integrated Demand Side Management*, November, 2017

Regulatory Opportunities for Expanding IDSM



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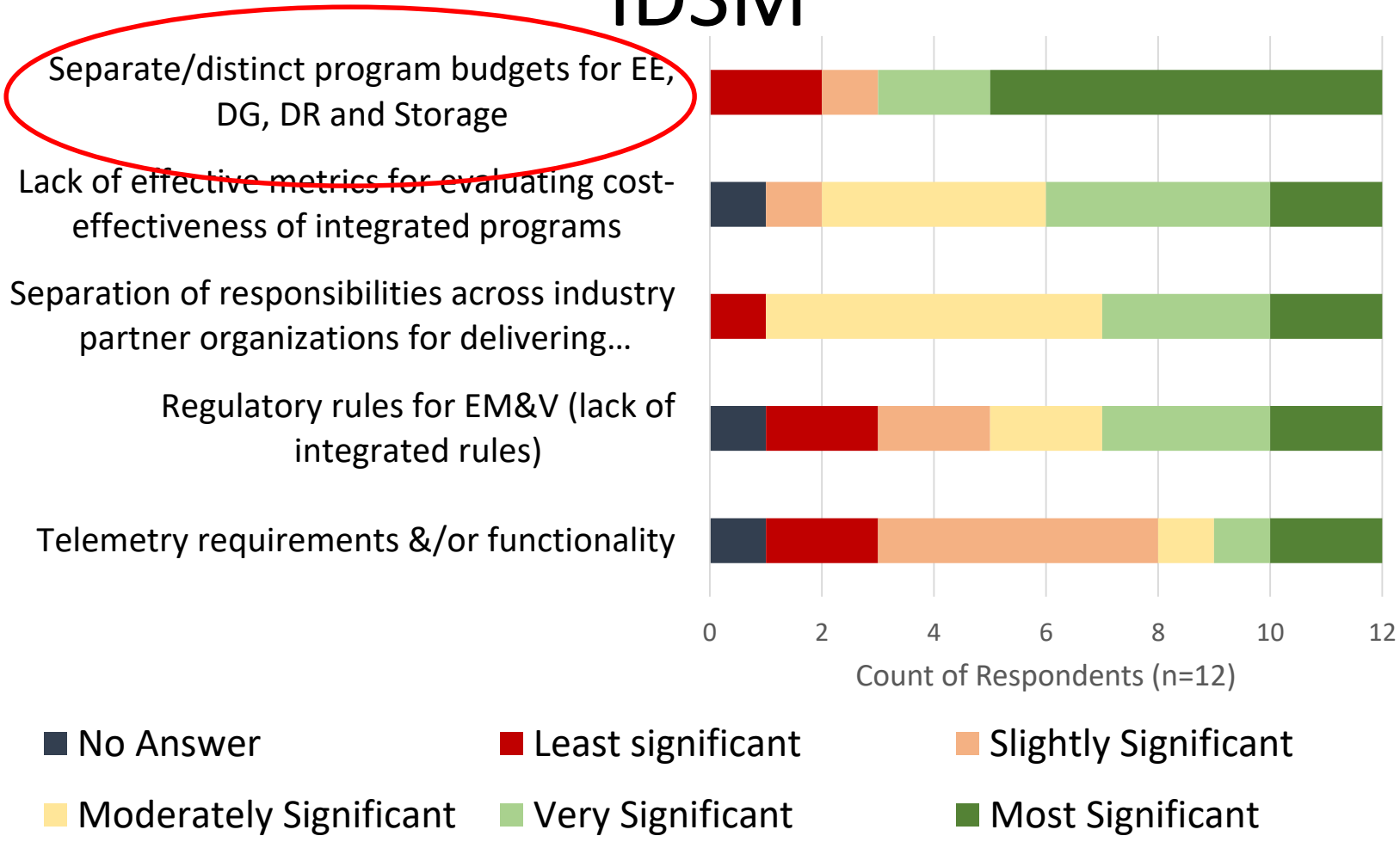
Regulatory Barriers to Implementing IDSM



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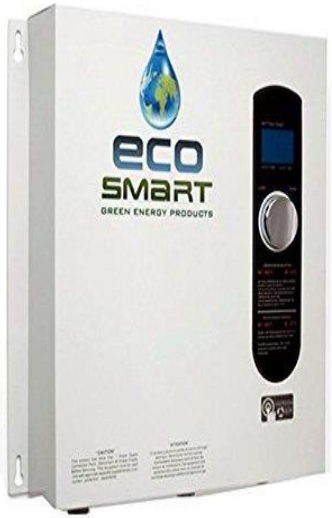
Source: Lawrence Berkeley National Laboratory, *Barriers and Opportunities to Broader Adoption of Integrated Demand Side Management*, November, 2017

Promising Residential IDSM Programmatic Opportunities

HVAC Controls

Electric Vehicles

Battery Storage



Water Heating

Advanced Solar Inverter

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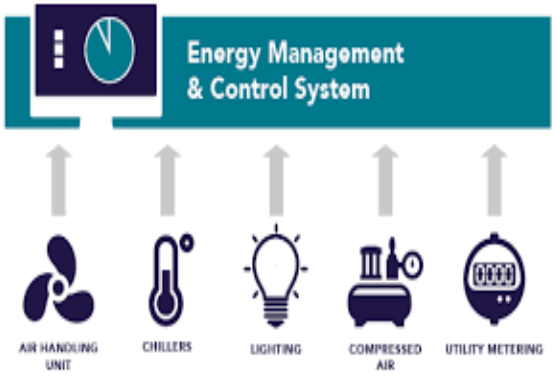
Source: Lawrence Berkeley National Laboratory, *Barriers and Opportunities to Broader Adoption of Integrated Demand Side Management*, November, 2017

Promising C&I IDSM Programmatic Opportunities

Lighting Systems & Control



Battery Storage

Electric Transportation

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Source: Lawrence Berkeley National Laboratory, *Barriers and Opportunities to Broader Adoption of Integrated Demand Side Management*, November, 2017

Conclusions

- Energy Efficiency is evolving, more complex
- Efficiency programs have value far greater than energy savings
- EE is now a portfolio of solutions with flexibility to support dynamic grids and customer needs.
- Integrated DSM is the new Efficiency. Cannot be considered as a stand alone solution.
- Primary consideration in developing energy policies and programs
- Should be budgeted as an IDSM portfolio

Building Technologies

- Zero Net Energy buildings (UH) and communities
- Building simulation and analysis
- Desiccant Dehumidification technology

FROG

Flexible
Response to
Ongoing
Growth

Test sites

- 3 locations
- 5 Modular classroom buildings

First Generation

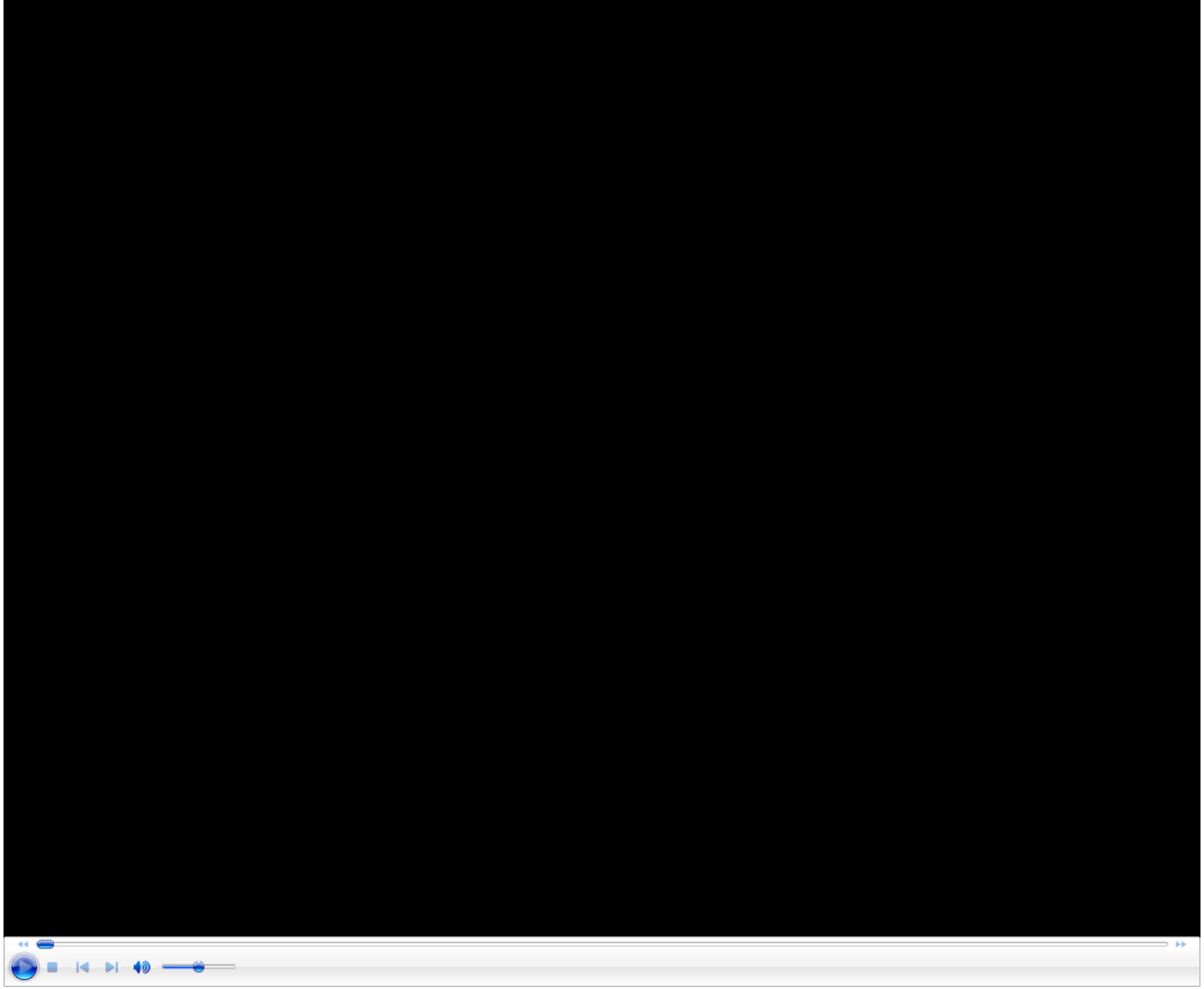
Location: Lihue, Kauai and Ewa Beach, Oahu

Year built: 2010-13

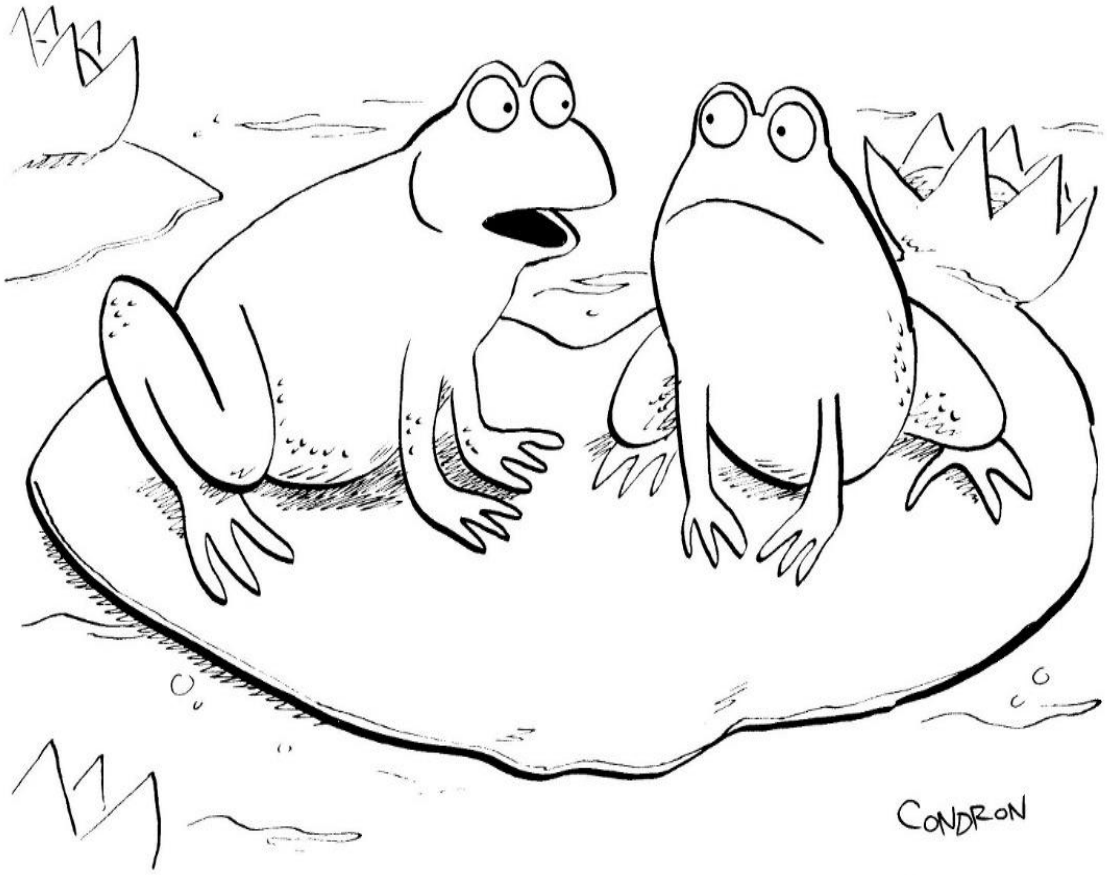
Second Generation

Location: UH Manoa, Honolulu Oahu

Year built: 2016

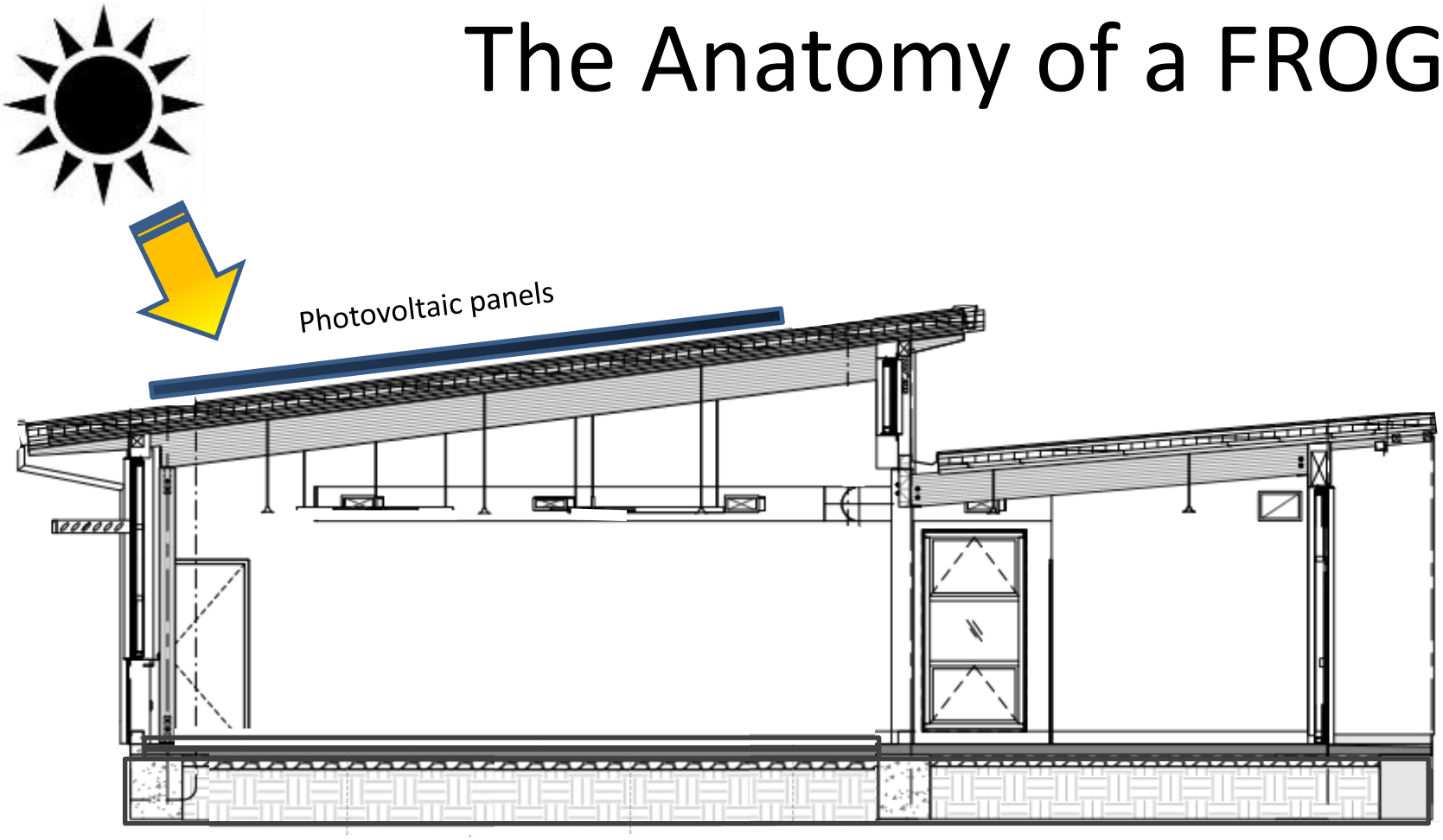


The Anatomy of a FROG



"I'M DONATING MY BODY TO SCIENCE CLASS."

The Anatomy of a FROG



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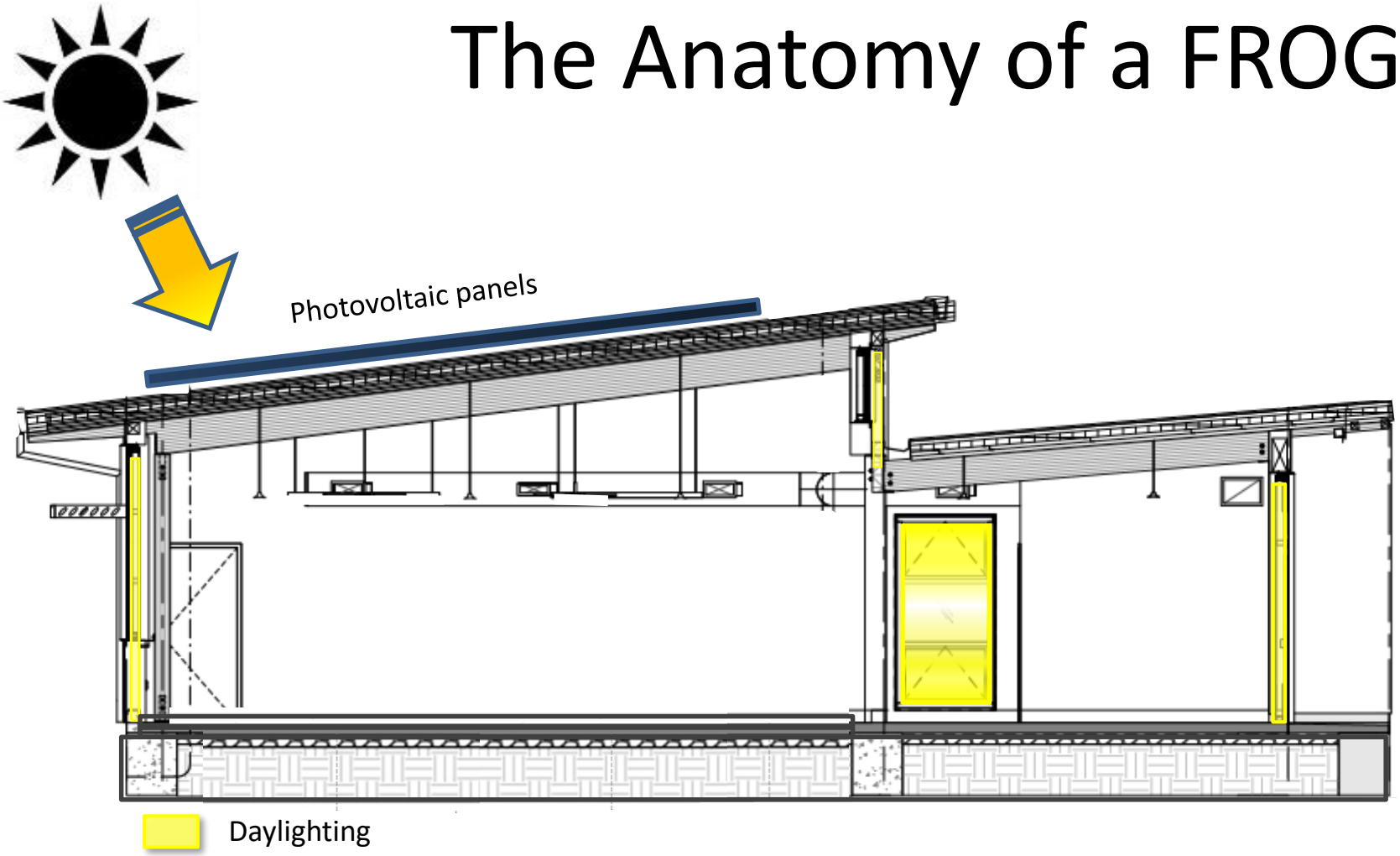

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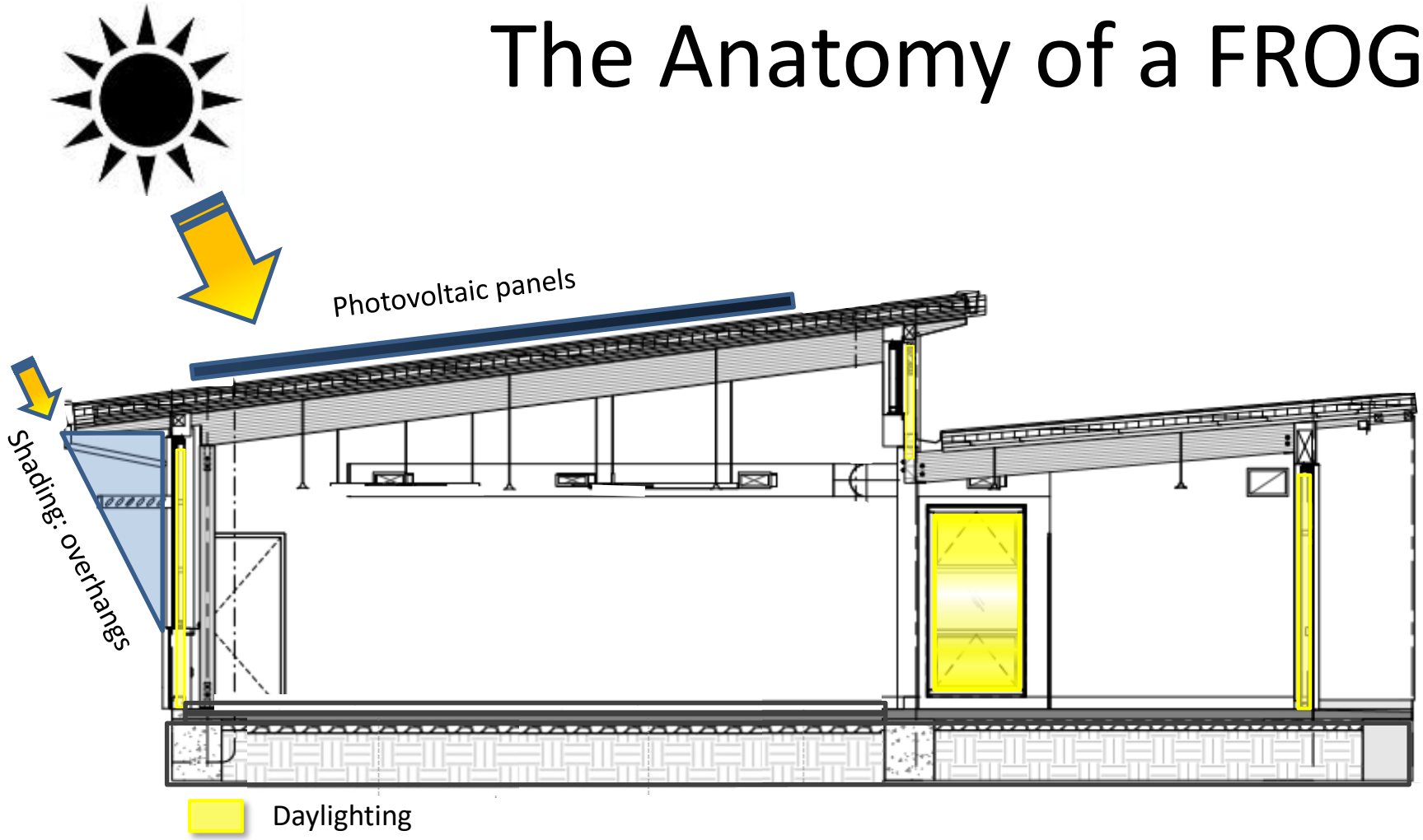

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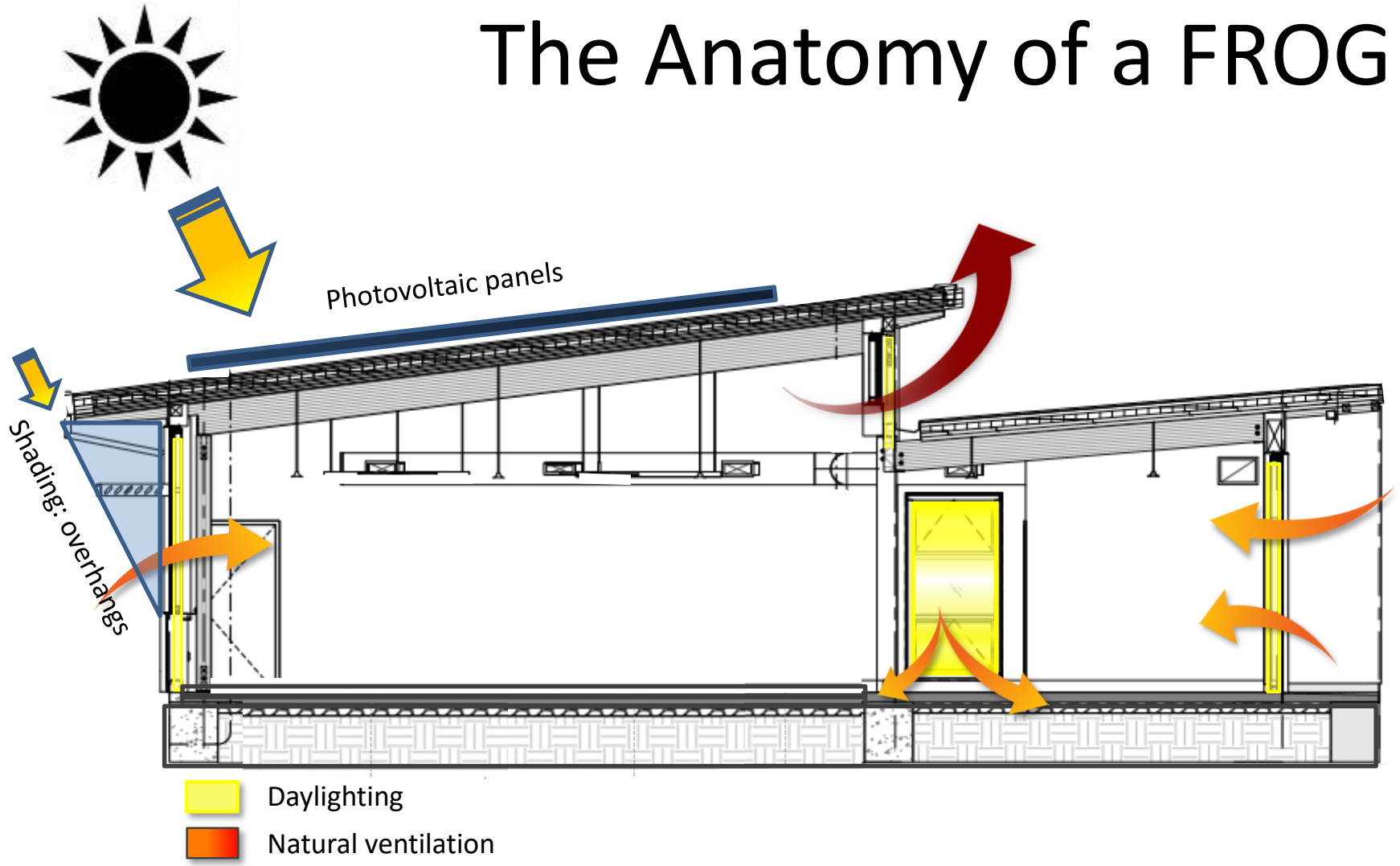

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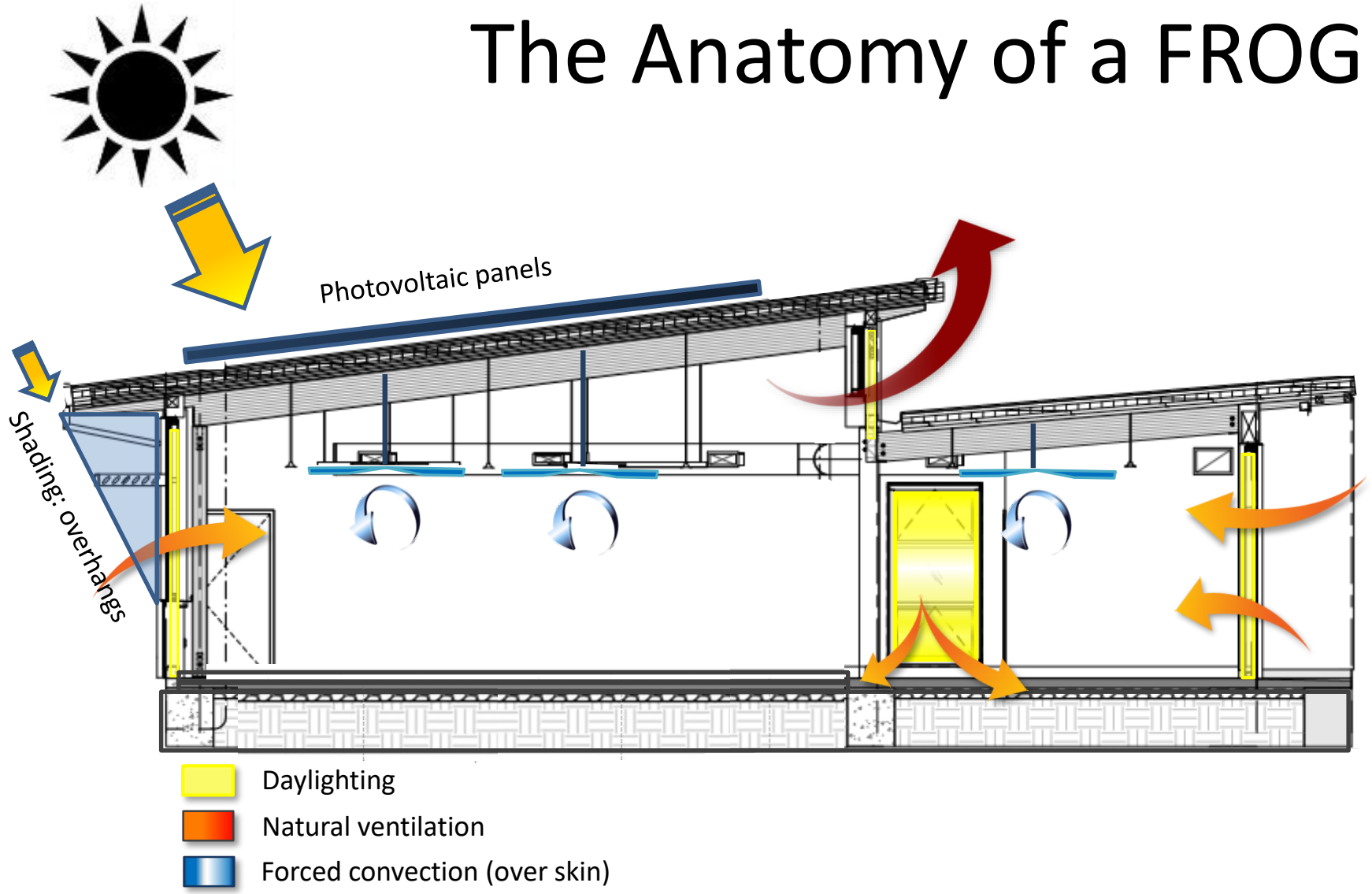

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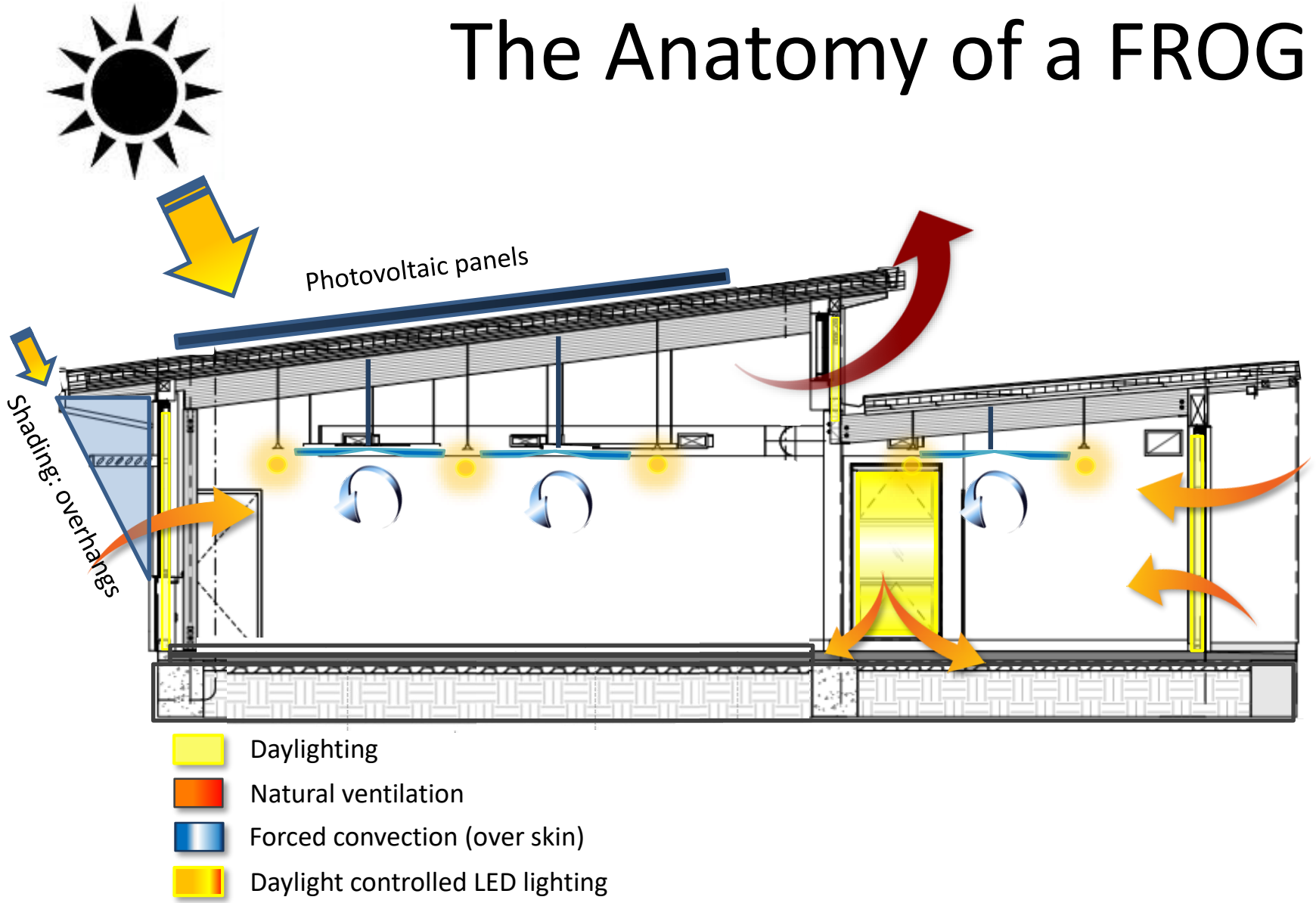

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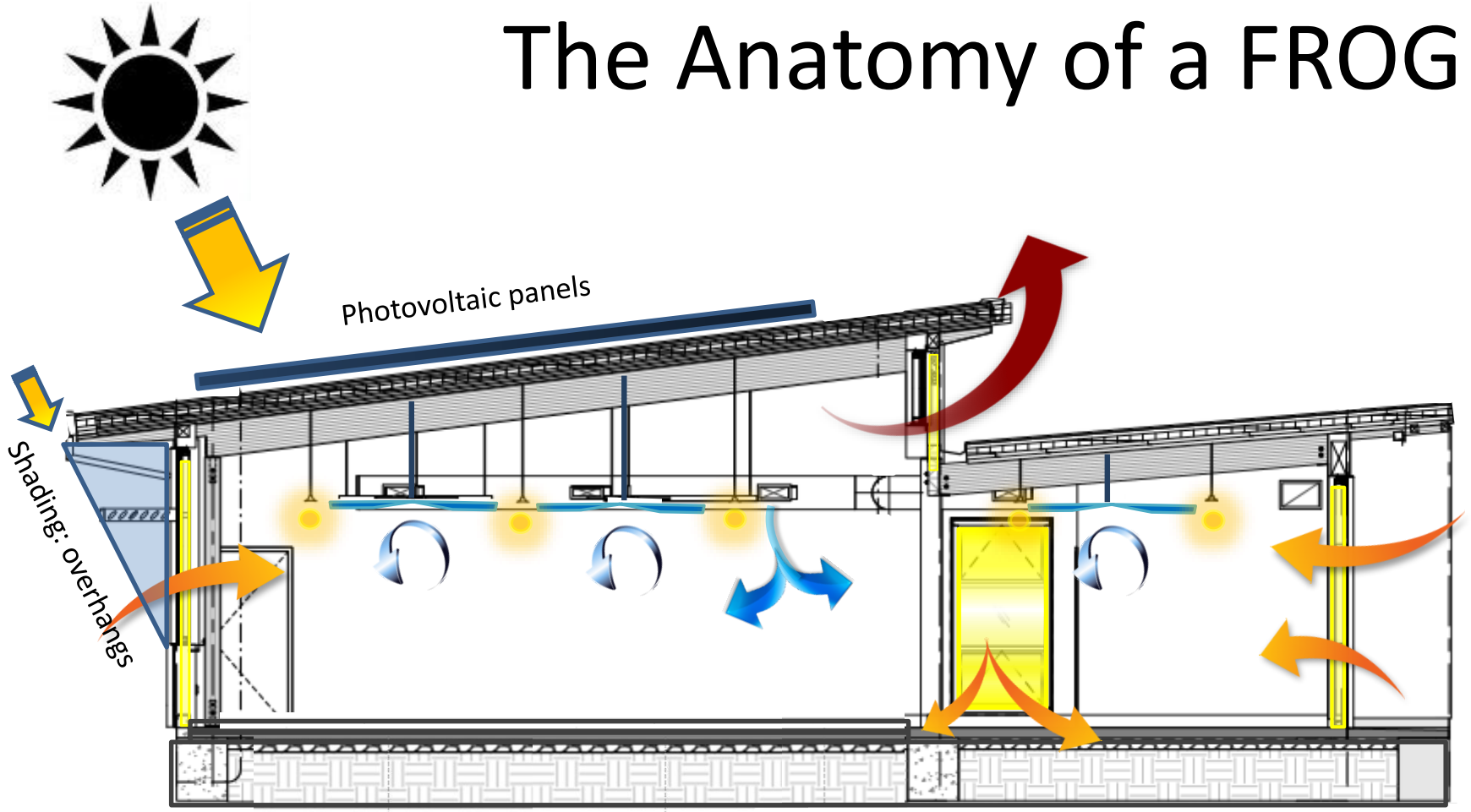


performance monitoring

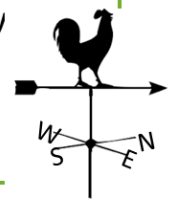
ENERGY SENSORS

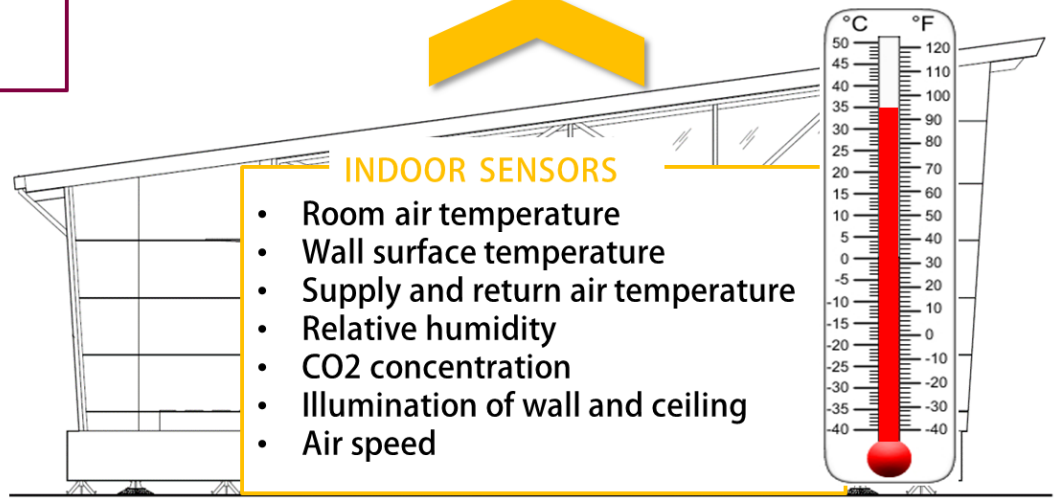
- AC condenser
- AC fan coil unit
- Lighting, indoors
- Lighting, outdoors
- Ceiling fans
- Exhaust fan
- Plug loads (all things plugged into sockets)
- Solar photovoltaic energy production

DATABASE

WEATHER SENSORS

- Temperature
- Relative humidity
- Solar radiation
- Wind speed
- Wind direction





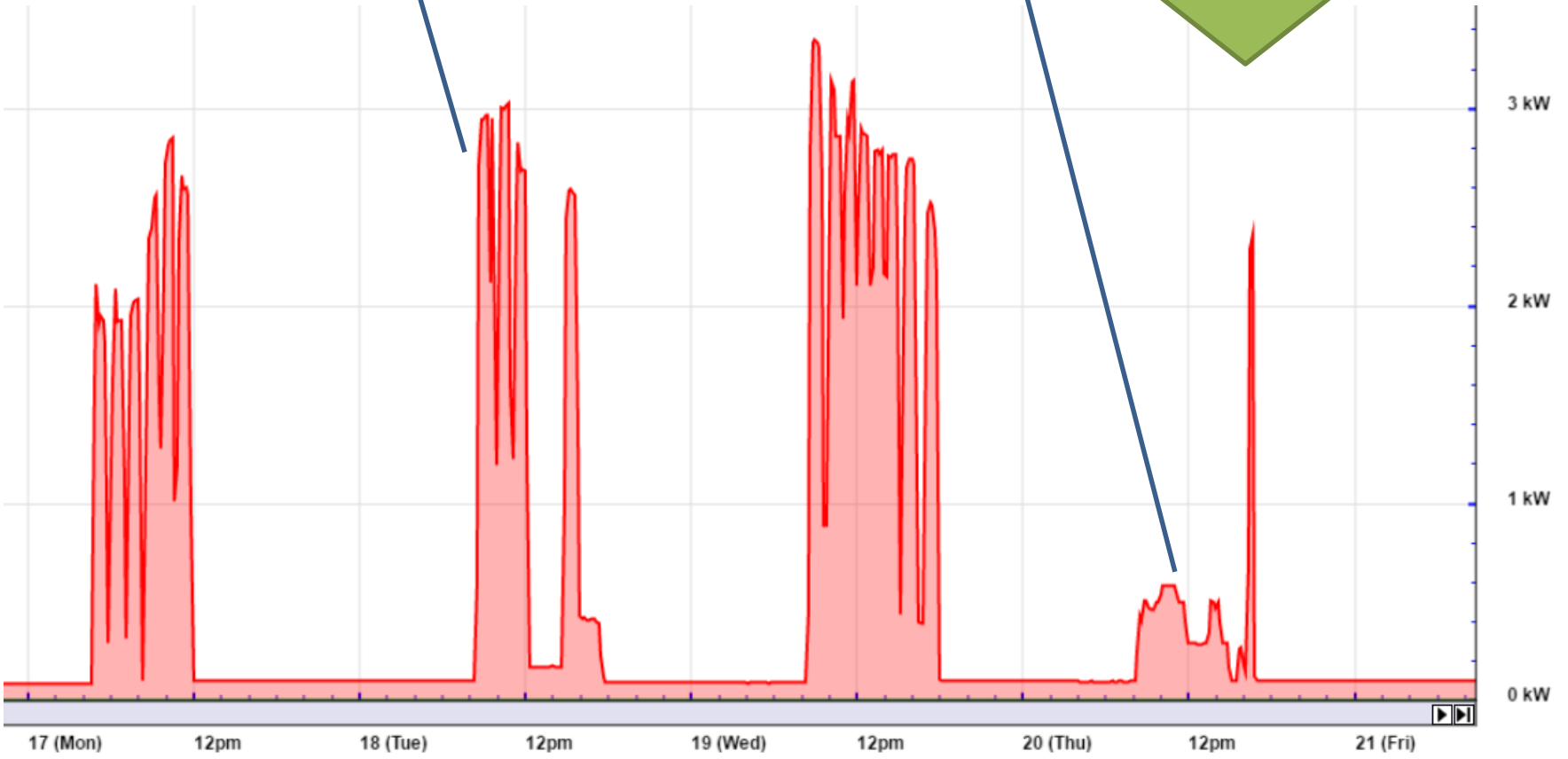
INDOOR SENSORS

- Room air temperature
- Wall surface temperature
- Supply and return air temperature
- Relative humidity
- CO2 concentration
- Illumination of wall and ceiling
- Air speed

Air conditioning, clg fans and lights ~3300 W

Clg fans and lights only ~ 400 W

88% reduction in energy



Monitoring/Value of Decisions

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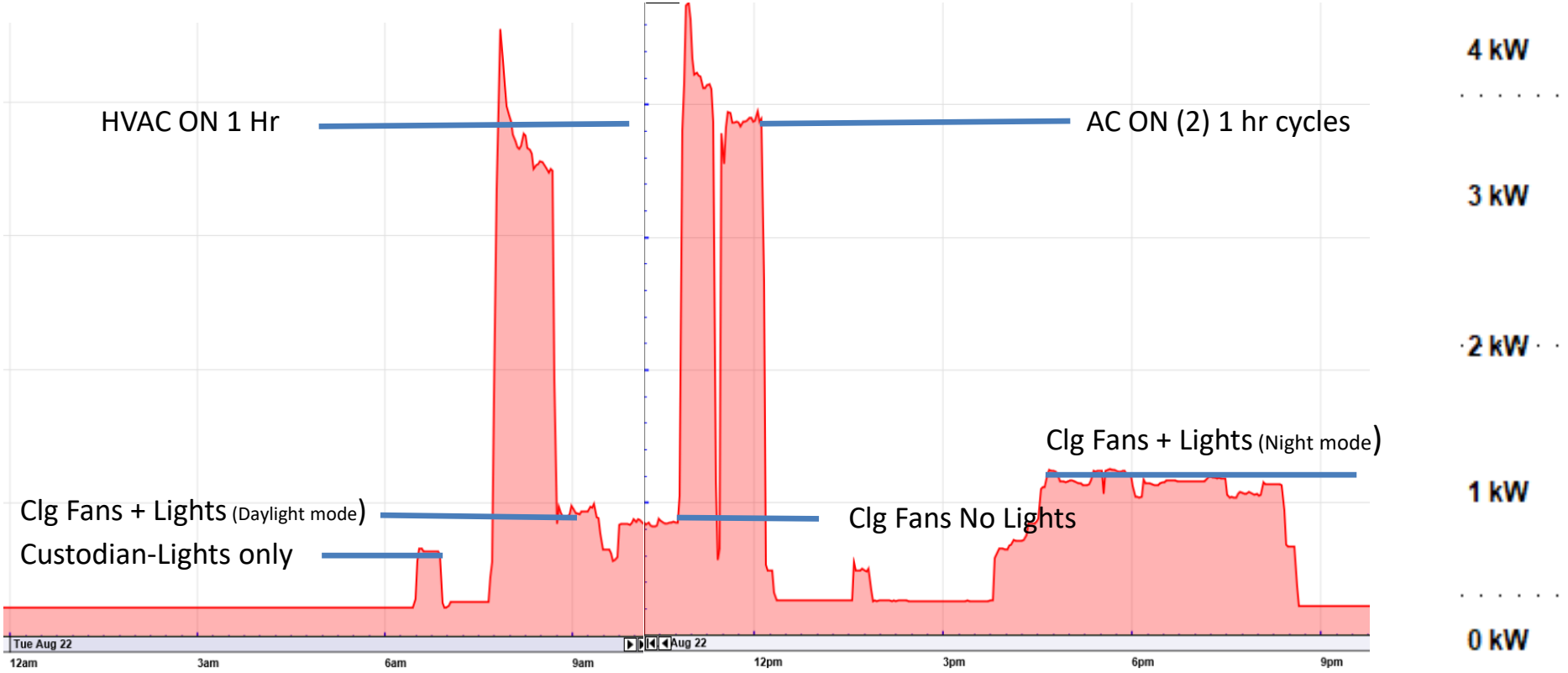
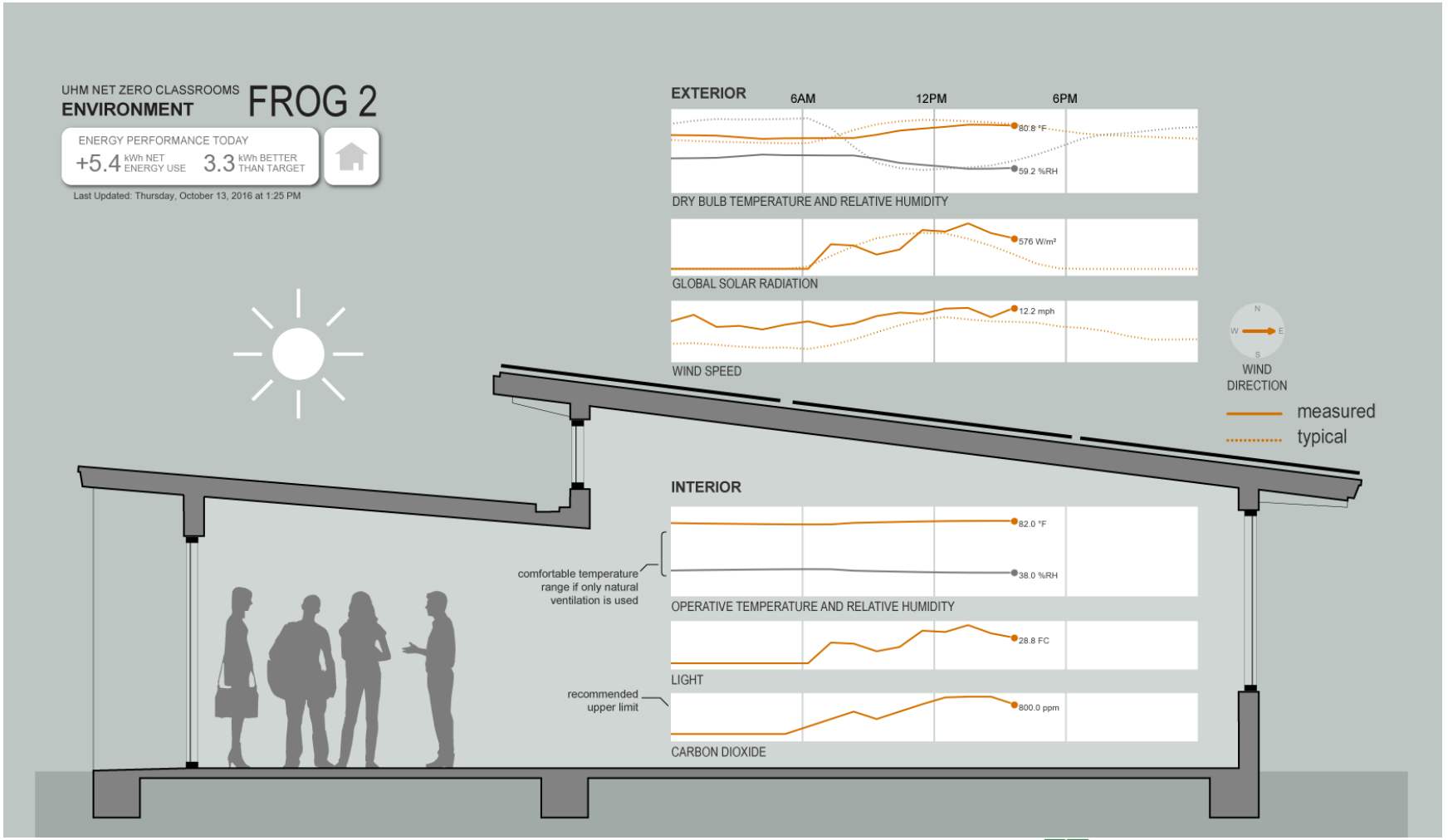
End-use fingerprints



Dashboard: Interior and Exterior Env. Conditions



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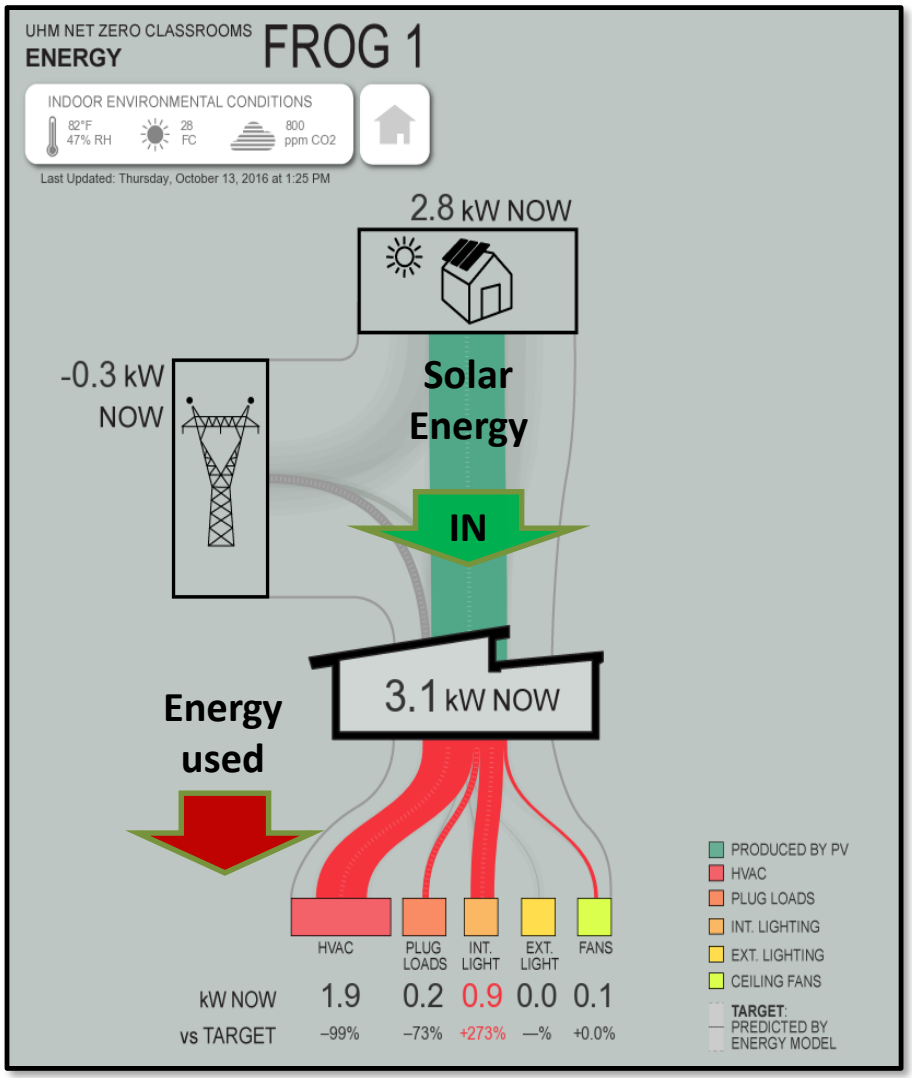
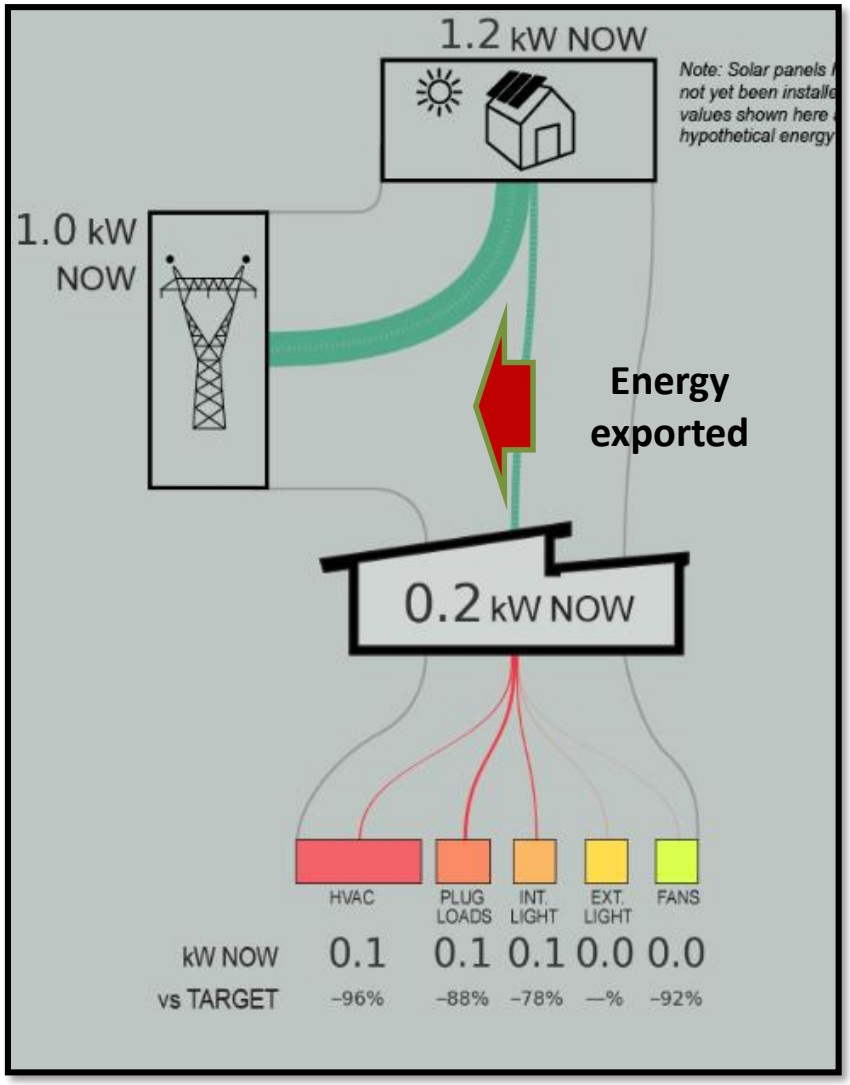
Dashboard: Energy Flows





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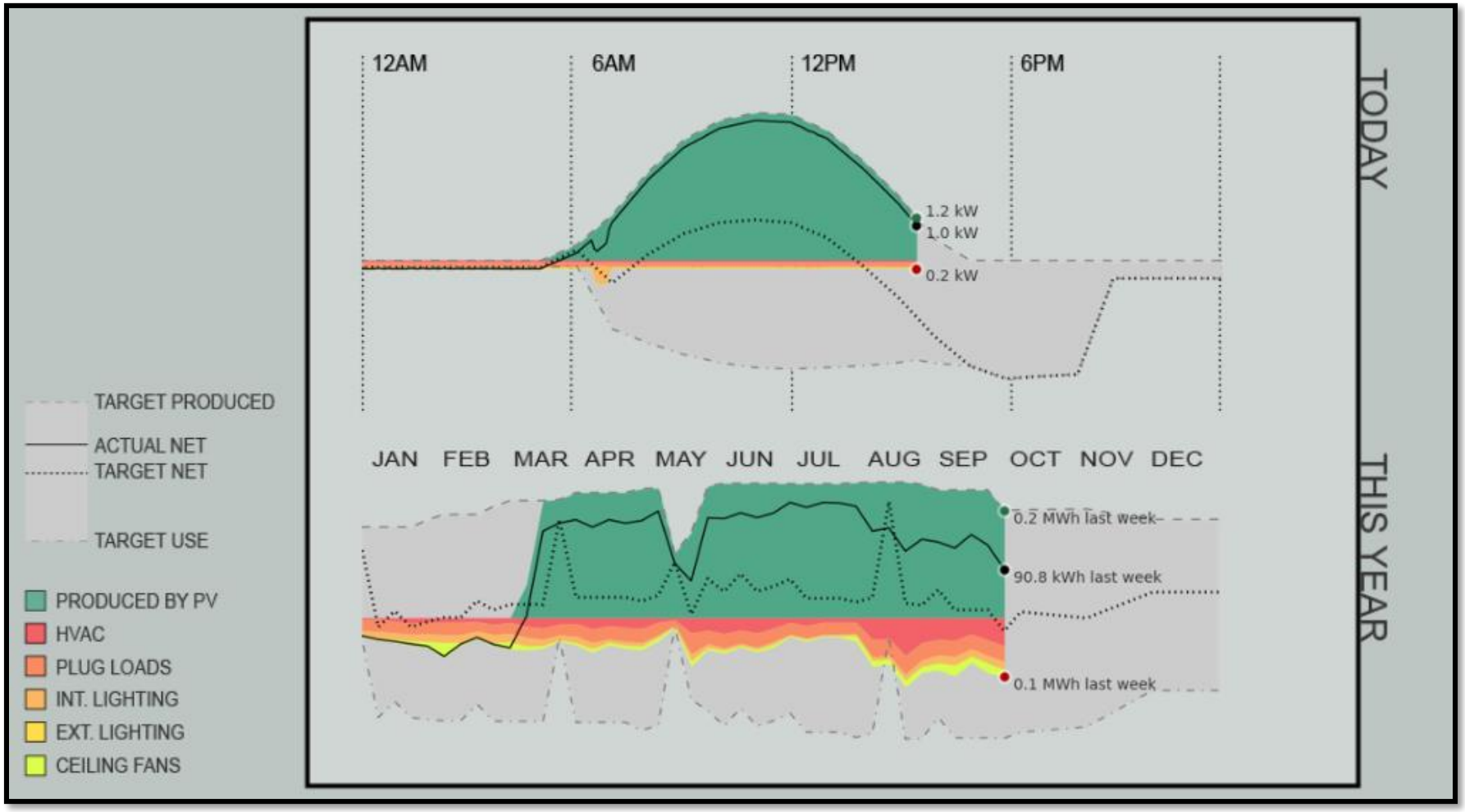
Dashboard: Actual and Forecasted Energy



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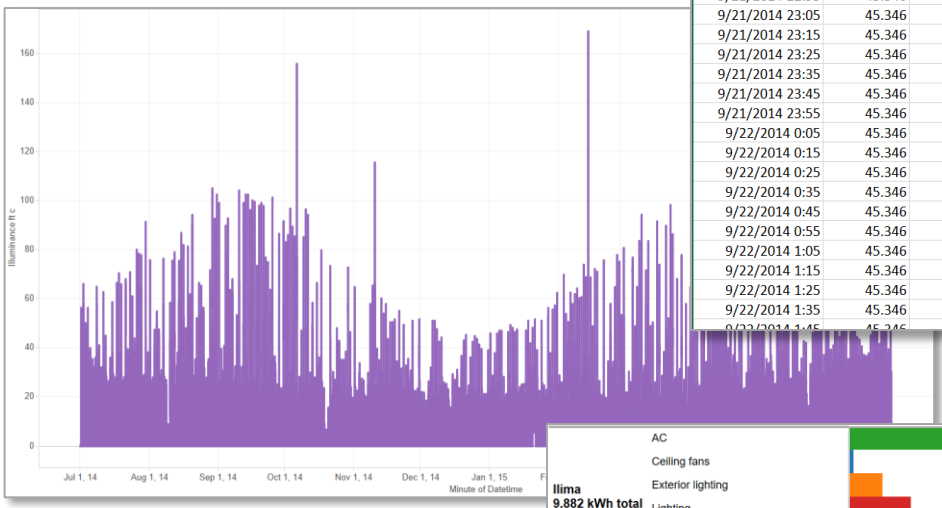
data analysis and findings



A	B	D	F	H	J	L	N	P	R	T
HI DateTime	Ceiling_Fans _kWh	Condensing_Unit _kWh	Exhaust_Fans _kWh	Fan_Coil_ Unit_kW	Lighting_Exterior _kWh	Lighting_Main_ Space_kWh	Panel_Feed _kWh	PV_Inverter _1 kWh	PV_Inverter _2 kWh	Plug Load kWh
9/21/2014 22:55	45.346	5454.928	0	872.44	902.938	780.183	9856.959	1949.346	2001.886	1772.094
9/21/2014 23:05	45.346	5454.928	0	872.442	902.952	780.183	9857.011	1949.346	2001.886	1772.130
9/21/2014 23:15	45.346	5454.928	0	872.442	902.965	780.183	9857.063	1949.346	2001.886	1772.169
9/21/2014 23:25	45.346	5454.928	0	872.444	902.978	780.183	9857.115	1949.346	2001.886	1772.206
9/21/2014 23:35	45.346	5454.928	0	872.444	902.991	780.183	9857.162	1949.344	2001.884	1772.240
9/21/2014 23:45	45.346	5454.928	0	872.446	903.004					
9/21/2014 23:55	45.346	5454.928	0	872.446	903.017					
9/22/2014 0:05	45.346	5454.928	0	872.448	903.03					
9/22/2014 0:15	45.346	5454.928	0	872.448	903.043					
9/22/2014 0:25	45.346	5454.928	0	872.45	903.056					
9/22/2014 0:35	45.346	5454.928	0	872.45	903.069					
9/22/2014 0:45	45.346	5454.928	0	872.452	903.082					
9/22/2014 0:55	45.346	5454.928	0	872.452	903.095					
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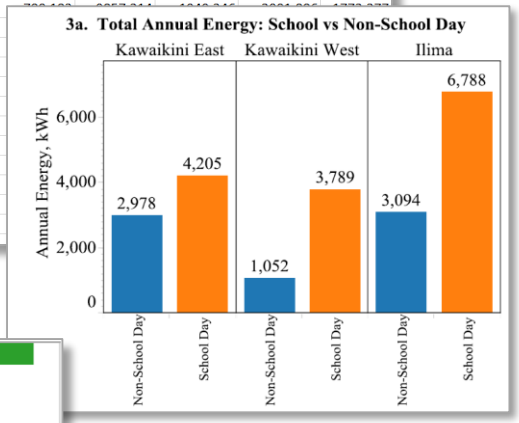
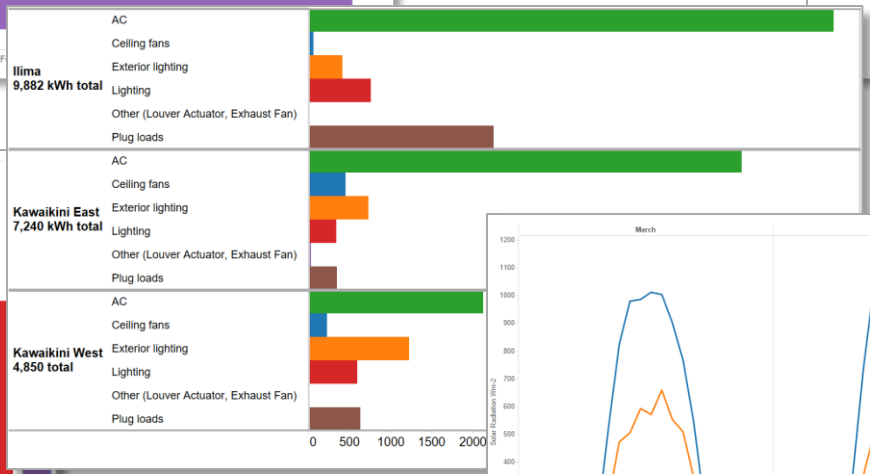
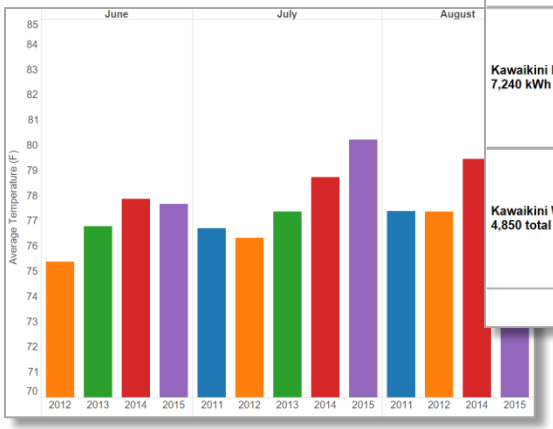
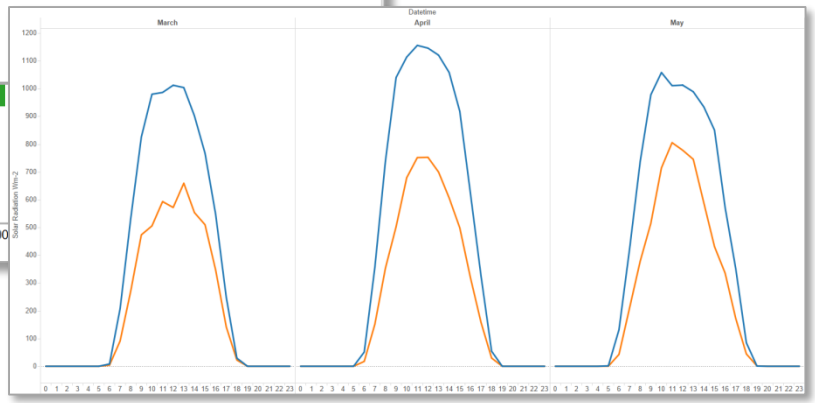
9/22/2014 1:15	45.346	5454.928	0	872.454	903.122					
9/22/2014 1:25	45.346	5454.928	0	872.456	903.135					
9/22/2014 1:35	45.346	5454.928	0	872.456	903.148					

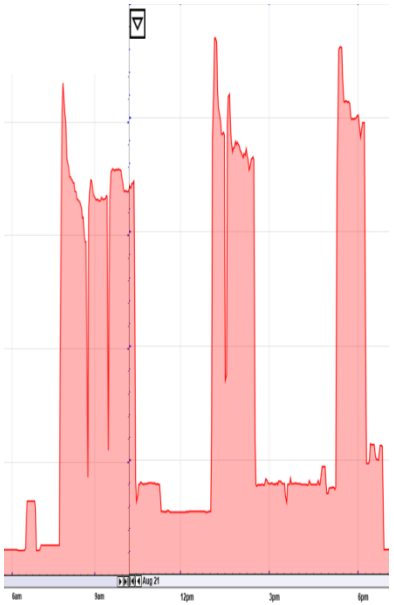






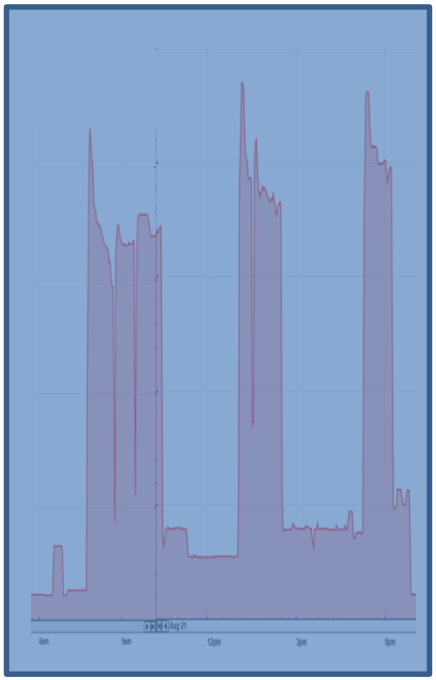


Energy Savings: On-Demand AC

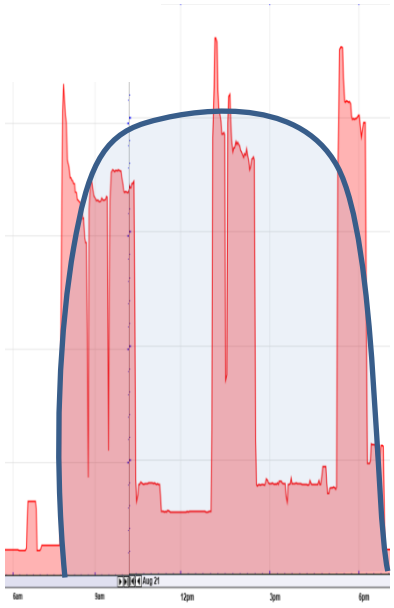


Actual Operation

Energy Savings: On-Demand AC

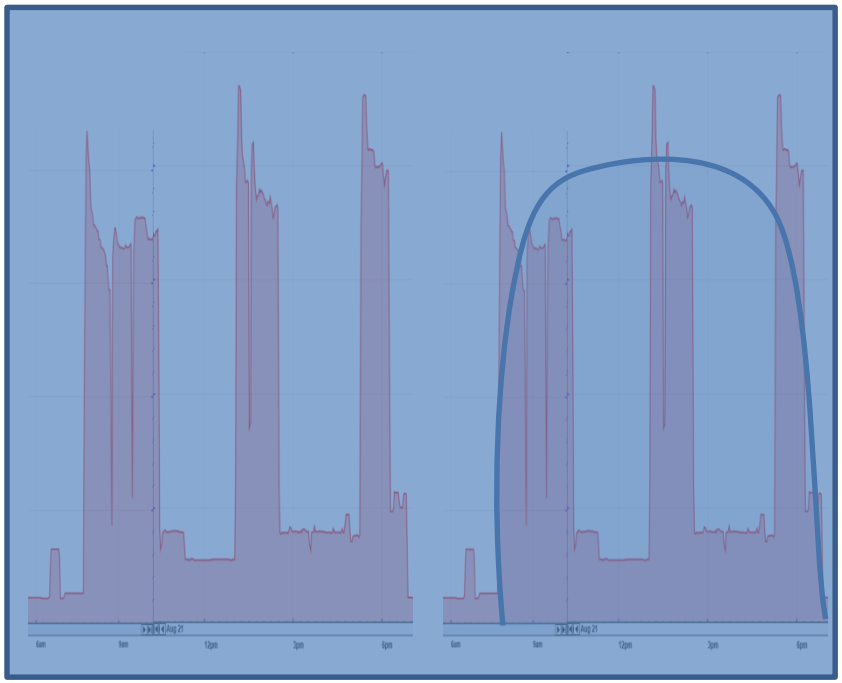


Actual Operation



Conventional HVAC Operation

Energy Savings: On-Demand AC



Actual Operation

Conventional HVAC Operation

45% Savings

Energy Savings due to FROG AC controls

Training and Education

- User awareness
- Real time feedback
- Sense of engagement

Net Zero Energy Classrooms

An energy research collaboration between College of Education and SOEST
Hawai'i Natural Energy Institute

Welcome to UH Mānoa's showcase of building energy efficiency designed by Project Frog. Every element of these structures is designed with energy and sustainability in mind. The classrooms are still in development and will soon be outfitted with photovoltaic energy to provide more power than they consume. A class mounted dashboard will display energy performance of the buildings for real-time feedback on how energy is used (and compared to its twin next door).

OPERATING GUIDELINES

1. OPEN operable windows first thing upon entering. Open rear windows and engage clerestory actuator button.
2. Turn ON ceiling fans.
3. Turn ON lights ONLY if needed for visual tasks at hand.
4. CLOSE all windows at the end of the last classroom session of the day, AND when the air conditioning system engages.

THE FOLLOWING ARE KEY DESIGN FEATURES OF THE CLASSROOMS TO MINIMIZE ENERGY CONSUMPTION.

SPACE COMFORT

These buildings utilize "Mixed-Mode" space conditioning. Most days the classrooms are comfortable with the windows open, and ceiling fans on, to offer enough breeze to maintain a comfortable environment. During the most uncomfortable of outdoor conditions, the instructor may opt to temporarily engage the on-demand air conditioning system.

LIGHTING

Natural daylight has been proven to enhance indoor learning environments. With new modes of technology, notetaking and reference materials (ipad, laptops, etc.) greater flexibility is required, including lower light levels for multi-media based teaching activities. On most days, natural daylight without any artificial lighting will suffice. Should additional light be required for a task, high efficiency LED fixtures can be turned on and photosensors will automatically adjust light levels across the room.

VENTILATION

Airflow is provided by operable windows along the south and north walls. High clerestory windows are operated by actuators to open, providing cross-ventilation and allowing warmer air to rise out of the room.

WINDOW DESIGN

The windows are strategically designed to avoid the harshest east and west sun. Direct southern sunlight is shielded by overhangs and sun shades so no direct sunlight penetrates the rooms. Indirect natural daylight enters from the north and the protected south windows. High performance, Low-E glass is used to allow light in and keep heat out.

CEILING FANS

Ceiling fans designed for high performance are most effective in providing comfort by moving air across your skin, creating a cooling sensation through evaporation and convection. Air motion is equivalent to 4 to 6 °F reduction in air temperature.

Sustainable energy design is only achieved when building users such as yourselves actively participate in its operation.

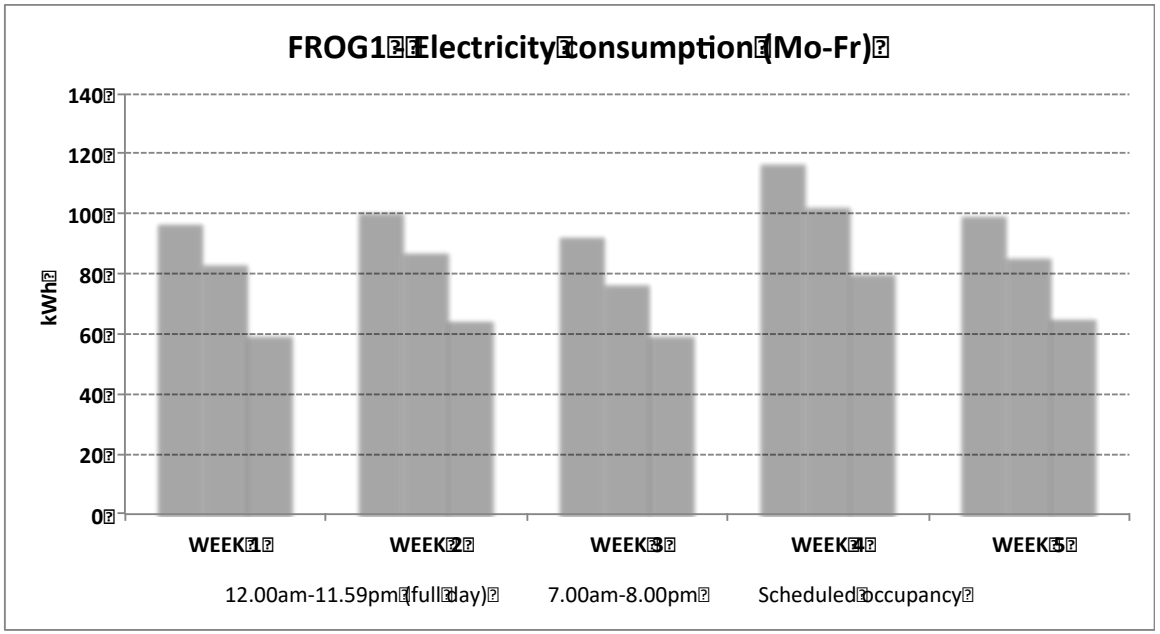
projectfrog HNEI Hawai'i Natural Energy Institute

Educational Poster

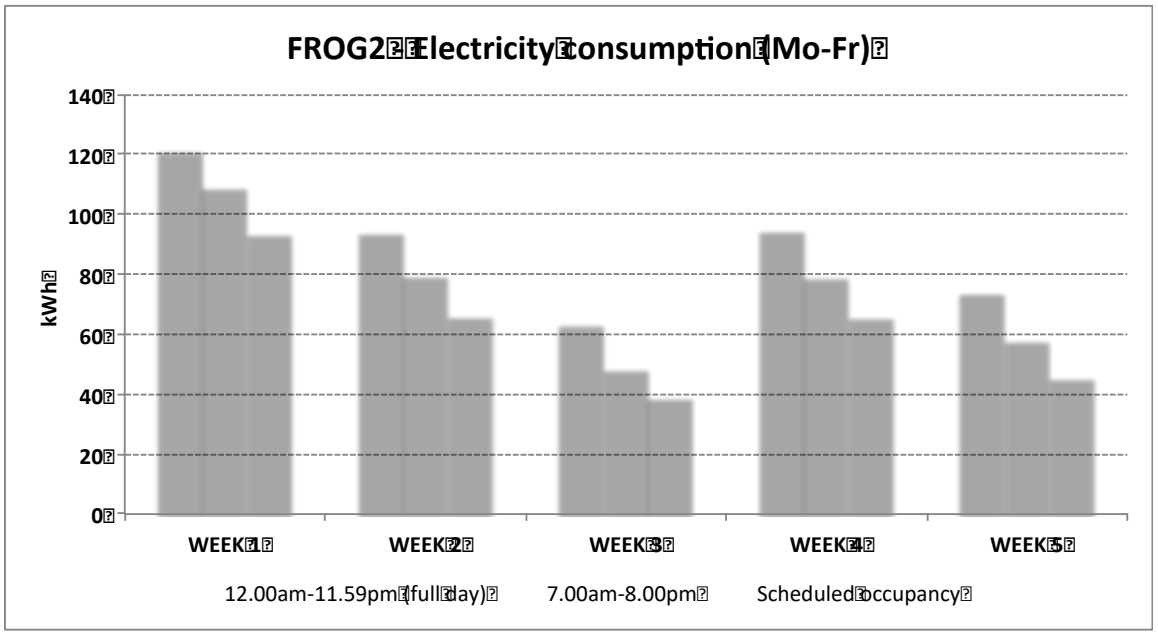
Simple cues

Decision based performance

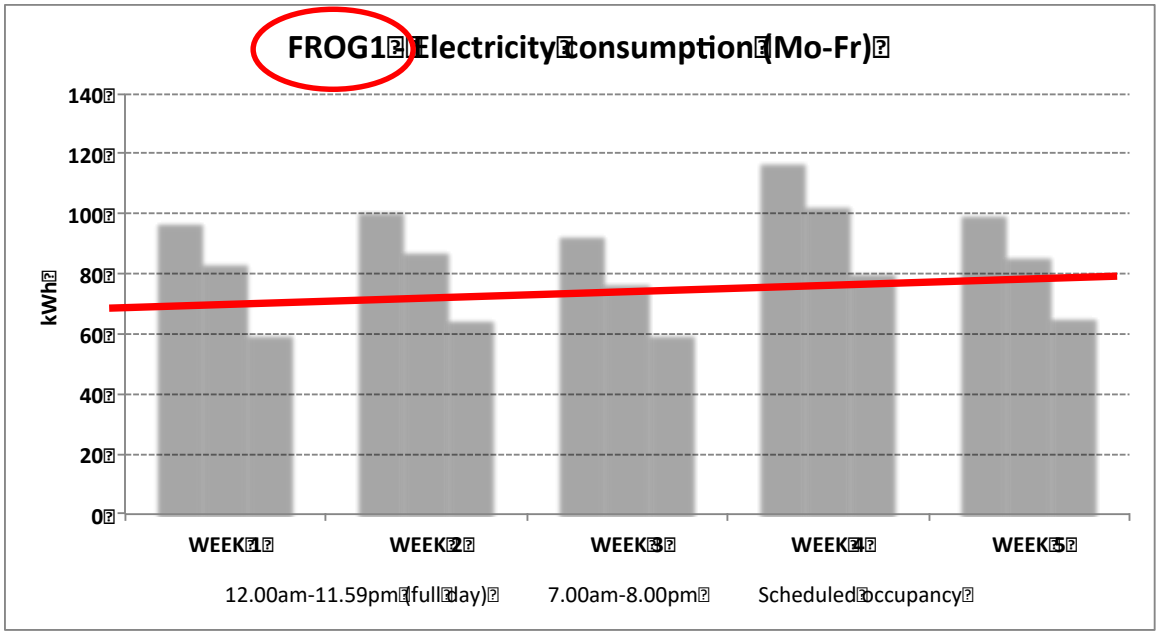
Hawaii Natural Energy Institute
University of Hawaii at Manoa



Level and consistent week over week

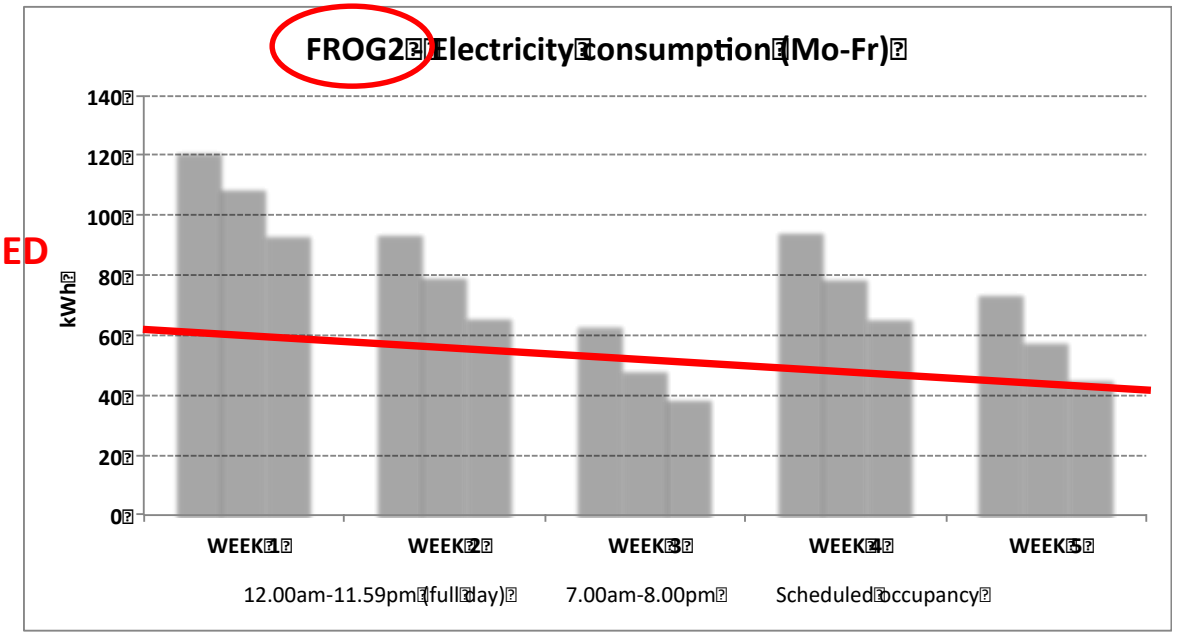


General trend downward between Weeks 1 and 5.



Level and consistent week over week

TRAINED

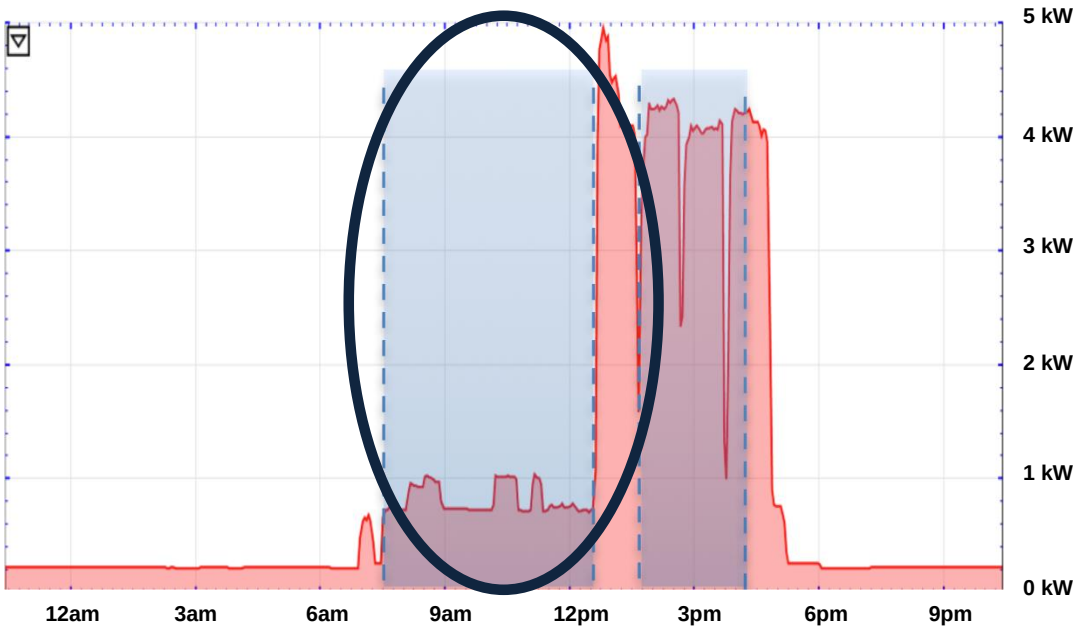


General trend downward between Weeks 1 and 5.

To cool or not to cool?

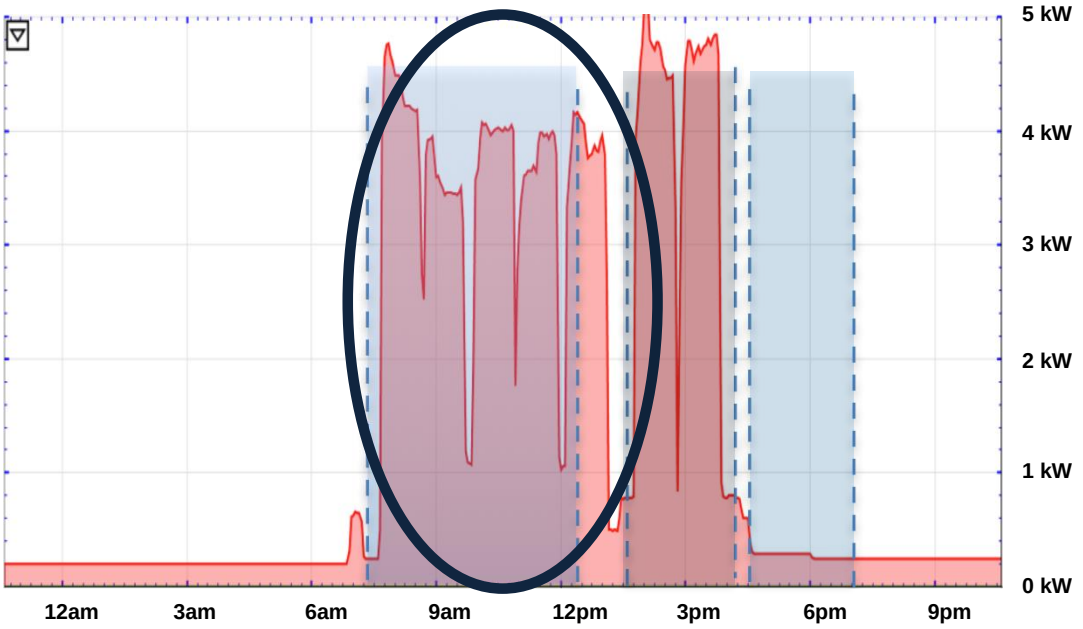
FROG 1

Mon, Aug 28



FROG 2

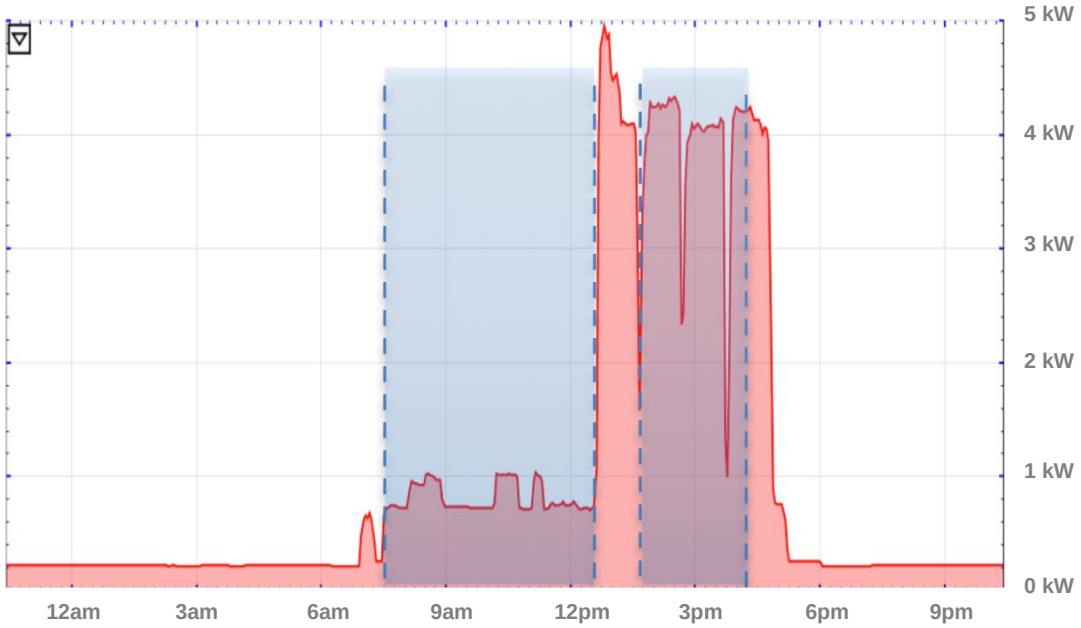
Mon, Aug 28



To cool or not to cool?

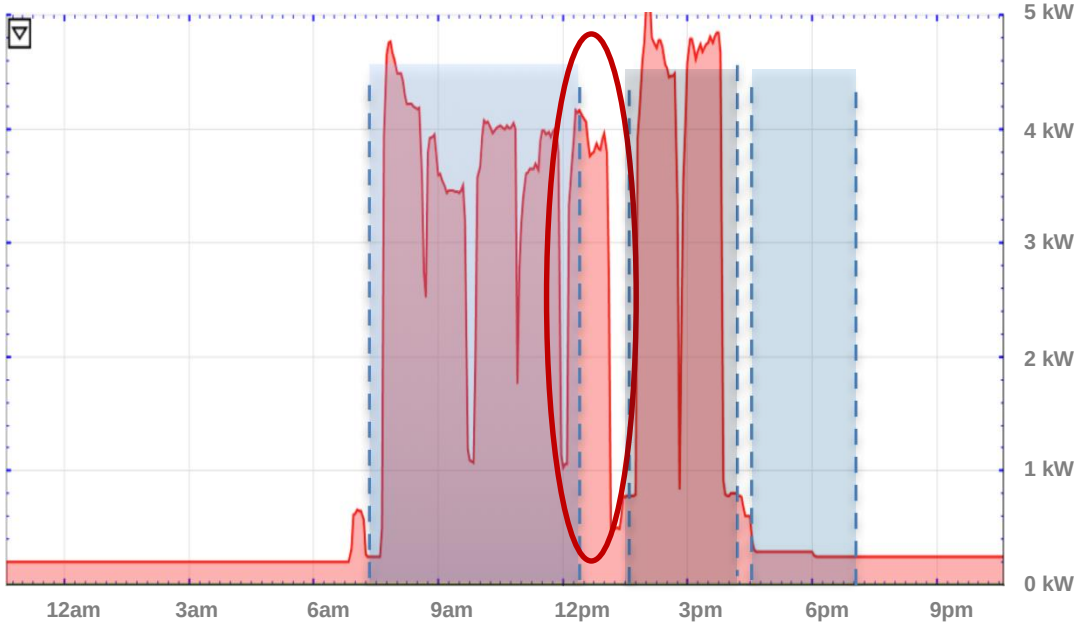
FROG 1

Mon, Aug 28



FROG 2

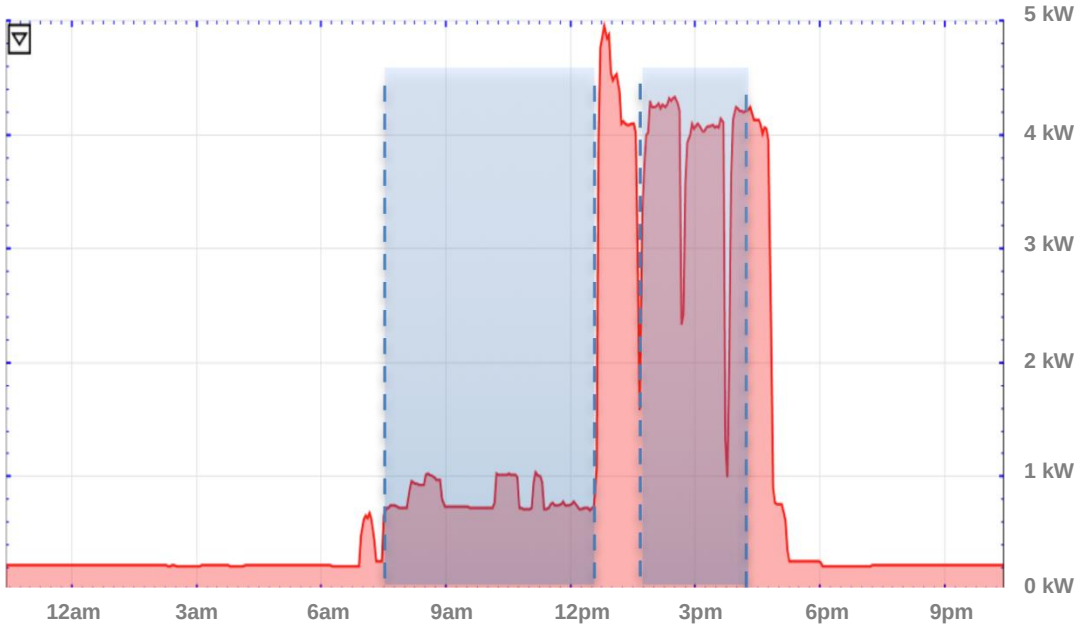
Mon, Aug 28



To cool or not to cool?

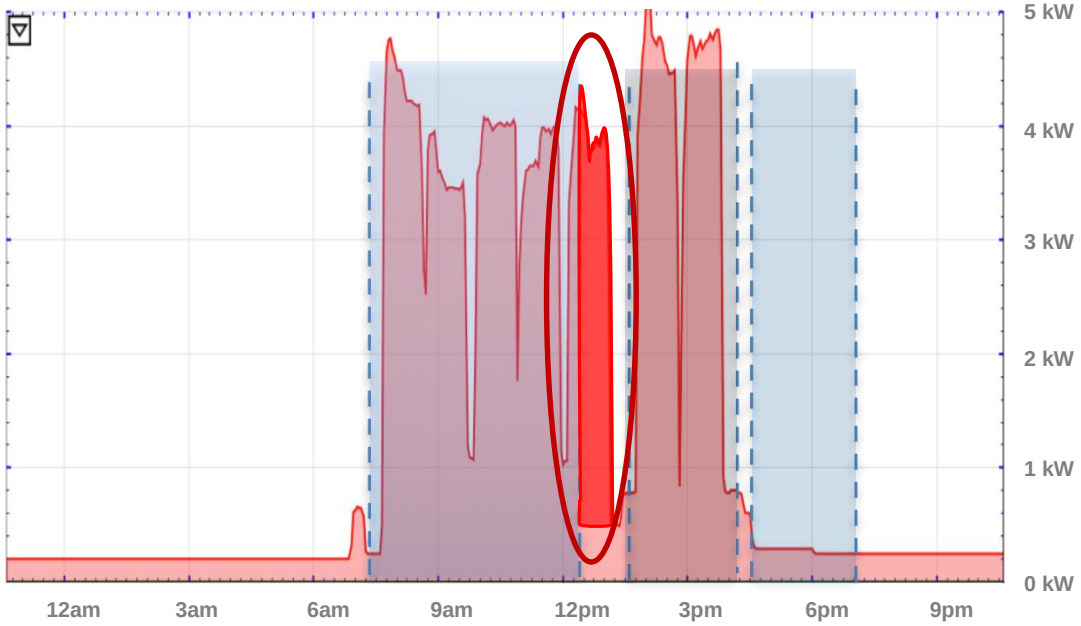
FROG 1

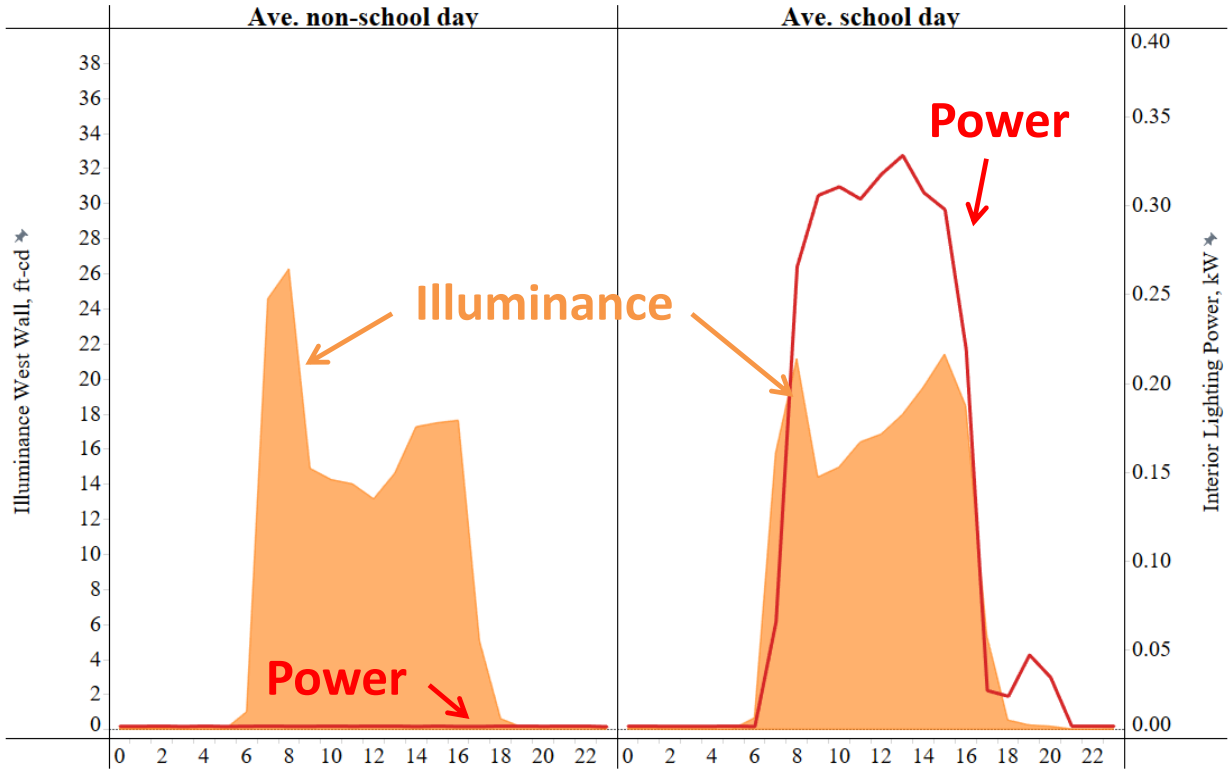
Mon, Aug 28



FROG 2

Mon, Aug 28




Ave. non-school day
Ave. school day
Illuminance West Wall, ft-cd
Interior Lighting Power, kW
Illuminance
Power
Power
0 2 4 6 8 10 12 14 16 18 20 22
0 2 4 6 8 10 12 14 16 18 20 22
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38
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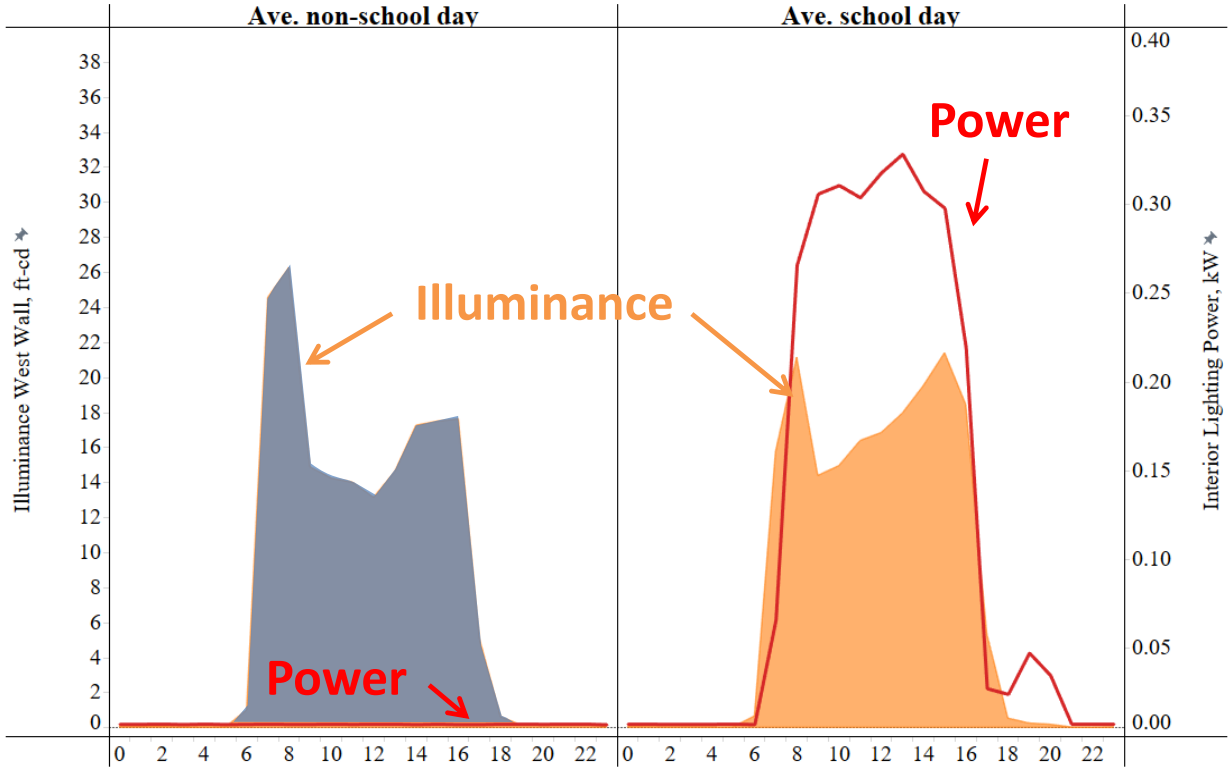
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Ave. school day
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Interior Lighting Power, kW
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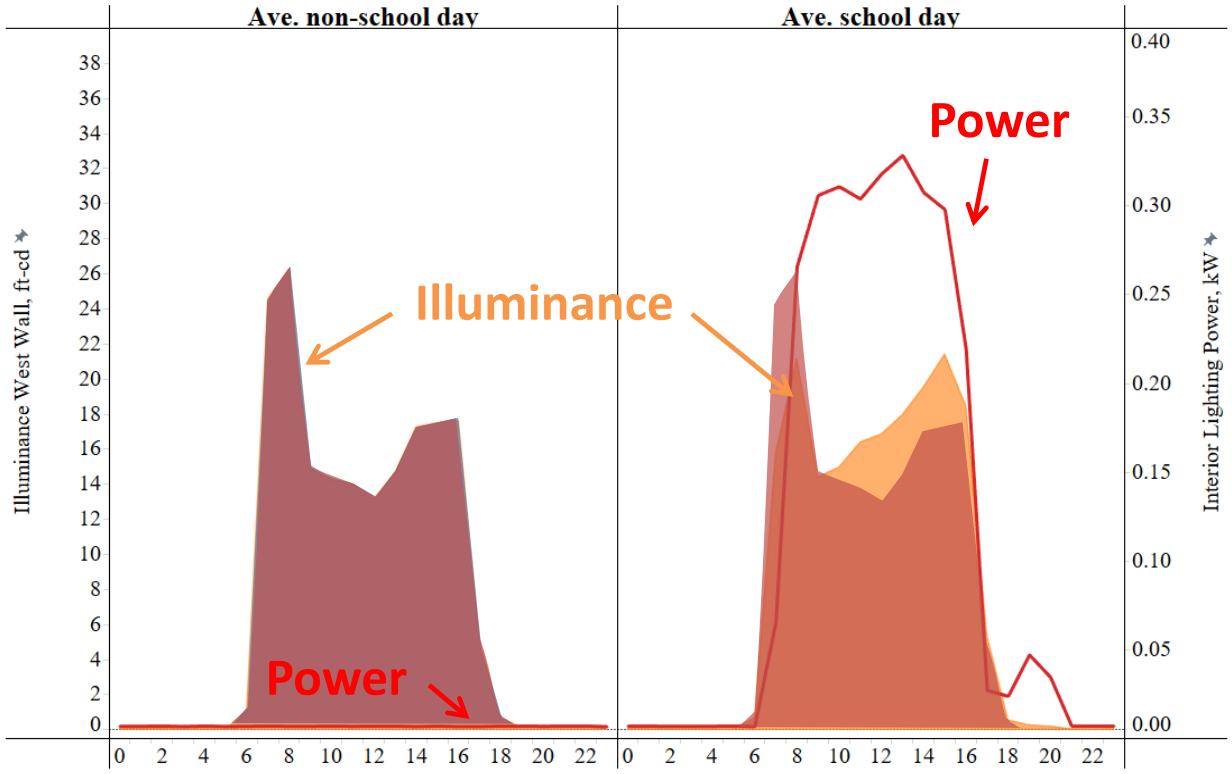
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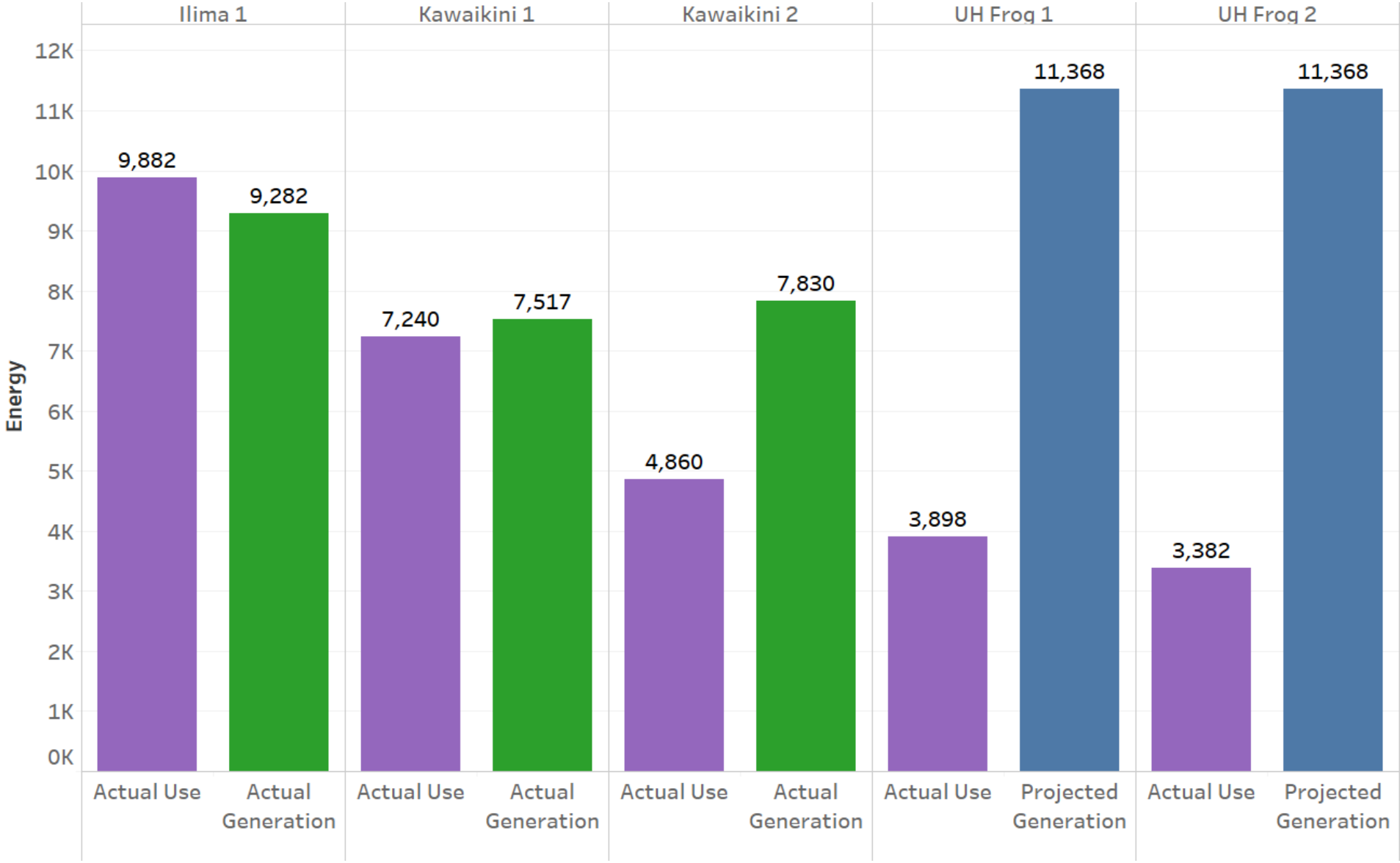
Did we hit net-zero targets?



Lessons Learned:

User engagement and sense of control is important ….

Train and Educate

Don’t make it complicated

Offer cues and clarity

Modeling is useful during design…

And then there is behavior.

Energy Efficient Building Technologies

Past and ongoing applied research at HNEI

Overview

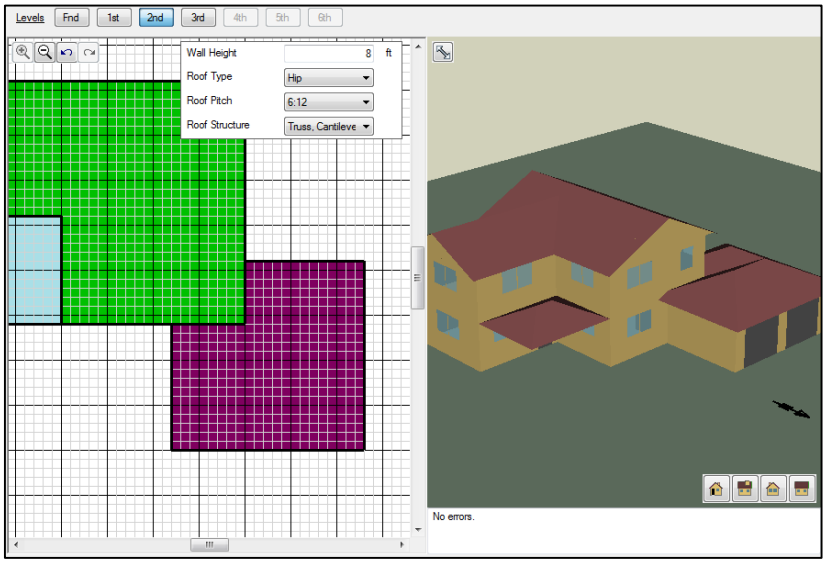
1. Whole-Building Modeling and Performance Simulation
2. Natural / Mixed Mode Ventilation
3. New Approach to HVAC: Separate Temperature and Humidity Controls – Liquid Desiccant Dehumidification

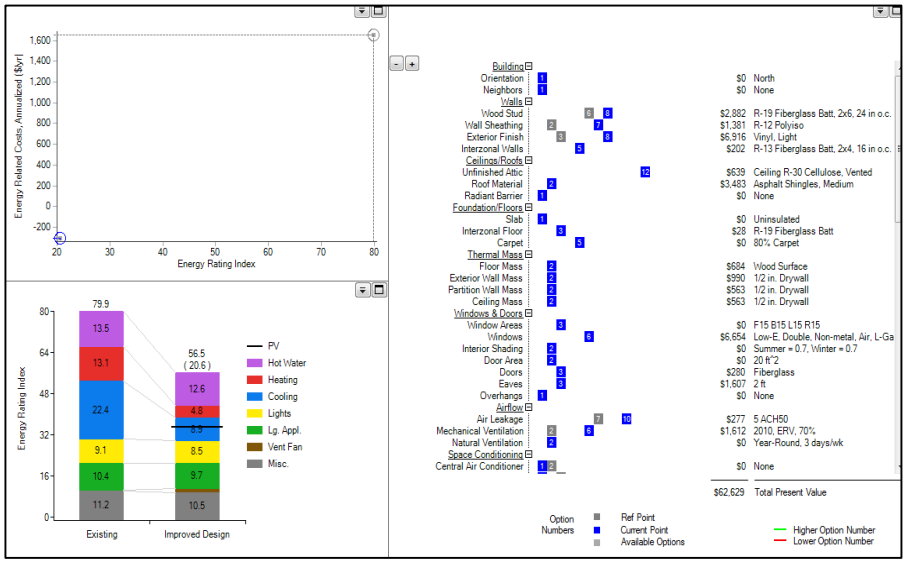
1. Whole-Building Modeling and Performance Simulation

Hawaii adopted the IECC 2015; whole building simulations offers compliance paths through whole house modelling:

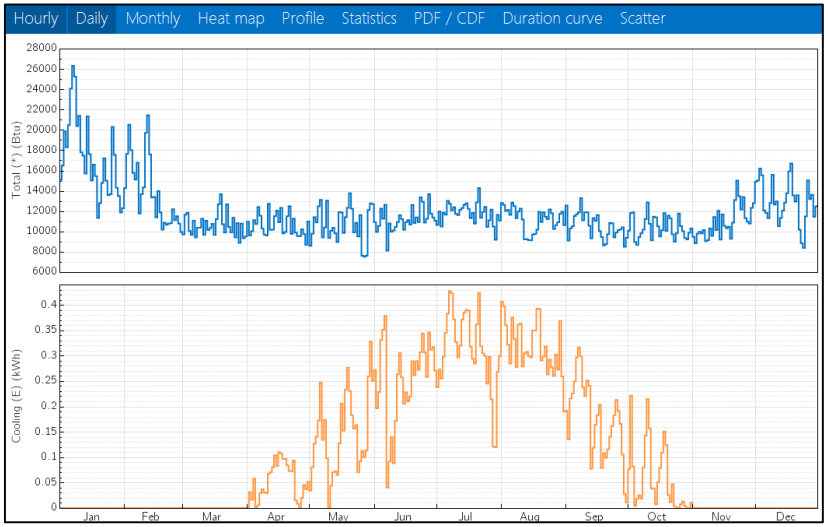
Ongoing projects:

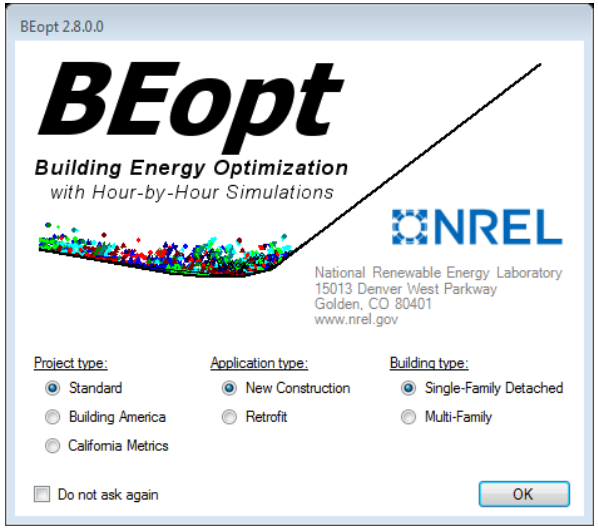
- Pilot project to showcase building energy performance simulation to industry and train students
- Using standard DoE2-based software and other advanced commercial software tools to optimize building envelope and performance
- Train industry professionals and students on energy efficiency
- Produce online webinars as introduction to building simulation and code compliance

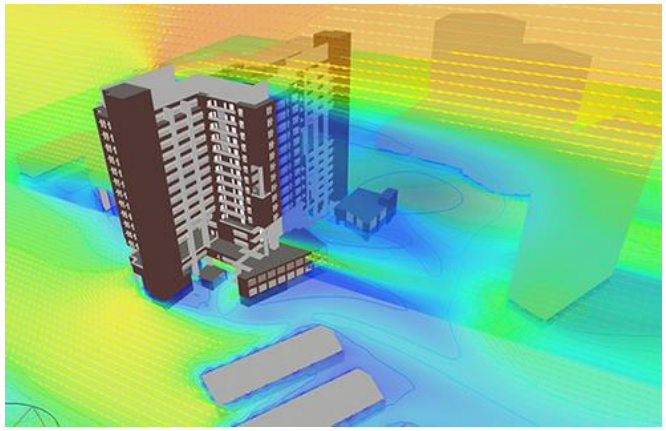


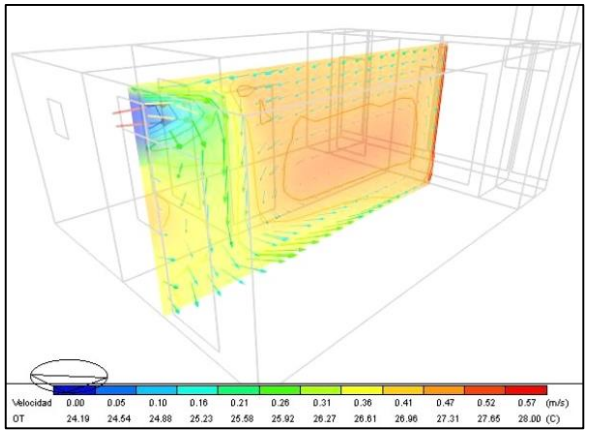


DoE (NREL) BEopt “Building Energy Optimization” software to model residential structures

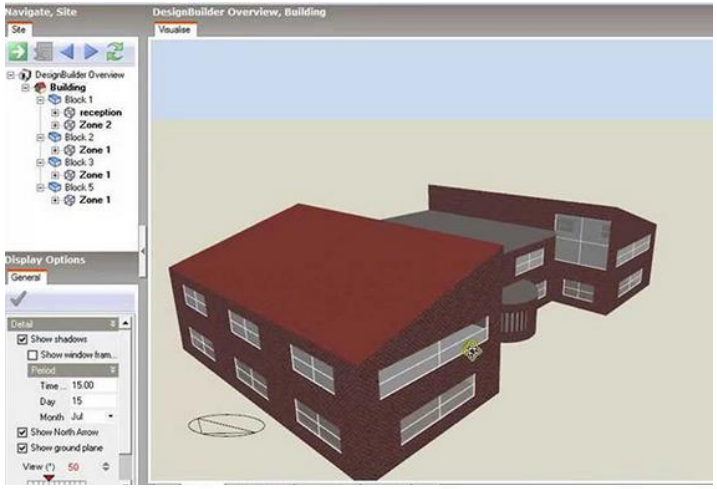




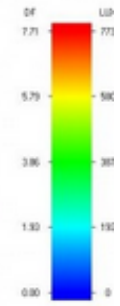


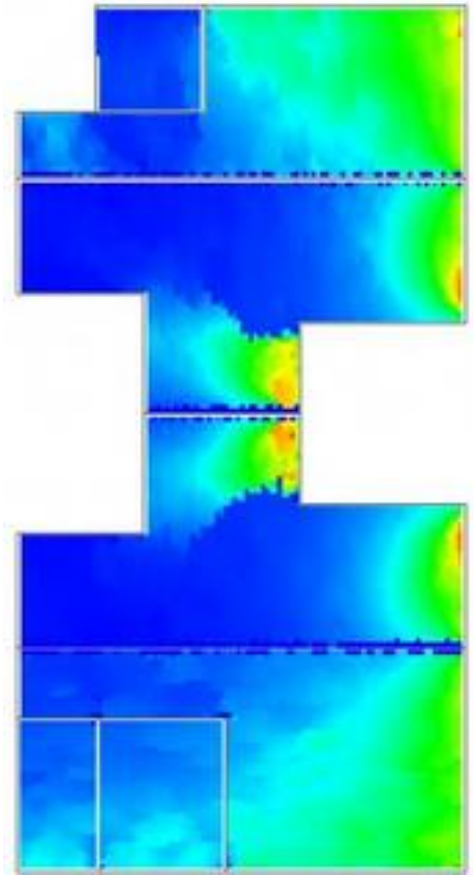


CFD (external and internal)

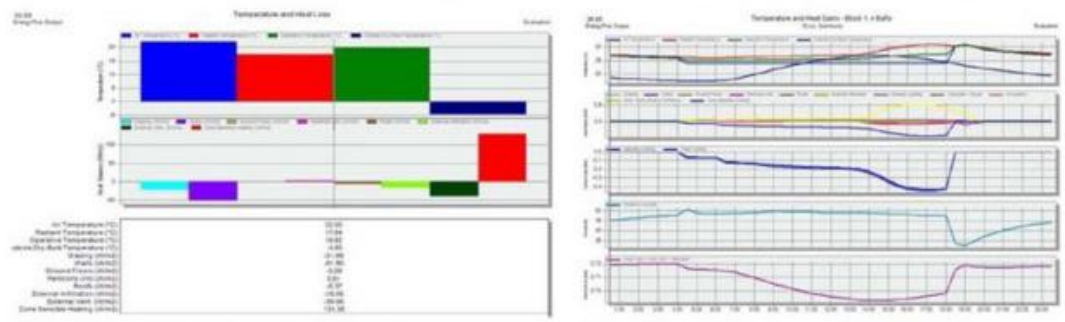


<<< Complex building geometry





Lighting analysis



Energy analysis

DesignBuilder SOFTWARE

Images shown provided by DB

2. Natural / Mixed Mode Ventilation

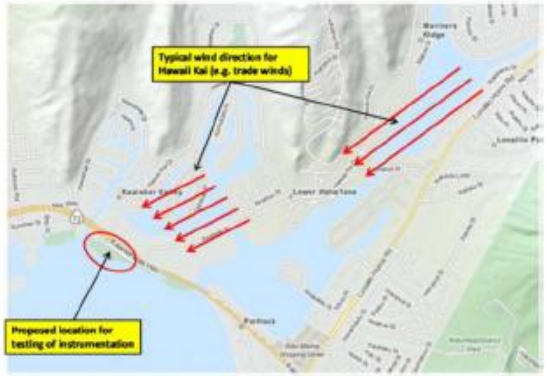
HNEI Conducted a 3-year investigation to investigate the use of Computational Fluid Dynamics (CFD) in modelling air flow and occupant comfort in mixed-mode ventilation building ventilation;

Past and ongoing projects:

- External CFD – assessment of air-flow around buildings to assess pressures on envelope
- Internal CFD - assessment of air movement through space
- Verification of air movement
- Thermal comfort – assessment of thermal comfort

External CFD Applications

SHAKE-DOWN TESTING WITH A CAR - "NATURAL WIND TUNNEL"



Site selection for wind consistence

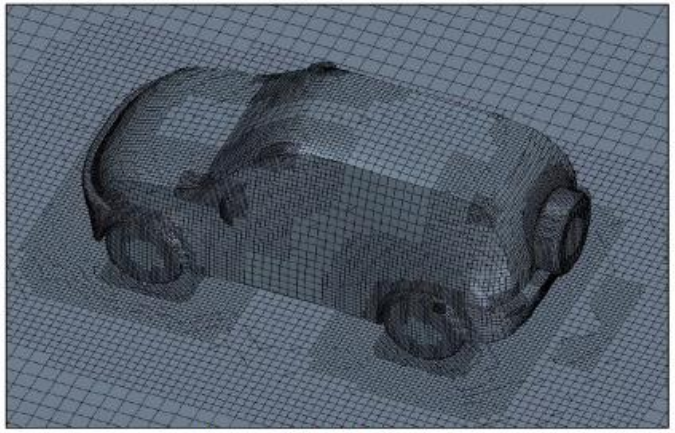
Installation of anemometers and pressure sensors

The test site at Hawaii Kai was chosen for quite consistent wind condition and few obstruction

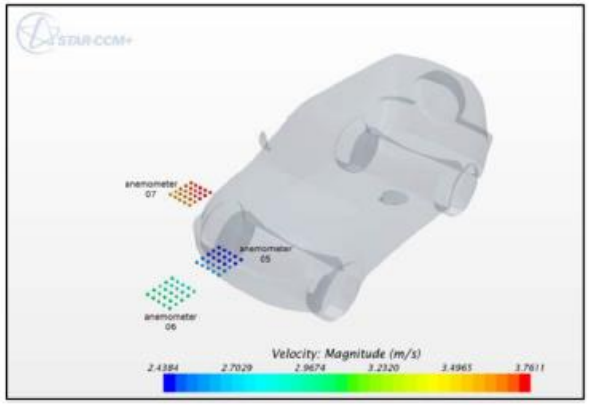
External CFD Applications

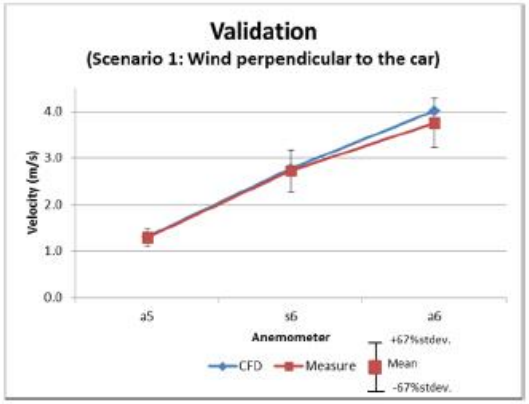
SMALL MODEL – A CAR

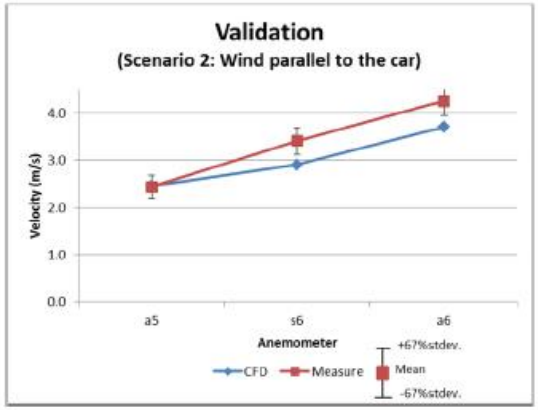
Installation of anemometers and pressure sensors



Volume cells of the car



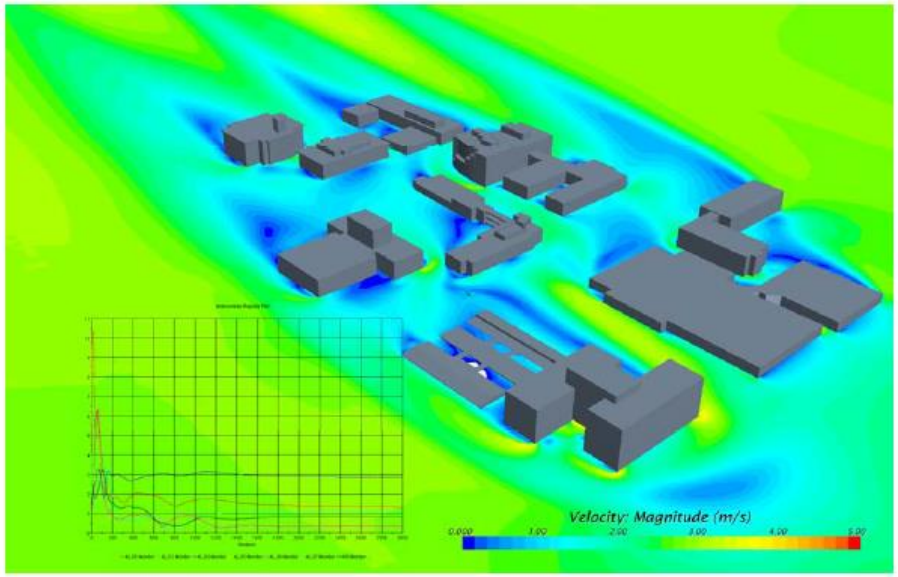




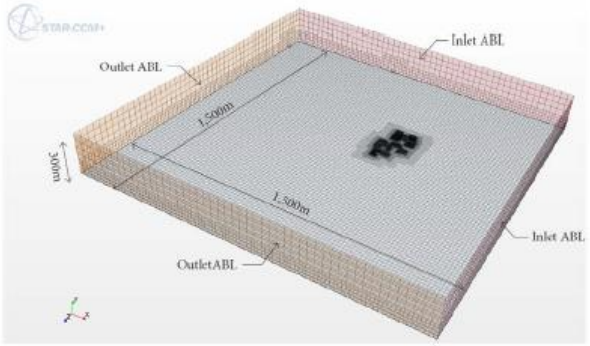
1'x1' presentation grid probes at locations of sensors to extract data for CFD validations (Scenario 2)

External CFD Applications

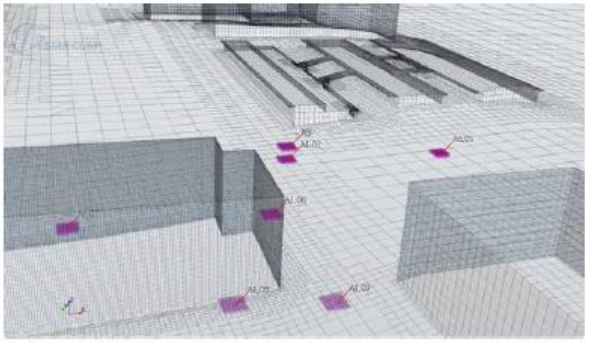
RESULTS



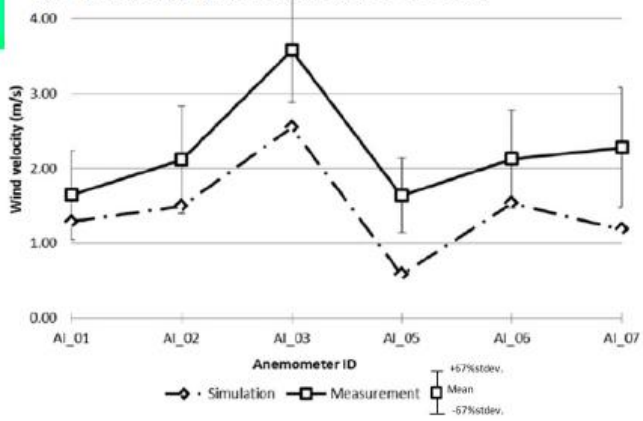
- Rhino3D (CAD) -> Mesher (Remesher/Wrapper)
- Trimmer
- Steady-state, isothermal model
- RANS Realizable k-epsilon turbulence model
- Two layer high y+ wall treatment with variable sizes for near-wall cells

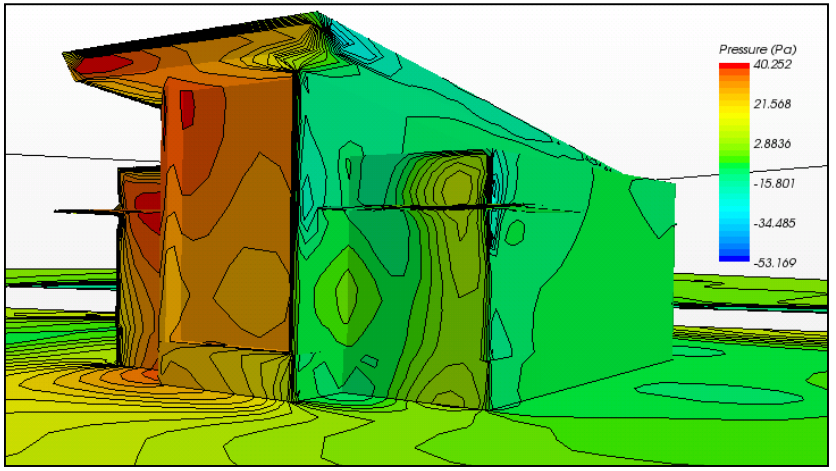


Volume cell meshing of the computational domain

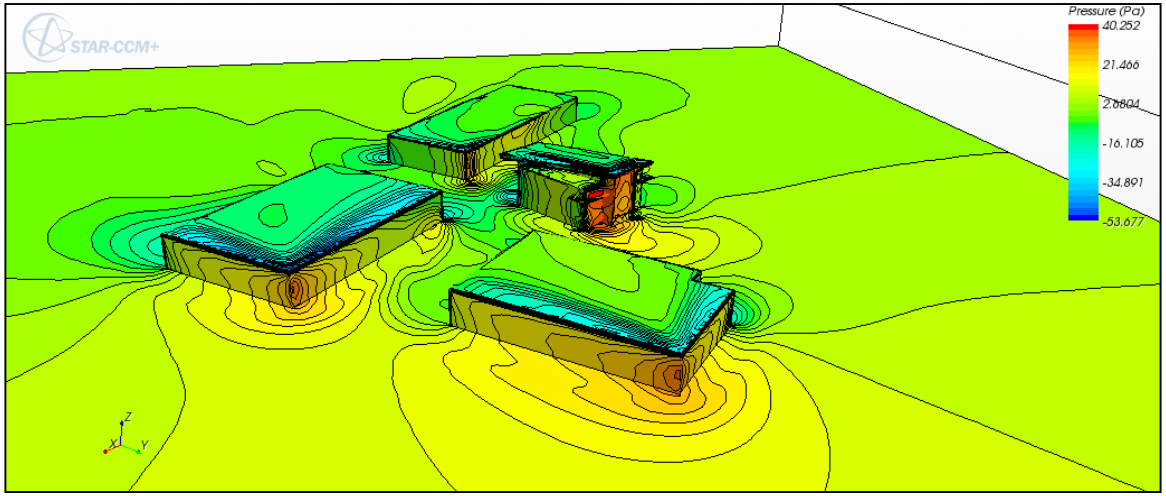


2'x2' presentation grids at anemometers' locations





External Wind pressure study on Classroom Building ILIMA International School EWA Beach, OAHU, Hawaii

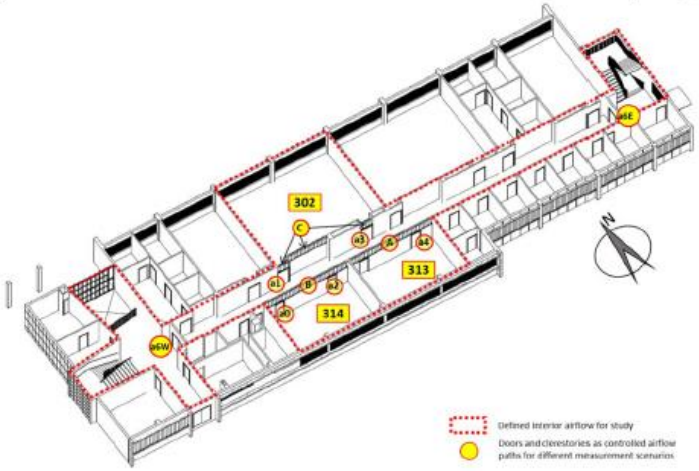


Internal CFD Applications

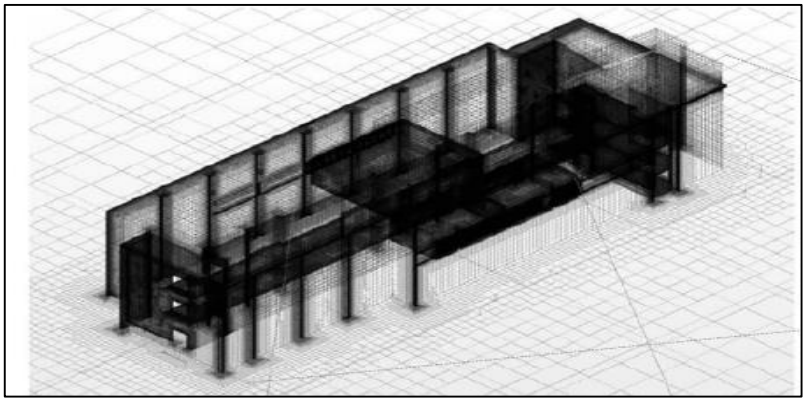
Field validation of CFD model

Installation of anemometers at the middle of the door ways

Installing the temporary tarp to seal sections of the louvered openings; seen from classroom 302



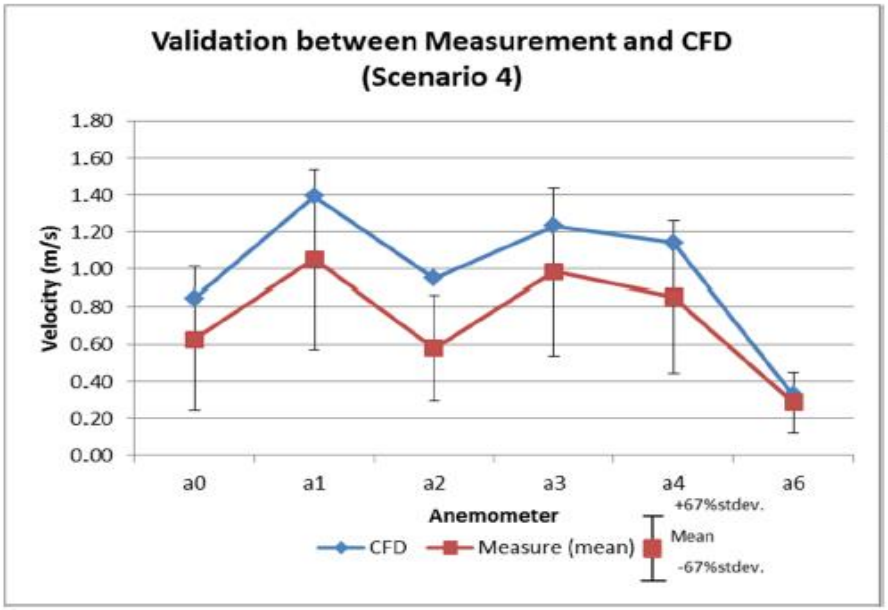
Layout of indoor spaces modelled



CFD computational mesh including building and indoor spaces modelled

Internal CFD Applications

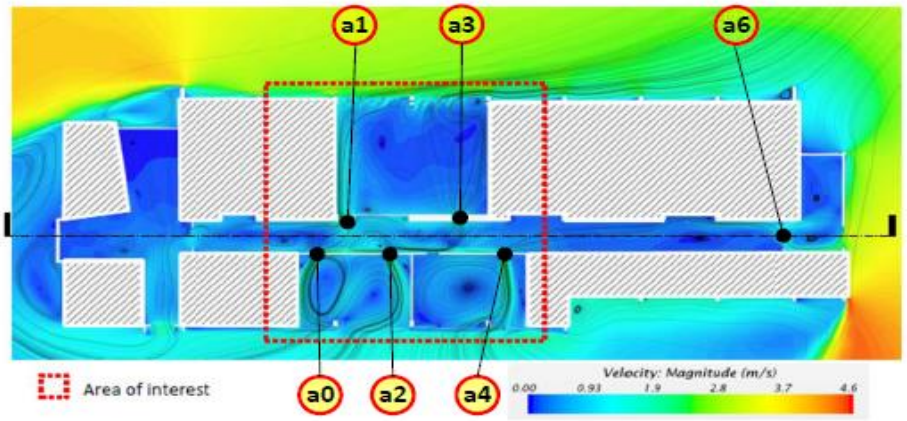
RESULTS & IMPORTANT CONCLUSIONS



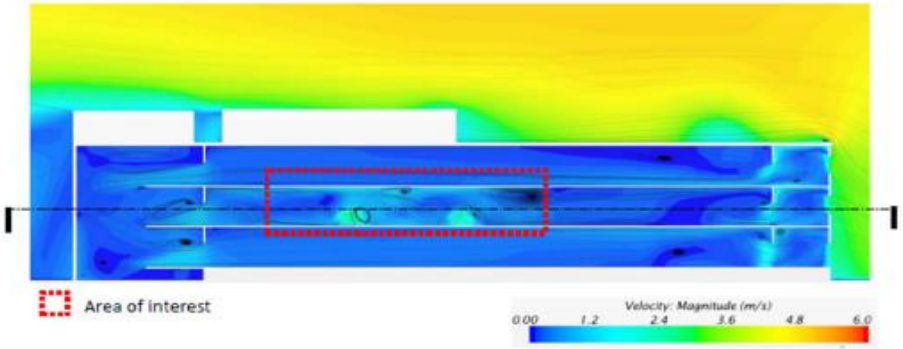
Comparison of air velocities between measurement and CFD for test scenario 4

SCENARIO 4

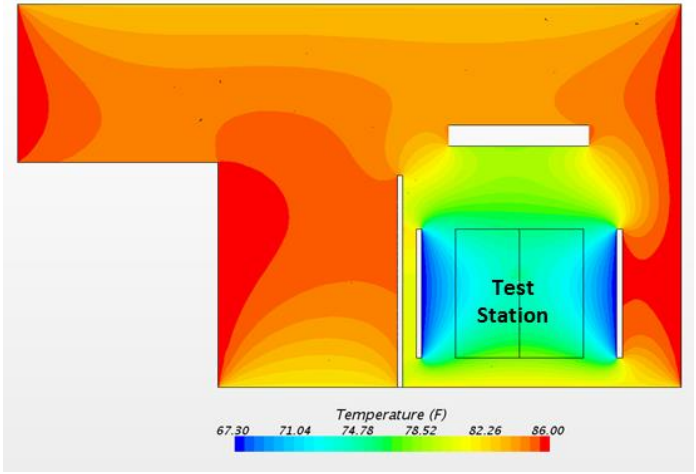
CFD Visualization Analysis

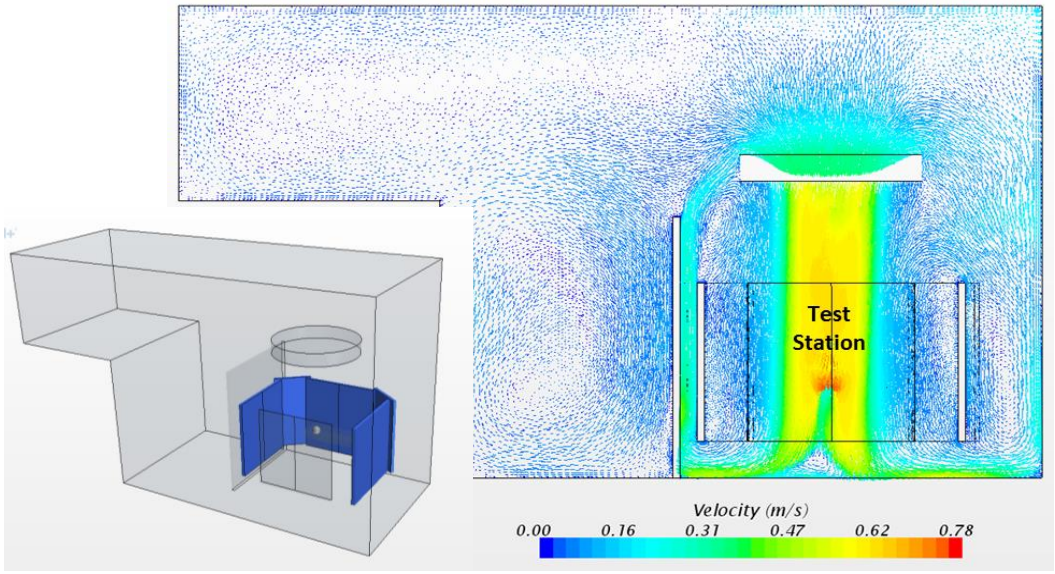


Streamline overlaid on Velocity Contour Map on the Horizontal Plane



Streamline overlaid on Velocity Contour Map on the Longitudinal Section Plane



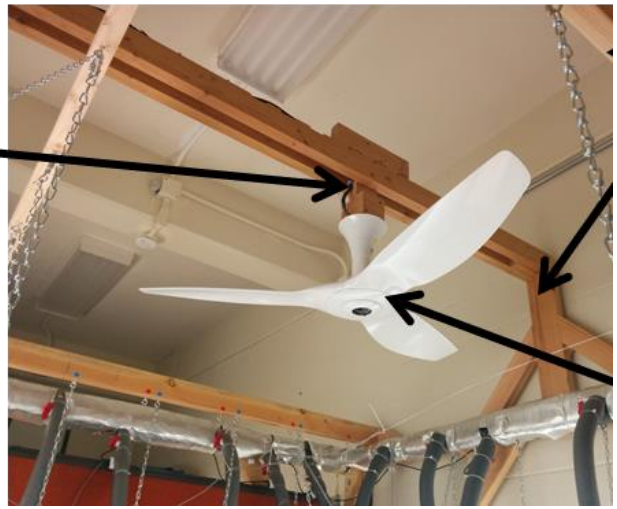


CFD Thermal comfort study and verification

Radiant panels suspended from wooded support structure

Small desk for test subjects

Movable mount of ceiling fan on wooded support structure



3. New Approach to HVAC: Separate Temperature and Humidity Controls – Liquid Desiccant Dehumidification

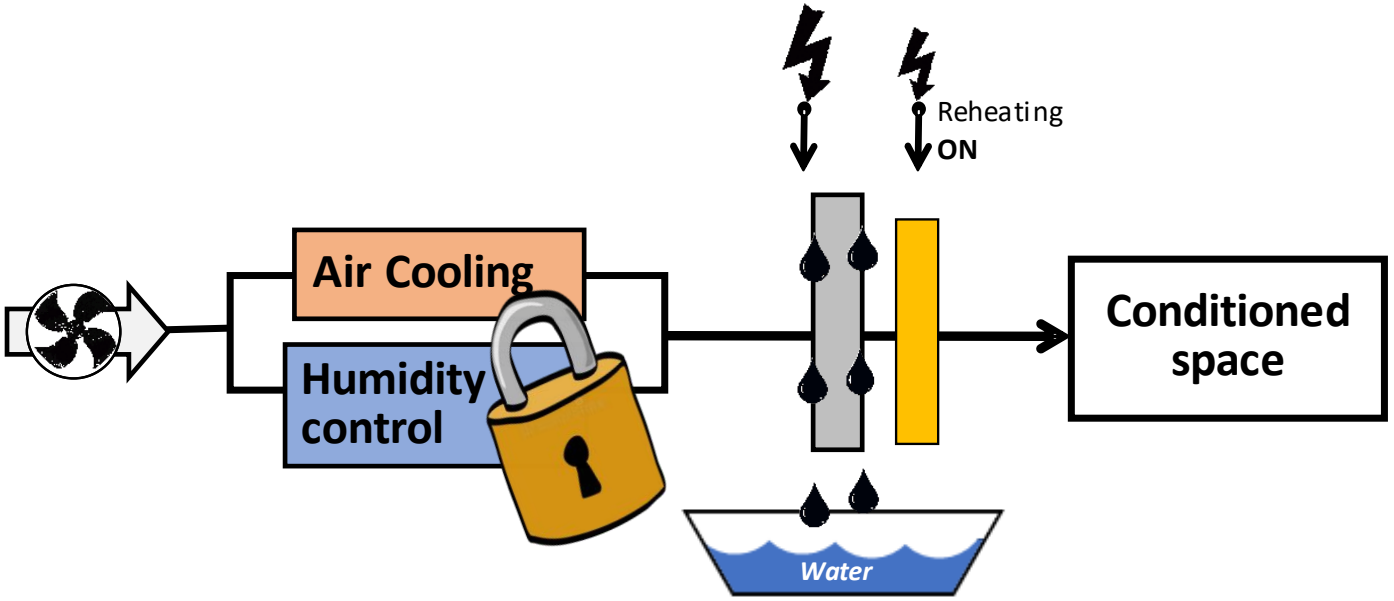
Problems with conventional HVAC:

- Air temperature and humidity controls are not currently separated
- Dehumidification occurs through cooling air below dew point to condense water vapor *("cooling based dehumidification")*
- Air must be reheated if too cold

Typical problems with conventional AC: **overcooling and reheat**

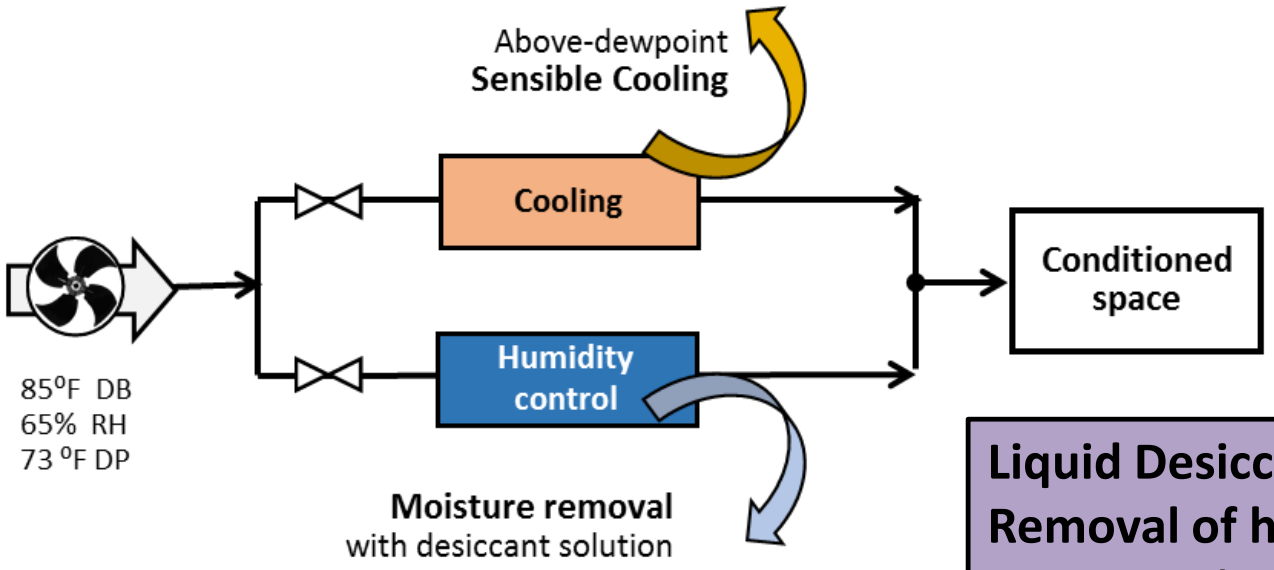
Insufficient dehumidification: Condensation & building damage

Conventional cooling based dehumidification



Water vapor is removed from air by cooling coils which are held below dew point

Most Effective Approach to Solve the Growing Humidity Problem – "Decouple Cooling Loads"

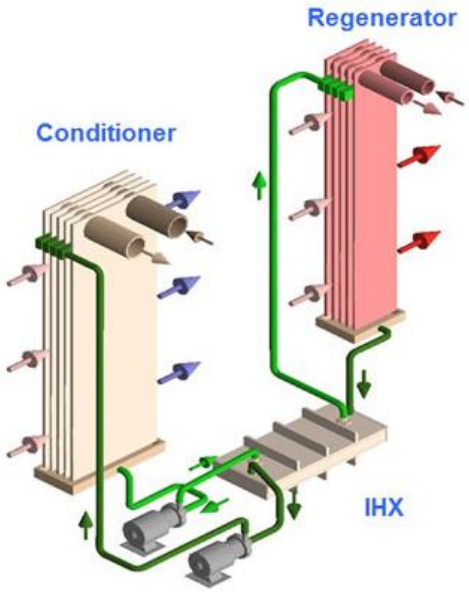


Liquid Desiccant Dehumidification: Removal of humidity at <u>above</u> dewpoint (warmer) temperatures

Advantages:

- Use other than cooling based dehumidification (avoid overcooling)
- Significant energy saving (no reheat)
- Use energy efficient hydronic cooling technologies such as radiant ceiling or radiant beam (without condensation problems)

Innovative “Low-Flow” liquid desiccant dehumidification processes developed by AIL Research for HVAC



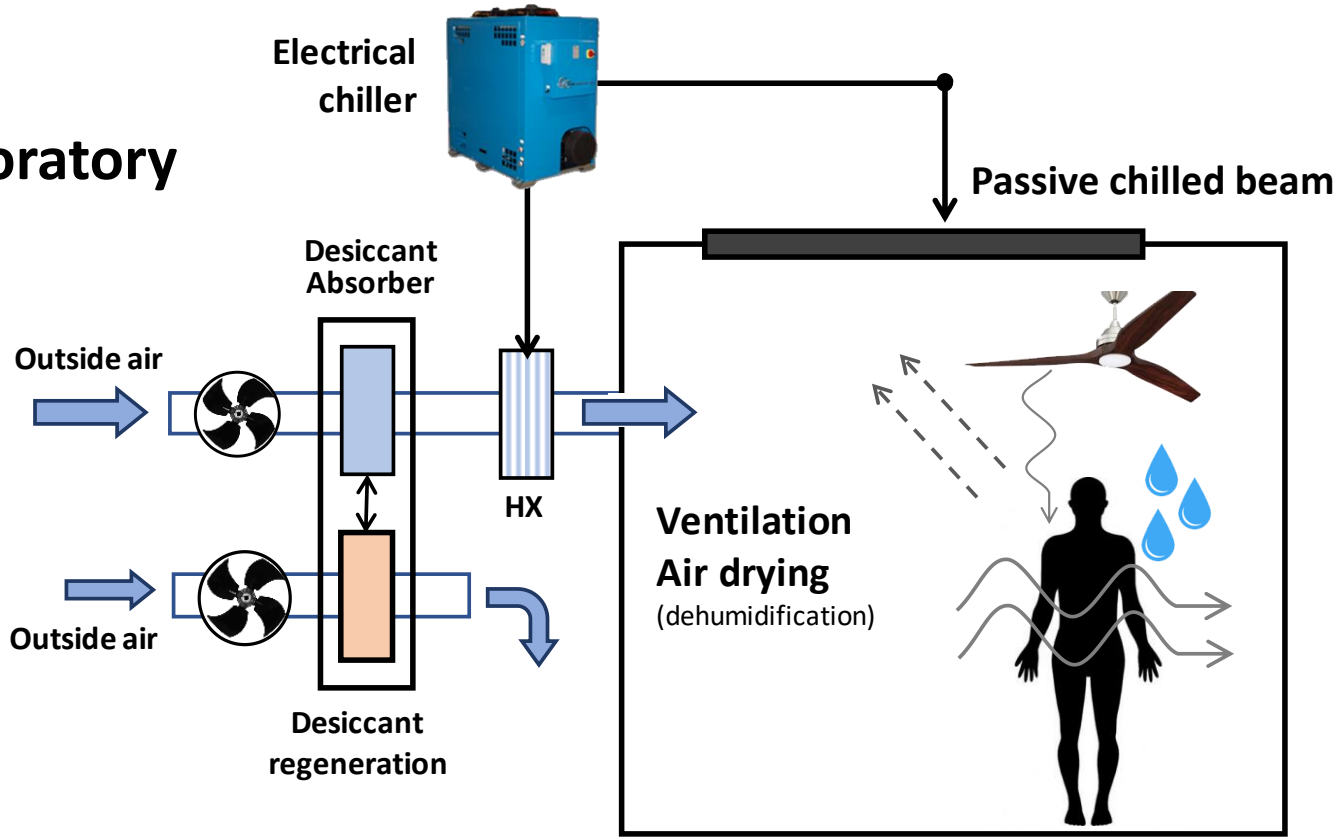
Main components:
Conditioner and Regenerator

Existing Commercial installations

Conditioner and Regenerator Design >>>

New LDAC Technology to be tested in Hawaii
Decoupled sensible & latent cooling

Design of Laboratory Test Set-up



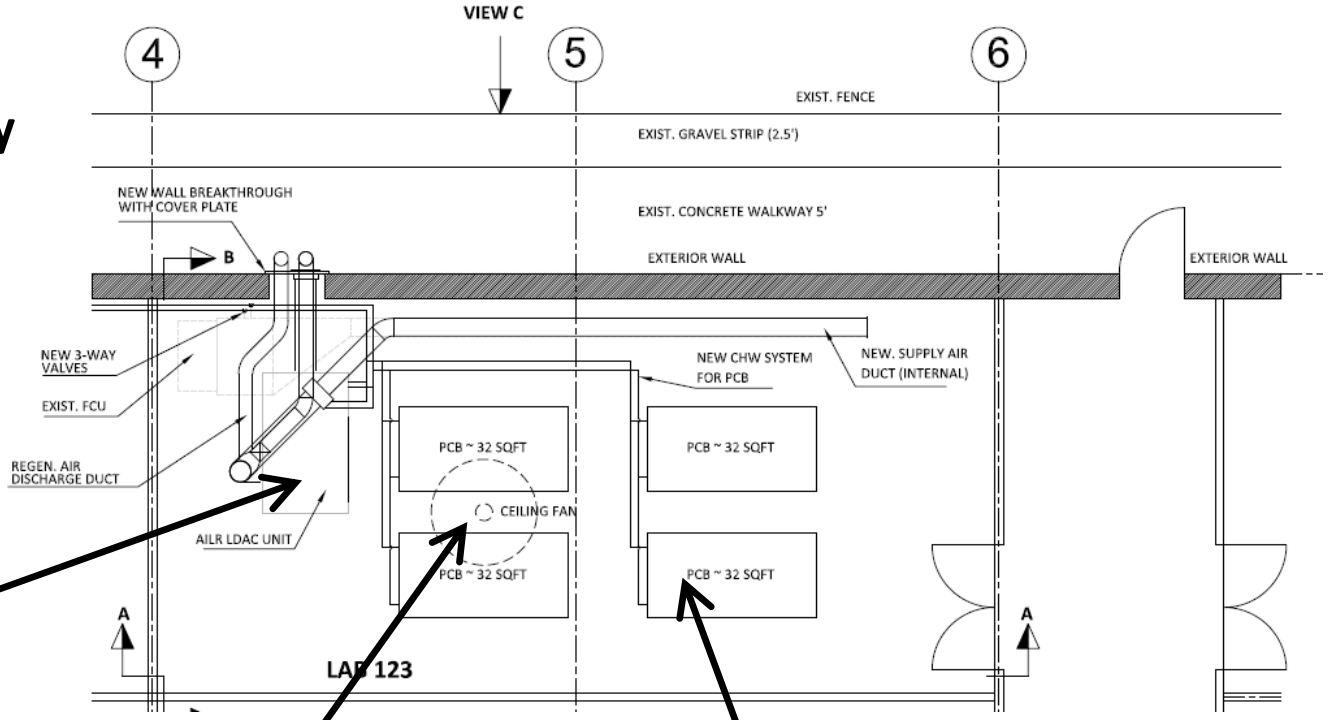
Latent heat removal = Dehumidification

Advanced AC – Desiccant dehumidification & separate sensible cooling

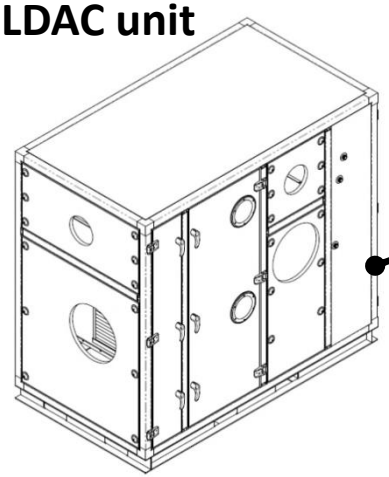
Pilot Project in Hawaii using two basic (decoupled) HVAC technologies:

- LDAC unit for precise dehumidification
- Passive chilled beam and ceiling fan for energy efficient sensible cooling

Design of Laboratory Test Set-up



LDAC unit



High performance ceiling fan

Passive chilled beam

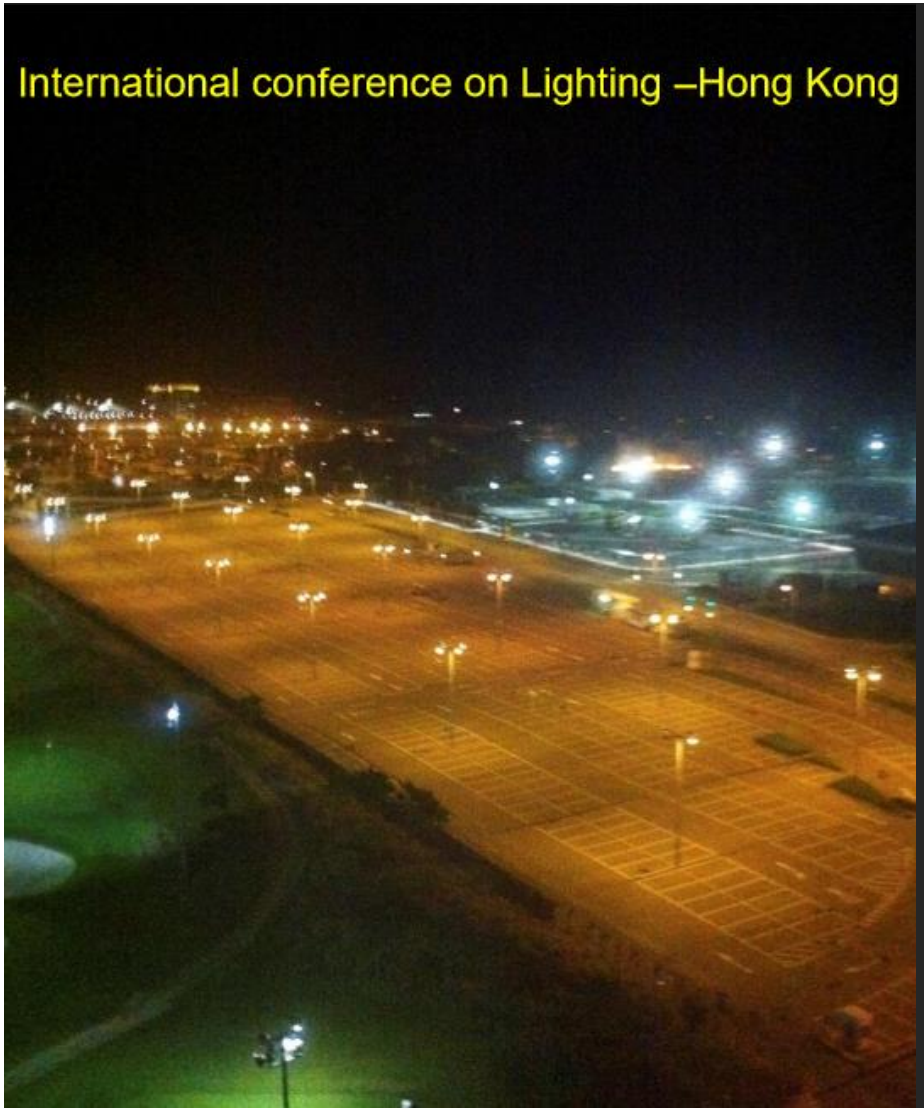
4. Future Research:
Proposed and/or Planned Projects

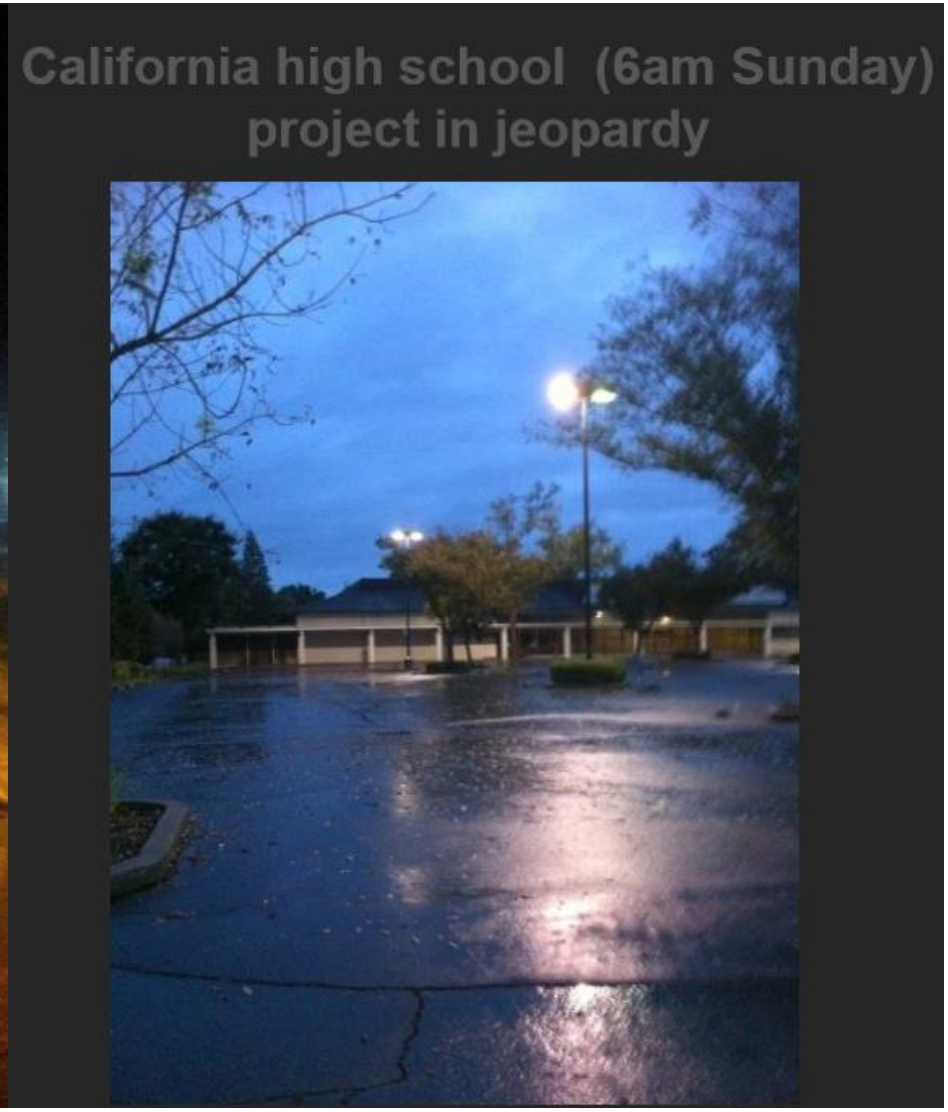
Overview

1. **Adaptive Lighting and Demand Response**
2. **Wellness in Buildings** / building healthy buildings and avoiding problems of highly energy efficient buildings
3. **Humidity problems in "Green Buildings"** - Hygrothermal building simulation to avoid humidity related health risk (i.e. Mold) and humidity related damages to building structure

Adaptive Lighting:

Collaboration with California Lighting Technology Center (CLTC)





Mid-night *six cars in structure*

How Low Can We Go?

- Benefits
  - Security: Lighting serves as visual “alarm”
  - Energy Savings
  - Reduced Night Sky light pollution

Demand Response for Lighting

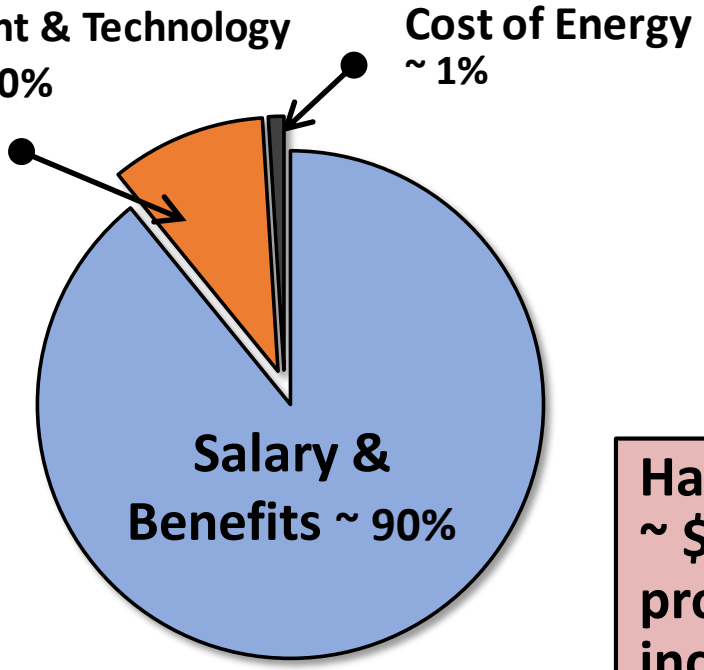
- Generally large buildings (>10,000 sf)
- 14-23% Savings
  - (National Research Council Canada-Institute for Research in Construction (NRC-IRC) study)
- Early Stages
  - More companies needed to provide product
  - Standardized signals from utility are needed
  - Advanced Meter Infrastructure (AMI) adoption
- Incentives required
- Drivers: Regulatory, infrastructure reduction, “smart grid”.

2. Wellness in Buildings

Building healthy buildings and avoiding problems with some highly energy efficient buildings

Goal: Develop technologies that provide BOTH good IEQ and energy savings

Cost of doing business (typical per employee)



Personnel costs can be reduced with improved IEQ. Wellness benefits can be significantly higher than energy savings

Harvard Healthy Building Program estimates ~ $6,500 per employees from increased productivity & lower costs through increased ventilation

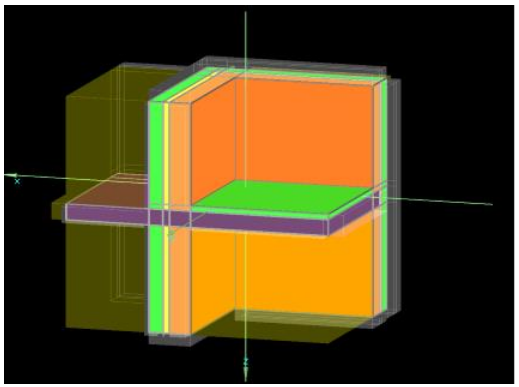
3. Humidity problems in "Green Buildings"

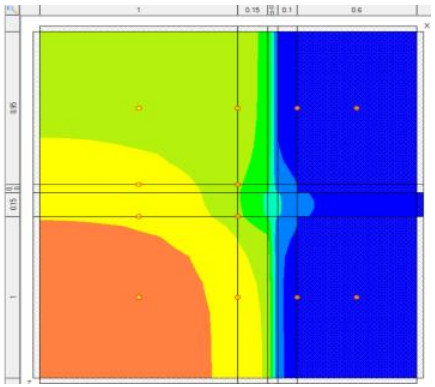
Hygrothermal building simulation to avoid humidity related health risk (i.e. Mold) and humidity related damages to building structure

Fact: More energy efficient (and tighter) building envelopes have potential humidity related problems

"Energy efficient enclosures built in hot-and-humid climate zones often result in reduced dehumidification provided to interior spaces by air conditioning systems- leading to serious hygienic consequences." (WUFI.de)

Goal: Advance Hygrothermal simulation software application in the design of effective building envelopes for the warm and moist climate – support moisture management in buildings





Hygrothermal analysis of building envelope

Images source: by WUFI software, ORNL

Thank you

QUESTIONS?

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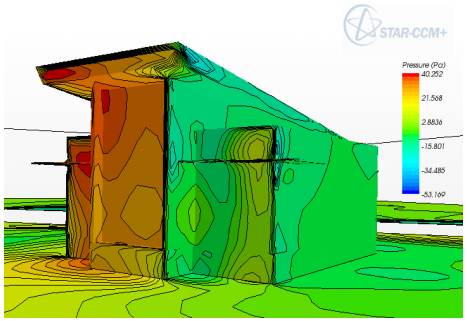

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