Super Low Energy Buildings Workshop

Strategies, Emerging Technologies and Case Studies

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BERKELEY LAB

INTEGRAL GROUP

Outline

0845 - 1045

1. SLE Design Process and Global Trends in Net Zero Energy Design [50 min]
2. Building Envelope Design Innovations and Emerging Technology [40 min]
3. Lighting Design Innovations and Emerging Technologies [30 min]

1045 – 1100 BREAK

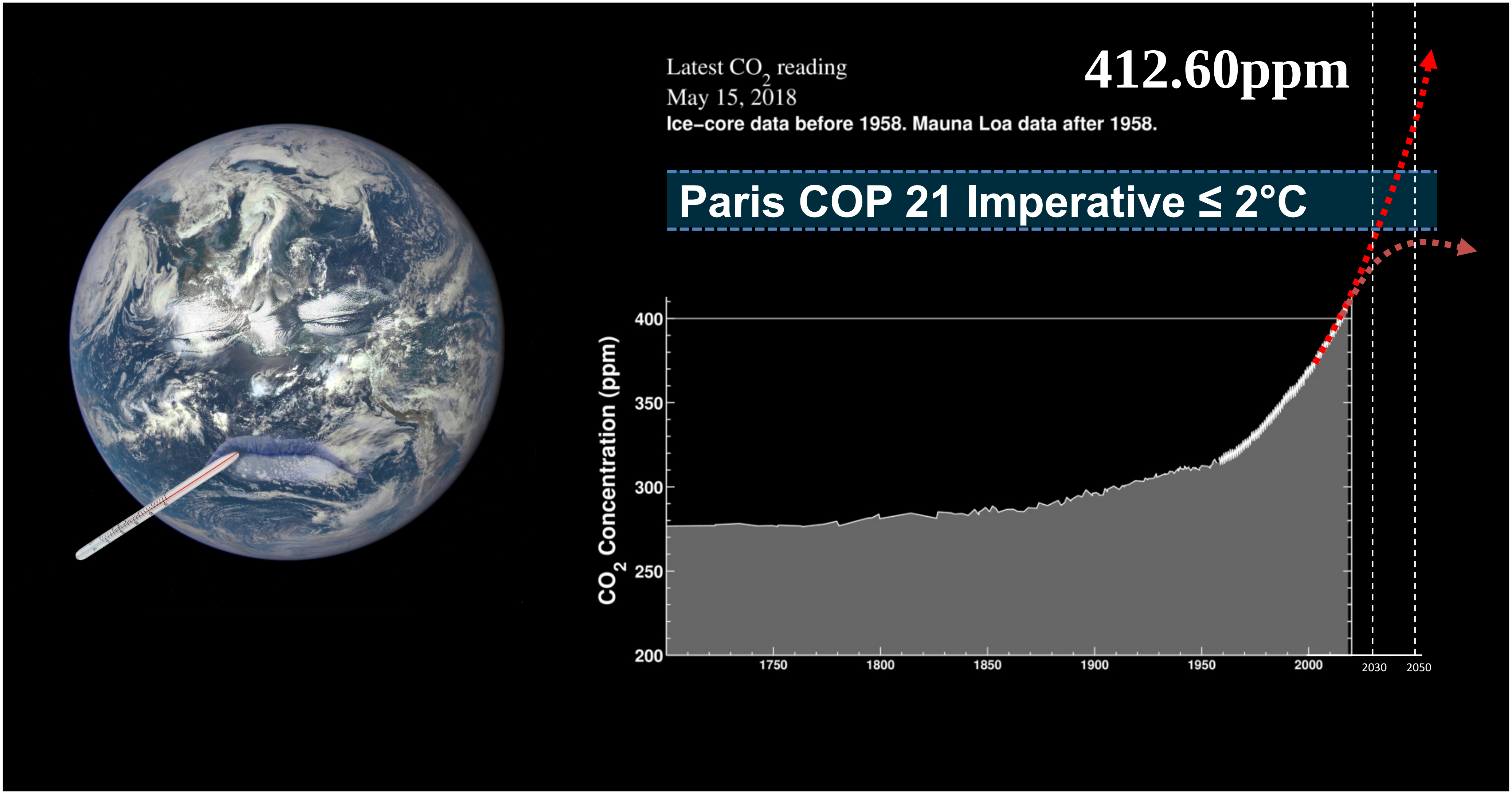
1100 - 1300

5. Plug Load Technologies [20 min]
6. ACMV Strategies and Emerging Technologies [60 min]
7. DC Power, Grid Integration Strategies and Emerging Technologies [40 min]

LUNCH

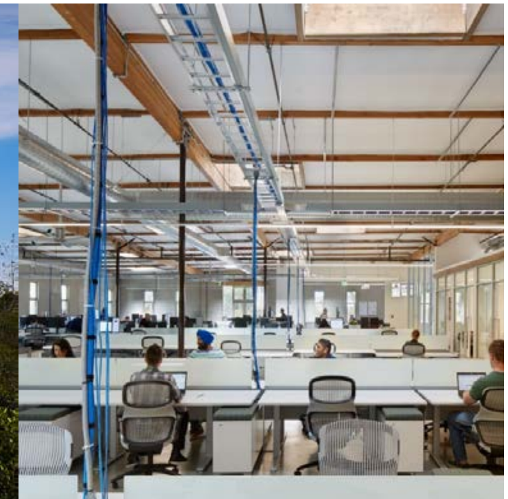
SLE Design Process and Global NZE Design Trends

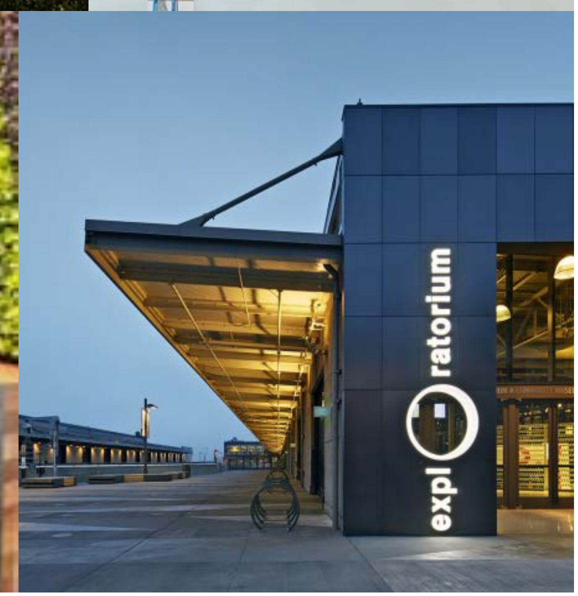
Key Motivation: Sick Planet Earth with no Planet B



California – Fertile Ground for Net Zero





NZE - Achievable. Affordable. Comfortable. Elegant. Integrated. Simple



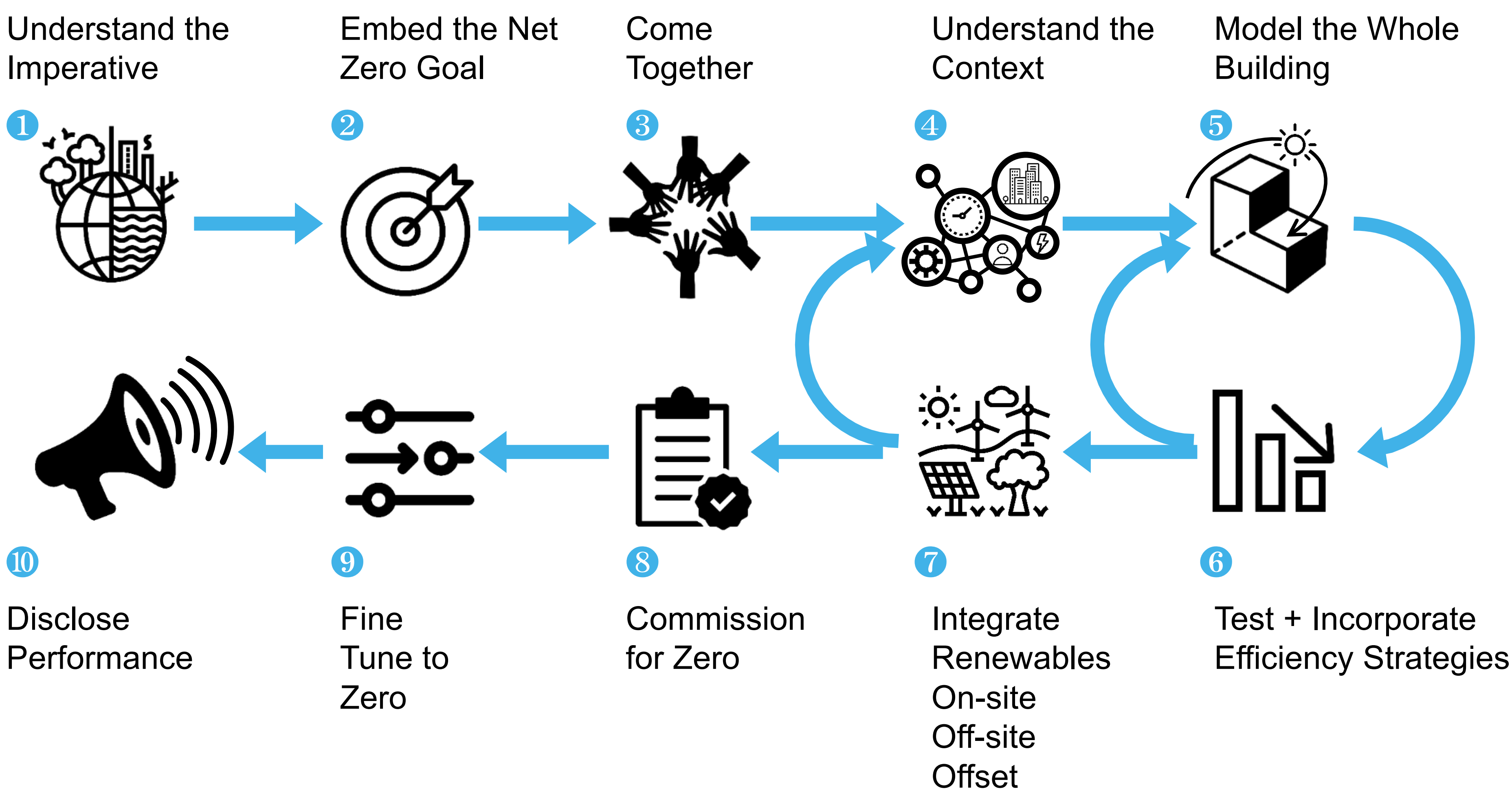




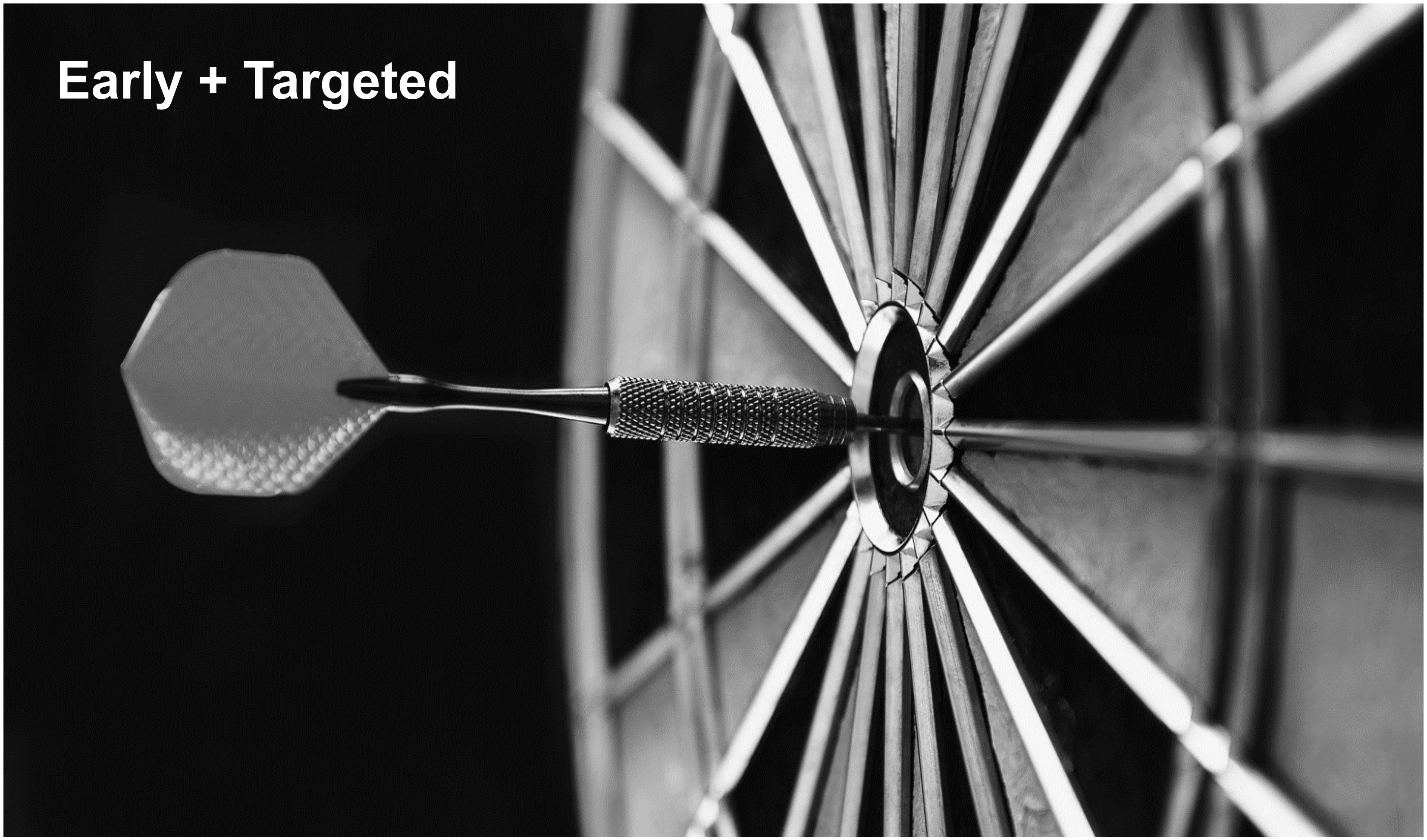
IDeAs HQ	Packard Foundation	Exploratorium	J Craig Venter Institute	DPR	Indio Way	Mathilda Avenue
10,000 SQFT Retrofit Office	49,000 SQFT New Build Office	210,000 SQFT New Build Museum	45,000 SQFT New Build Laboratory	22,000 SQFT Retrofit Office	32,000 SQFT Retrofit Office	30,000 SQFT Retrofit Office
2007	2012	2013	2013	2014	2015	2015
Passive + GSHP + Radiant	Passive + DOAS + Chilled Beam	Baywater Cooling + Radiant	DC Vent + Chilled Beam	Passive + Roof Top Unit	Passive + Roof Top Unit	Passive + Roof Top Unit
Market Cost + PV Grants	Institutional	Museum + PPP $10m	Laboratory	Market Cost	Market Cost	Market Cost + PV Grants
First Certified ILFI Net Zero Energy Builidng	2012 ENR - Best Green Project 2013 ASHRAE Technology Award First Place 2013	2014 Honor Award Energy + Sustainability, AIA SF Chapter 2014 ULI Global Awards for Excellence	2015 Architizer A+ Awards – Architecture + Sustainability Award	2014 ENR California Project of the Year 2014 ENR California Best Green Project	2015 Silicon Valley Business Journal Best Reuse/Rehab	2015 Silicon Valley Business Journal Green Project of the Year

Collaborative Net Zero Roadmap

Teams Making Better Decisions with Better Data



Integrative Process

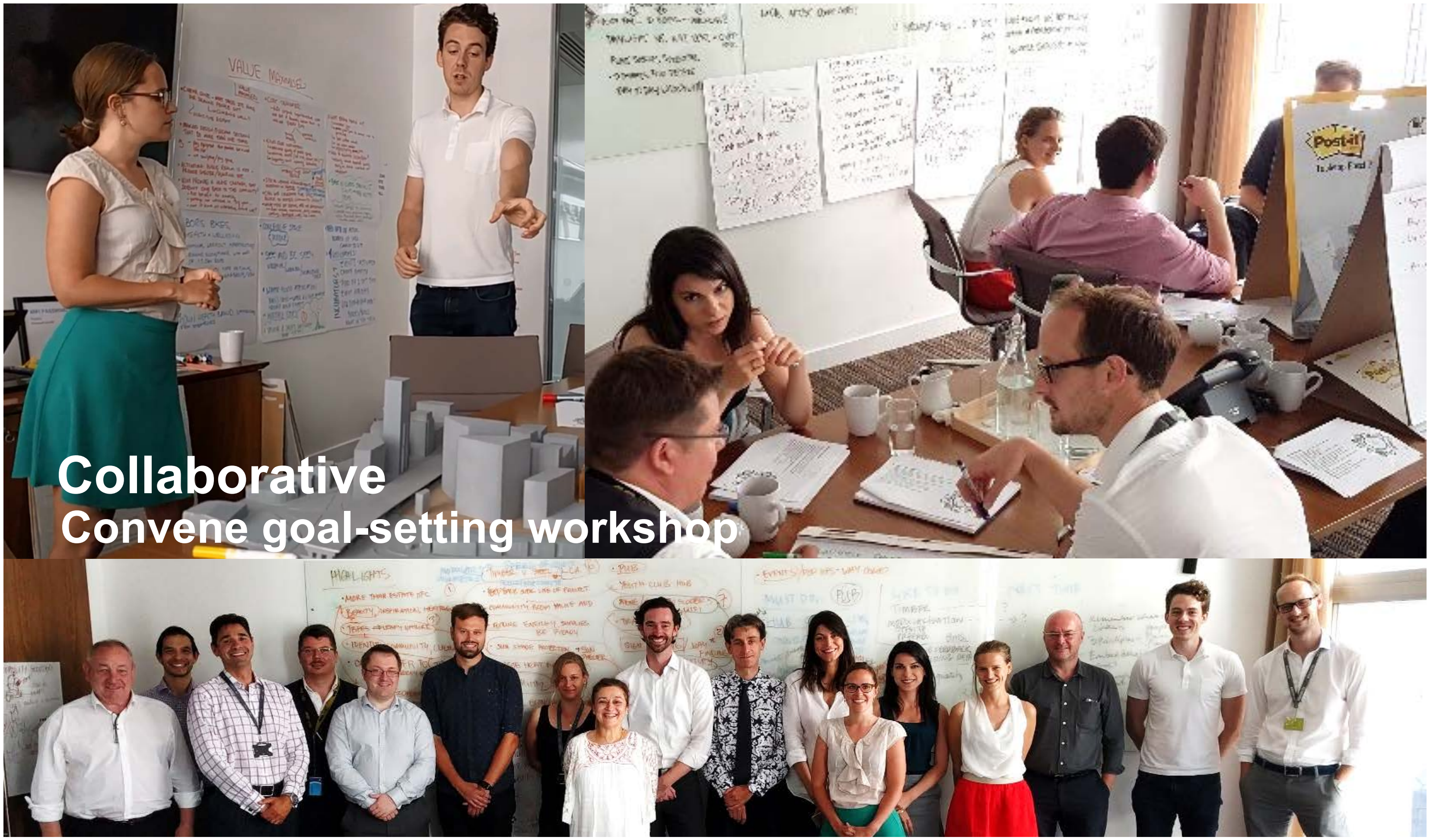


1. Understand the Imperative

2. Embed the Net Zero Goal

3. Come Together

Integrative Process



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Integrative Process - Discovery

1. Understand the Imperative

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3. Come Together

Integrative Process - Discovery

39,666

255,141
MWh

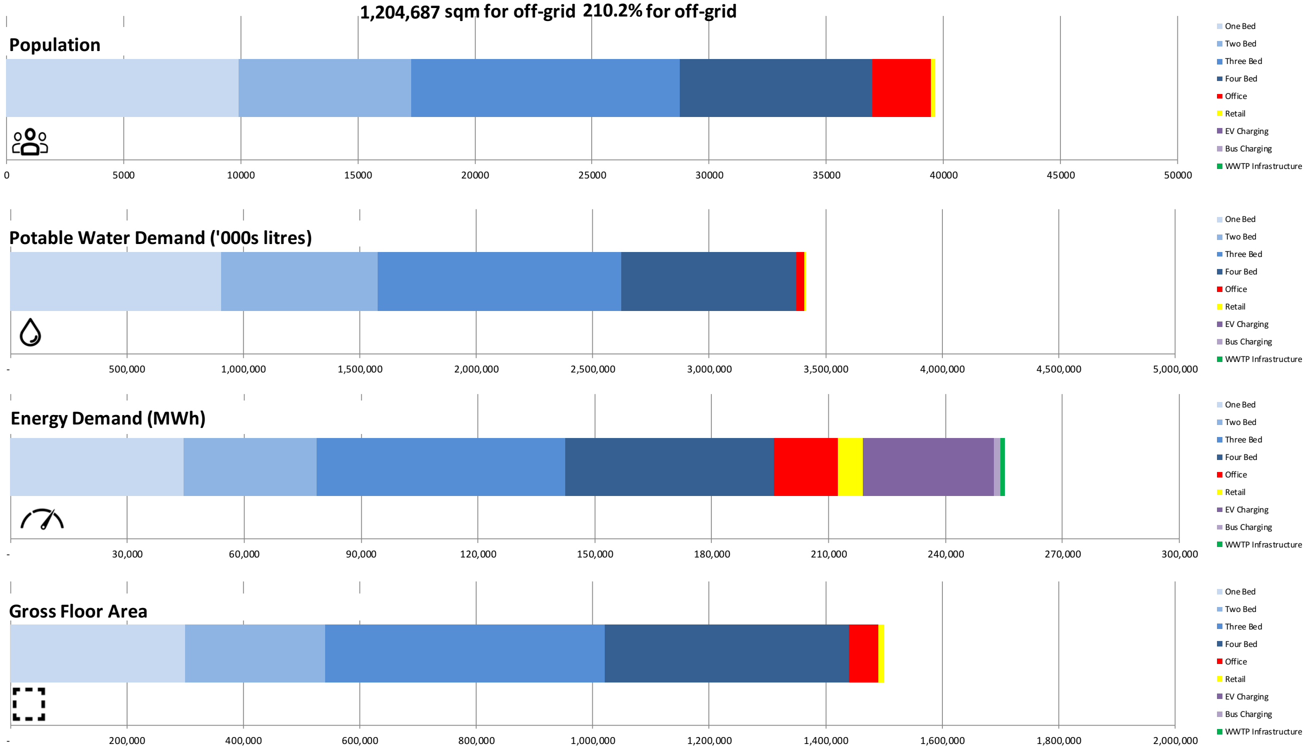
762,204
sqm for 105%
1,204,687 sqm for off-grid

139.7%
roof coverage by PVs
210.2% for off-grid

3,415,684
'000s litres

14,800
homes

1,500,000
GFA



1. Understand the Imperative

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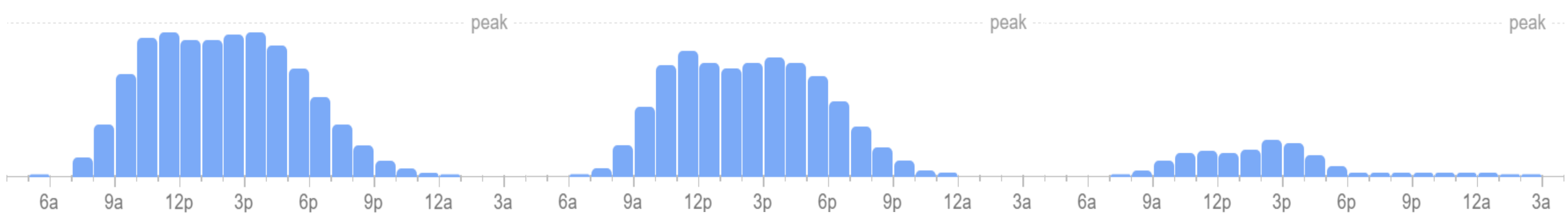
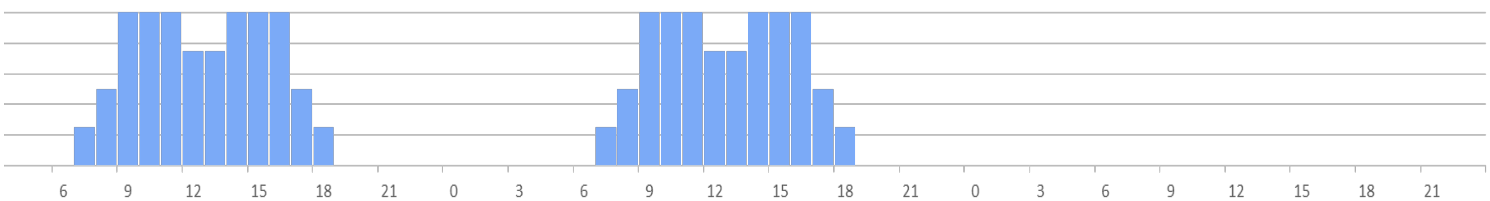
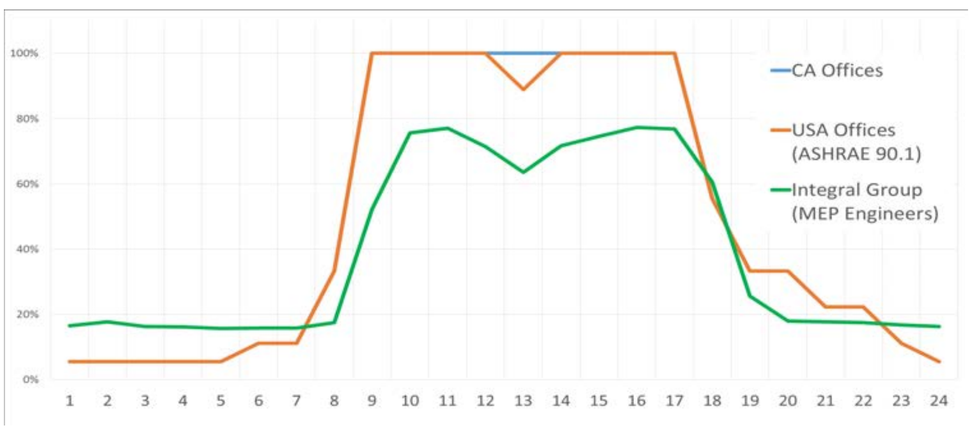
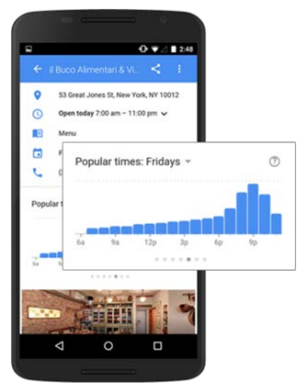
3. Come Together

Understand the Context - Profiles

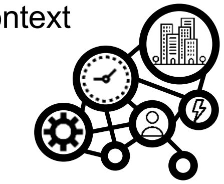




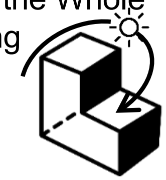




4 Understand the Context



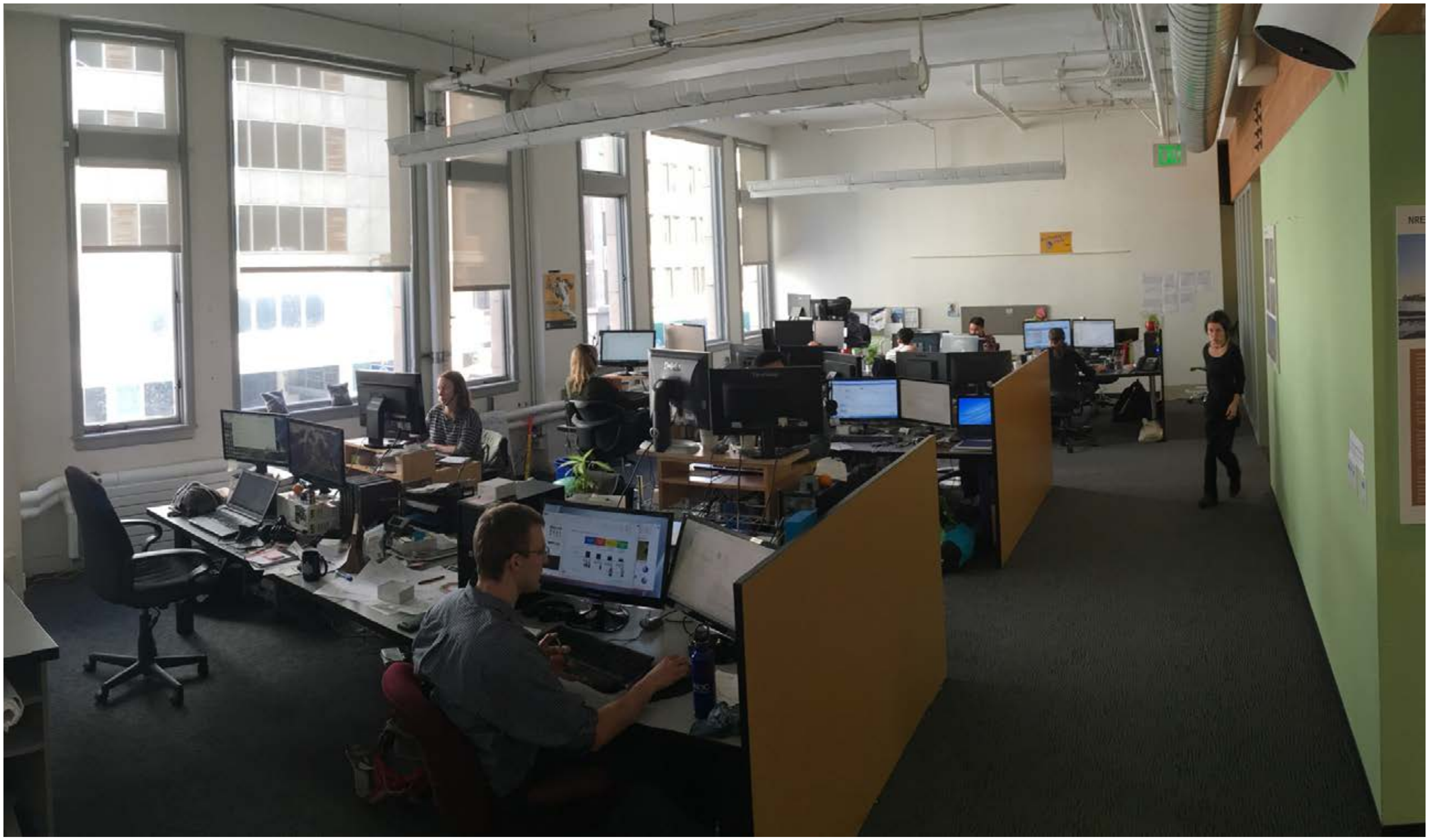
5 Model the Whole Building



6 Test + Incorporate Efficiency Strategies

7 Integrate Renewables
On-site
Off-site
Offset

Understand the Context - Equipment



4. Understand the Context

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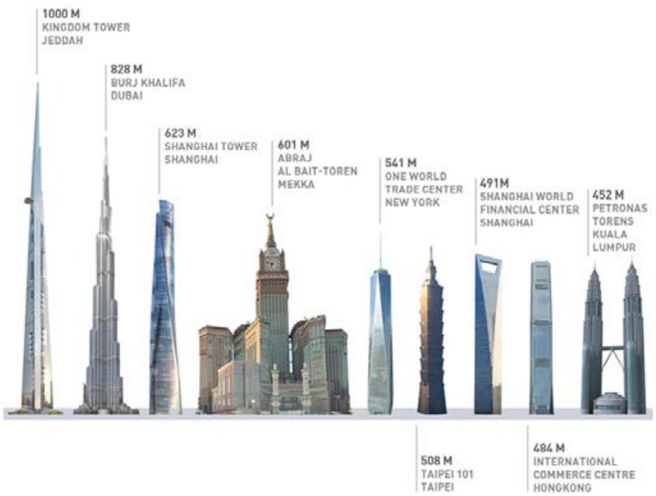
   - On-site
   - Off-site
   - Offset

Understand the Context - Scale



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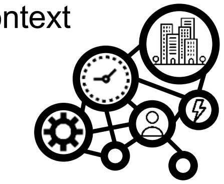

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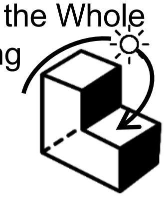

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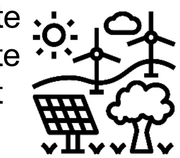
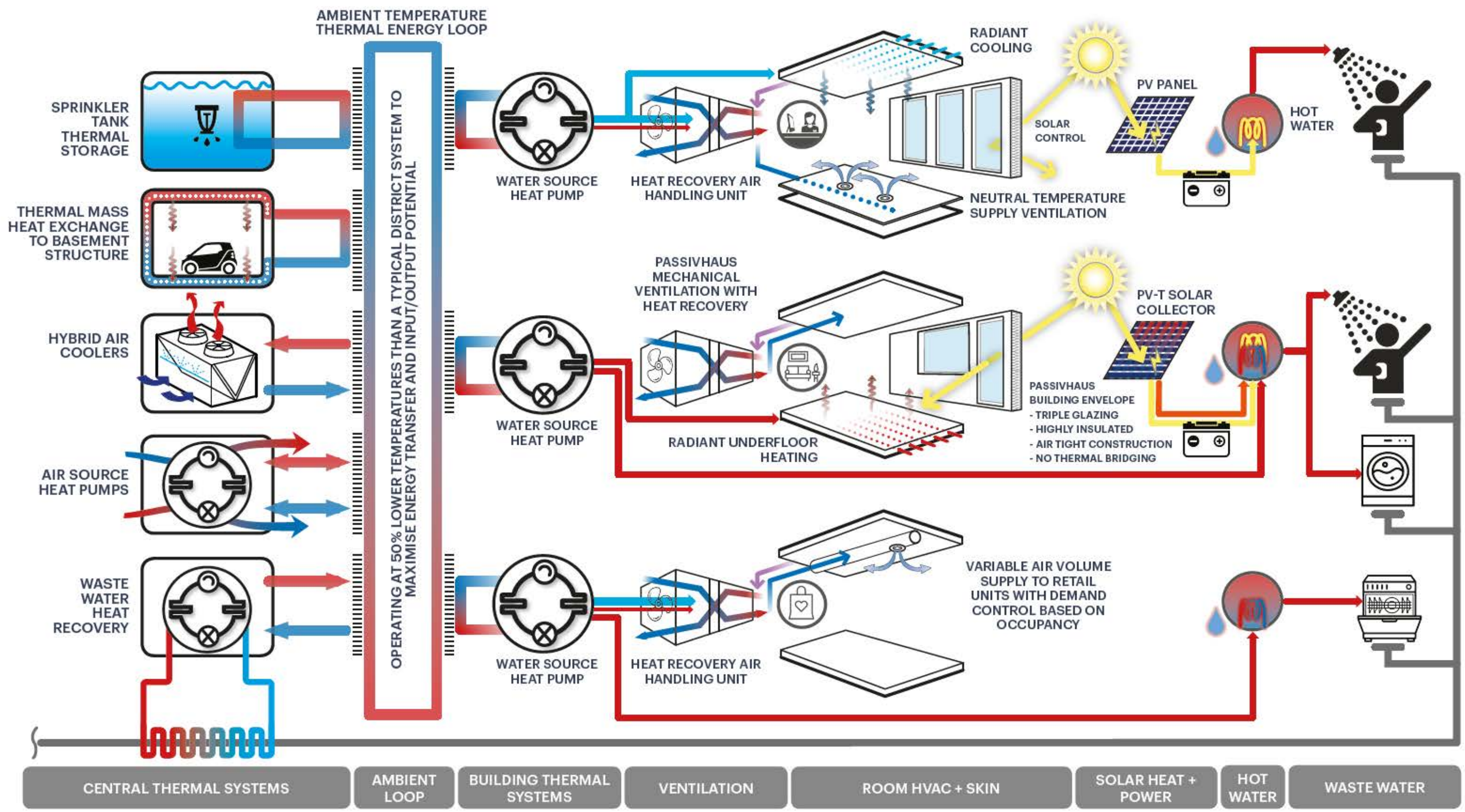


Understand the Context - Districts



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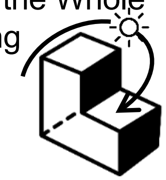

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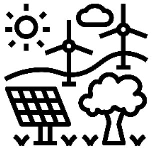
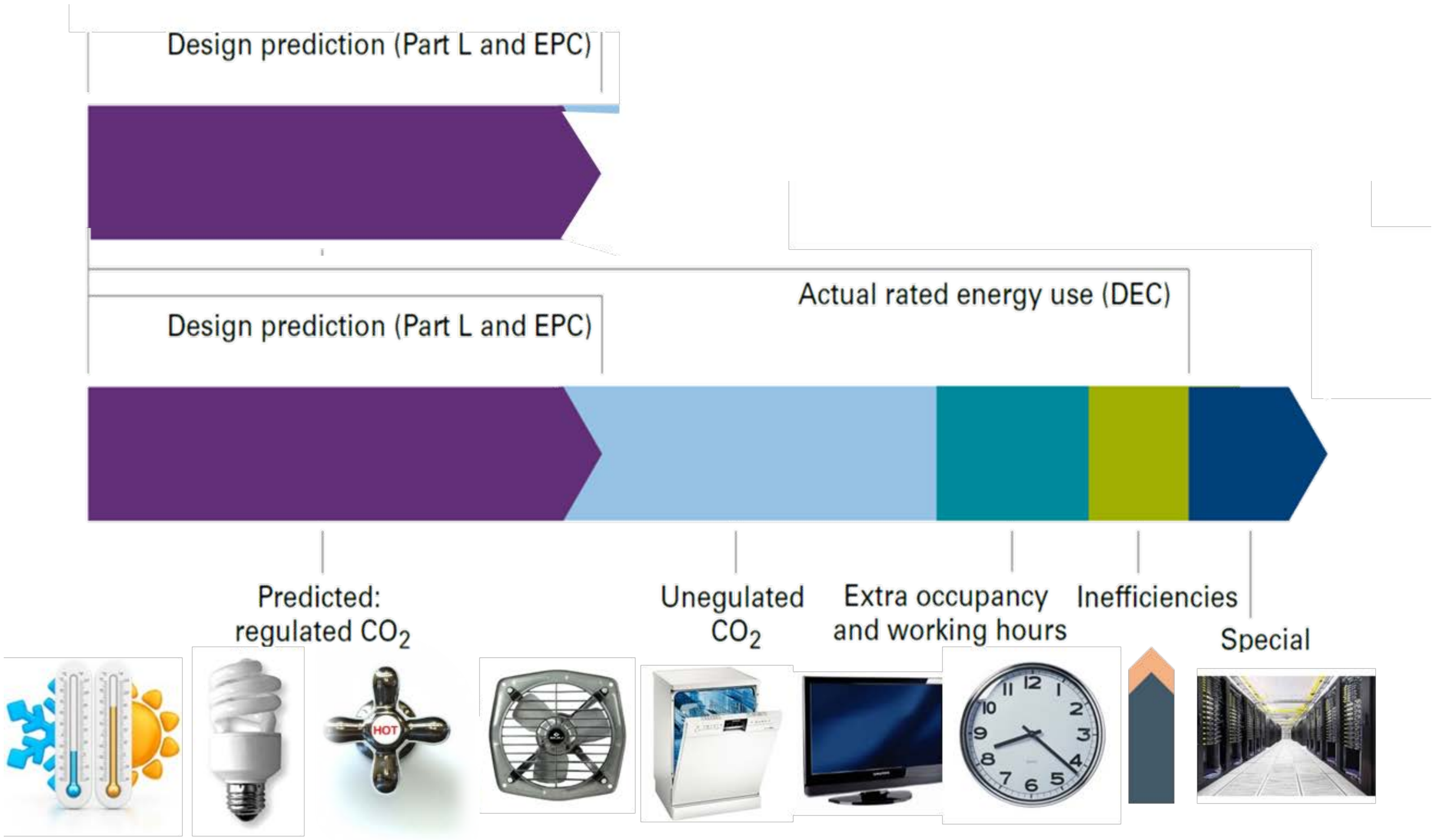


Model the Whole Building



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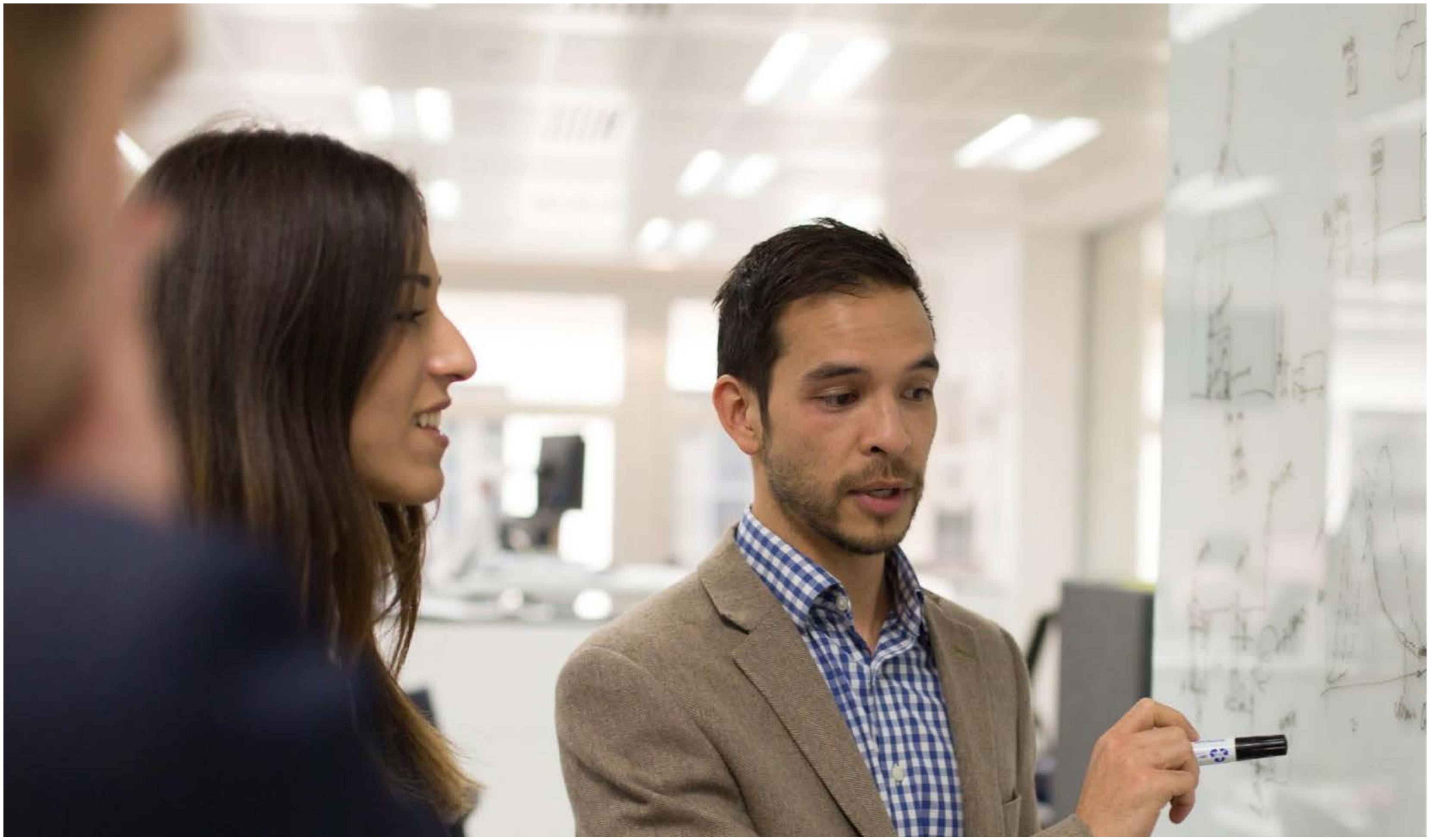
Offset

Efficiency Strategies - Development



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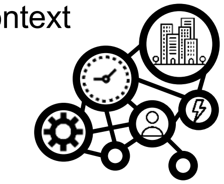

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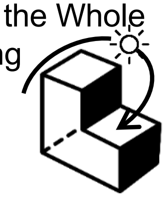

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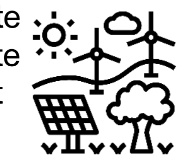
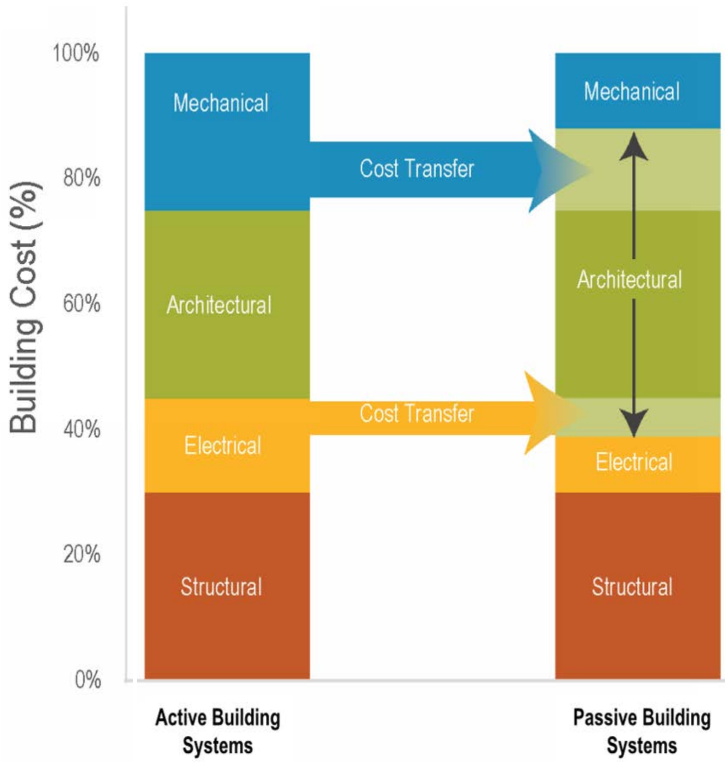
- Off-site
- Offset



Efficiency Strategies - Envelope



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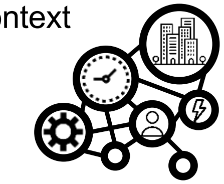

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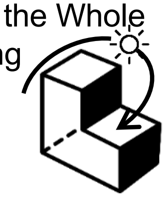

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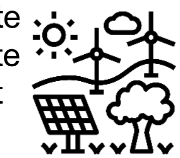
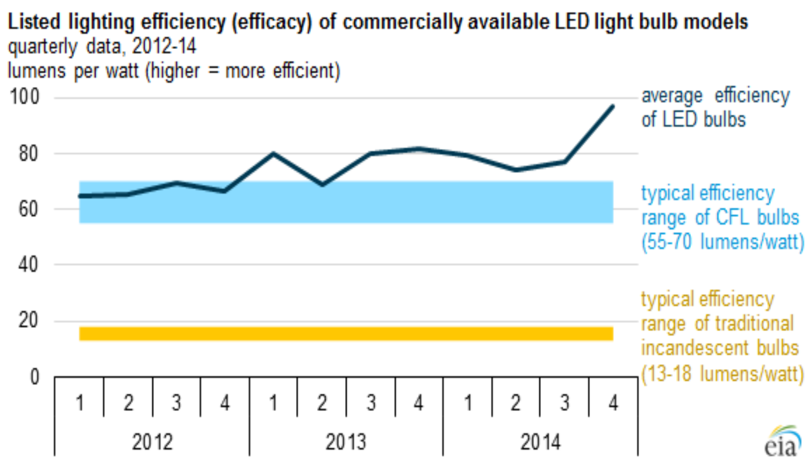
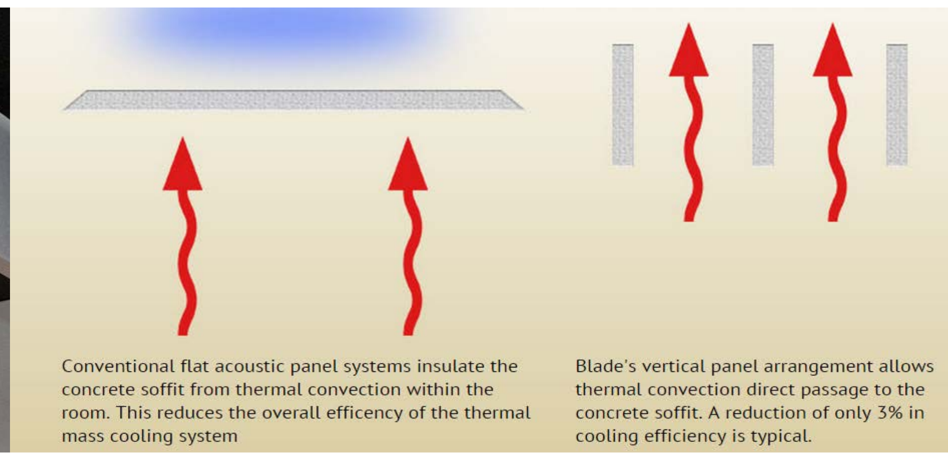
7. Integrate Renewables
   On-site
   Off-site
   Offset



Efficiency Strategies – Lighting + Thermal Mass





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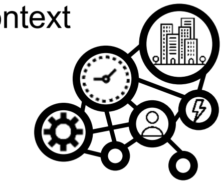

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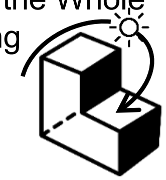

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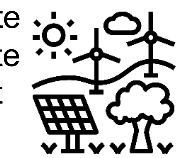
   - Off-site
   - Offset



Efficiency Strategies - Ventilation

Safe · Smart · Efficient
AIRCUITY®

4 Understand the Context

5 Model the Whole Building

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On-site
Off-site
Offset

Renewable Energy Integration - Onsite

4 Understand the Context

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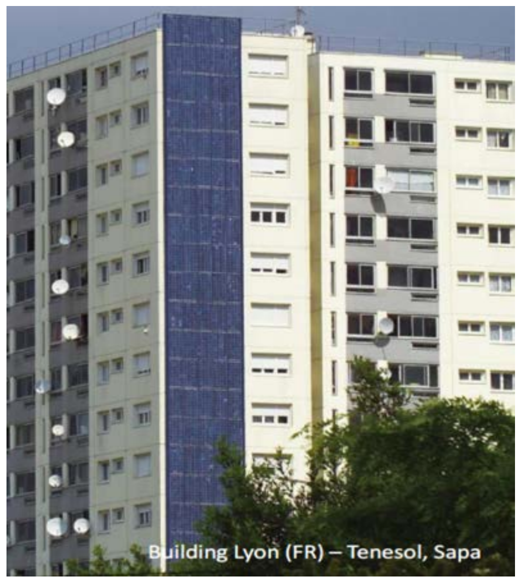
7 Integrate Renewables
On-site
Off-site
Offset

Renewable Energy – Building Integration

Rooftop locations important, but other locations are needed for aggressive SLE designs

- Vertical orientations
- Building integrated PV – glazing, skylights
- Incorporate into Shading designs



Building Lyon (FR) – Tenesol, Sapa

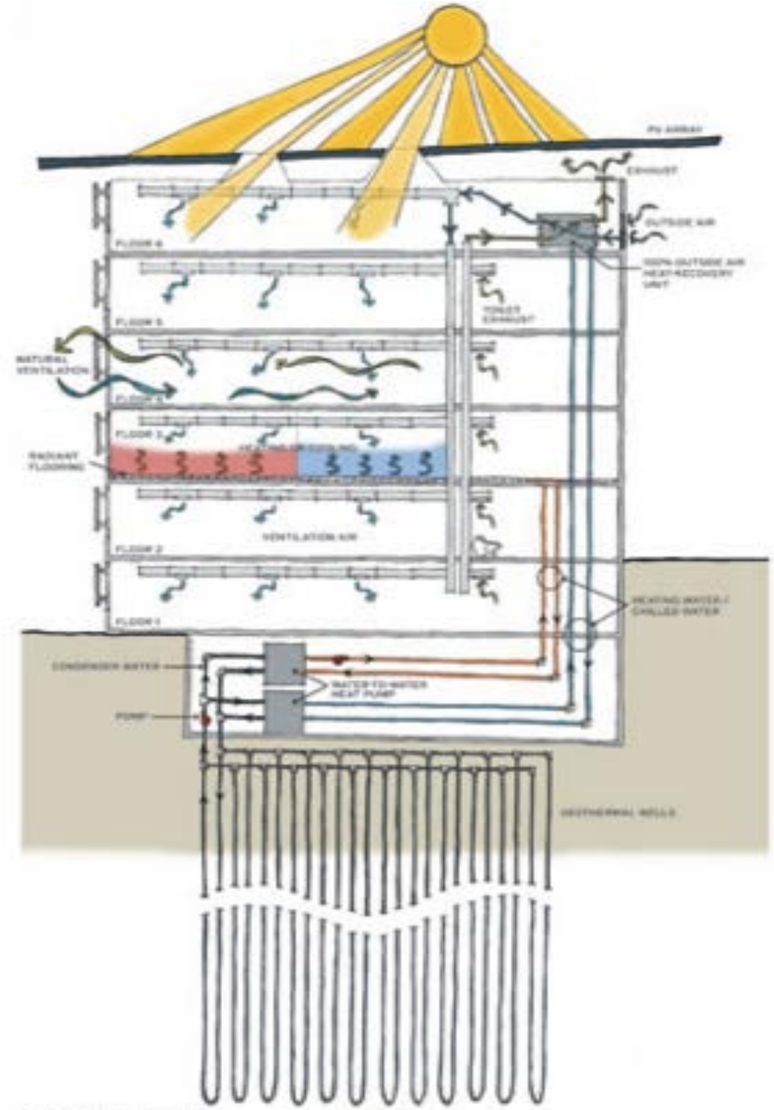
REC factory Norway – Sapa Building System

Commission for Zero + Fine Tune to Zero

8. Commission for Zero
9. Fine Tune to Zero
10. Disclose Performance

Case Study – Bullitt Foundation

5 story office building, ~ 5000 m^{2}, Seattle, WA
http://www.bullittcenter.org/



Case Study – NUS School of Design and Environment

Using PV as a shading element

Source – NUS School of Design and Environment, SDE4

Building Envelope

Technology Appraisal

#1 Form & Orientation

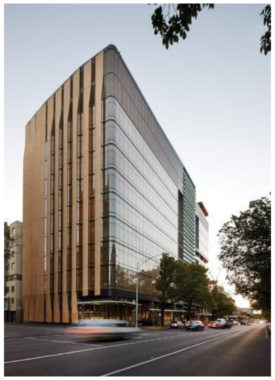
Architectural

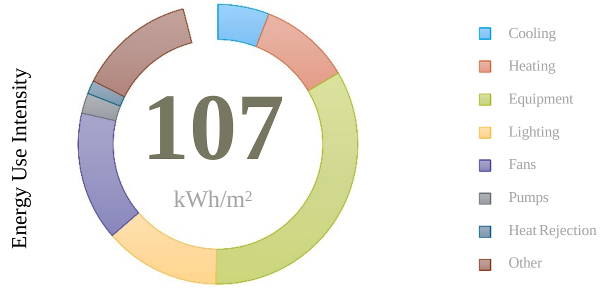
Feasibility

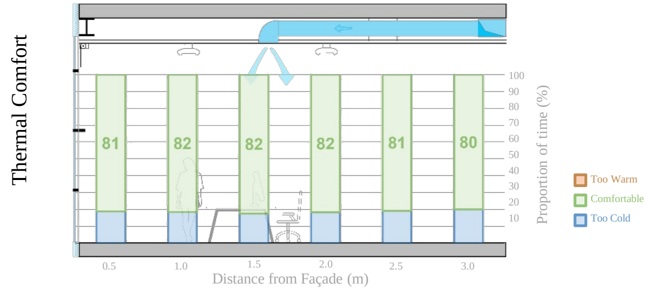
A building's form and orientation are considered at the earliest stages of design and are influenced by a number of factors including site constraints, relationships to adjacent buildings, and architectural aesthetic.

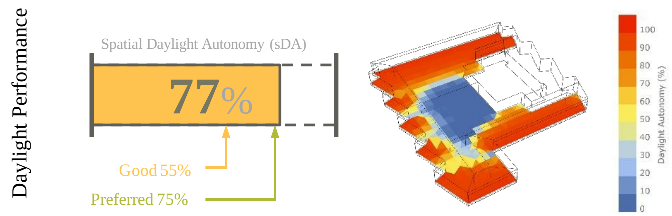
Consideration of energy efficiency and occupant comfort can significantly impact a building's form and orientation. Due to the sun's movement, it is often more difficult to control solar gain on east and west elevations, leading to a desire for buildings with a greater proportion of north and south façade. Site constraints can make a north-south oriented building difficult to achieve, but there are design solutions that can overcome a large east- or west-facing elevation. Notable examples are shown below by Bjarke Ingels Group in Shenzhen and Grimshaw in Melbourne.

For the purposes of this assessment, a modified floorplate form has been analysed, incorporating a sawtooth façade design minimising east- and west-facing glazing.









Perceived Innovation	Limited innovation impact as widely used approach	★☆☆☆☆
Market Tested	Standard practice in Australian market	★★★★★
Capital Cost	Minimal cost impact if considered at concept design. Some increase if stepped façade.	★★★★☆
Energy Cost	Score based on EUI calculation	★★★☆☆
Maintenance Costs	Significant annual outlay, but equipment likely to last longer than baseline system	★★★★☆
Ease of Operations	No impact on operations	★★★★★
Flexibility/Adaptability	No impact / minimal impact	★★★★★
Long Term Rental Return	Optimising form for energy performance may conflict with optimum external views	★☆☆☆☆
Daylight & Views	Reducing east/west facing glazing will improve energy performance, but will impact views if desired	★★☆☆☆
Thermal Comfort	Appropriate massing can minimise thermal discomfort near the façade	★★★★☆
Indoor Air Quality	No impact / minimal impact	★☆☆☆☆
Impact on Certification	Impacts associated with energy reduction due to reduced cooling and heating requirements and improved daylighting	★★★★★
Net Zero Emissions Impact	Score based on EUI calculation	★★★☆☆

Technology Appraisal

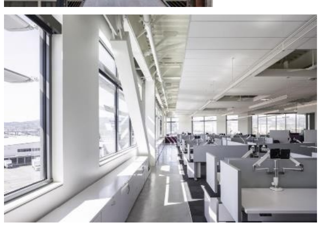
#2 Exposed Thermal Mass

Architectural

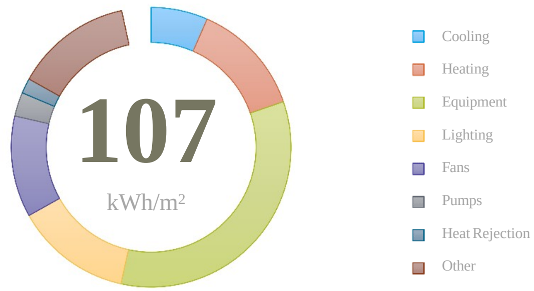
Feasibility ✓

Thermal mass has been used for thousands of years to moderate the temperature of buildings. The mechanism that drives the behaviour of thermal mass is its heat capacity, which allows the material to absorb excess heat from a space, thereby reducing the thermal demand on cooling systems. This is particularly effective when the thermal mass is exposed to solar radiation, which is absorbed in the material instead of warming up the internal air. In cooling climates, an exposed thermal mass strategy is often coupled with a night flush strategy, which removes the heat absorbed by the thermal mass during the day and readies the material for the following day of occupancy.

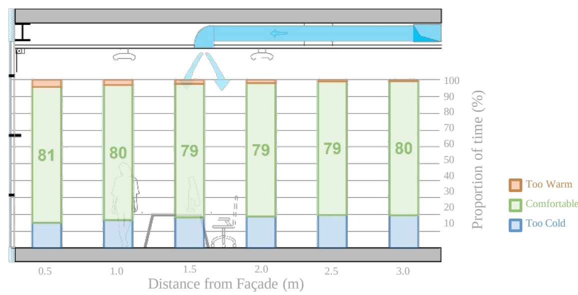
Thermal mass can be introduced in a number of ways, with varying impact. For example, mass can be introduced via exposed concrete columns, ceilings or flooring. If carpet is required in occupied spaces, an exposed slab can be limited to the perimeter zone, as implemented at the SFO Consolidated Administration Campus, pictured bottom right.



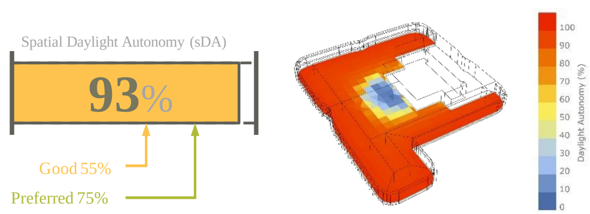
Energy Use Intensity



Thermal Comfort



Daylight Performance



Perceived Innovation — Not particularly innovative, but also not implemented often enough	★★☆☆☆
Market Tested — Commonly executed in the market but not the default approach	★★★★☆
Capital Cost — Considered response may result in cost savings from ceiling/floor finishes	★★★★☆
Energy Cost — Score based on EUI calculation	★★★☆☆
Maintenance Costs — Significant annual outlay, but equipment likely to last longer than baseline system	★★★★★
Ease of Operations — No impact on operations	★★★★★
Flexibility/Adaptability — Exposure of thermal mass can impact flexibility of space usage	★★☆☆☆
Long Term Rental Return — No impact / minimal impact	★★★☆☆
Daylight & Views — No impact / minimal impact	★★★☆☆
Thermal Comfort — Thermal mass can moderate space conditions by absorbing or releasing energy	★★★★☆
Indoor Air Quality — No impact / minimal impact	★☆☆☆☆
Impact on Certification — Impacts associated with energy reduction due to reduced cooling and heating requirements	★★★★☆
Net Zero Emissions Impact — Score based on EUI calculation	★★★☆☆

Technology Appraisal

#3 Window-to-wall Ratio

Architectural

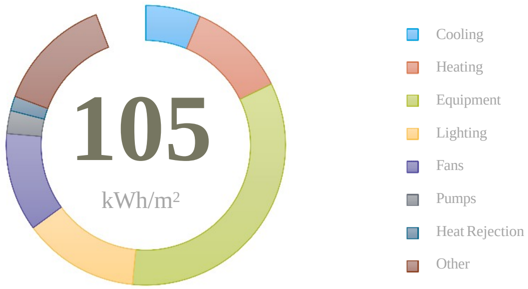
Feasibility

Window-to-wall ratio (WWR) is a measure of how much glazing there is in a building's façade design. Generally, the higher the proportion of glazing, the higher the energy demand of the building and the greater the risk of occupant discomfort near the perimeter. Conversely, high WWR buildings maximise the external view for occupants within the building.

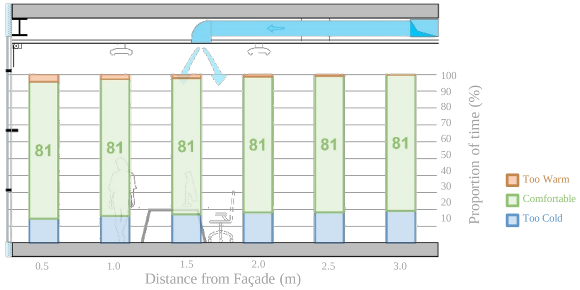
Despite energy codes becoming more stringent, the last few decades have seen fully glazed facades become the norm, particularly in new build commercial real estate. The consequential increase in building energy demand has been somewhat moderated by the use of improving glass technologies, but the challenges in reaching net zero energy and net zero carbon buildings make WWR a key consideration in the design of high performing buildings.

For the purposes of this assessment, the proposed floor- to-ceiling glazing of 435 Bourke St has been reduced through the introduction of a 300mm sill and 300 downstand, which maintains external views for occupants.sdaf;kjjflkHFLkdjfhLKjdflkJdhfLKJHkjh

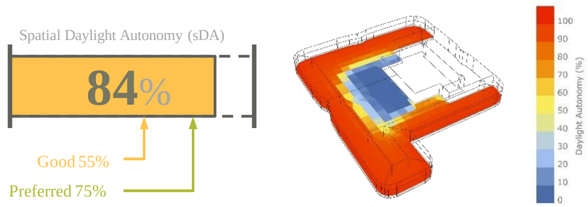
Energy Use Intensity



Thermal Comfort



Daylight Performance



Perceived Innovation Limited innovation impact as widely used approach	★☆☆☆☆
Market Tested Standard practice in Australian market	★★★★★
Capital Cost Potential cost savings through reduced glass	★★★★★
Energy Cost Score based on EUI calculation	★★★★☆
Maintenance Costs Significant annual outlay, but equipment likely to last longer than baseline system	★★★★☆
Ease of Operations No impact on operations	★★★★★
Flexibility/Adaptability No impact / minimal impact	★★★★★
Long Term Rental Return Current perception is maximum glazing is desired by tenants	★★☆☆☆
Daylight & Views Reduced glazing will reduce daylight availability somewhat, but can be designed appropriately	★★☆☆☆
Thermal Comfort Reduced glazing proportions likely to reduce risk of discomfort near façade	★★★★☆
Indoor Air Quality No impact / minimal impact	★☆☆☆☆
Impact on Certification Impacts associated with energy reduction due to reduced cooling and heating requirements	★★★★★
Net Zero Emissions Impact Score based on EUI calculation	★★★★☆

Technology Appraisal

#4 Fixed Shading

Architectural

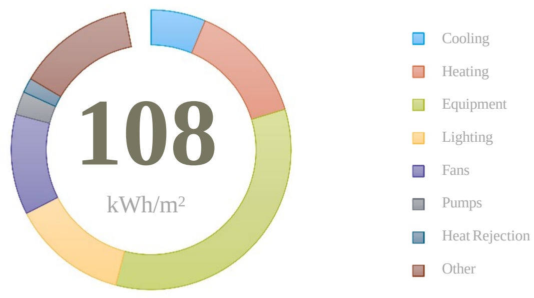
Feasibility ✕

Fixed external shading is one of the most common methods of reducing solar gain and resulting cooling energy. The simplest approach, driven by the sun's movements, is to attach horizontal shading on the north (in the southern hemisphere) and vertical shading on the east and west, which has been simulated for the purposes of this assessment.

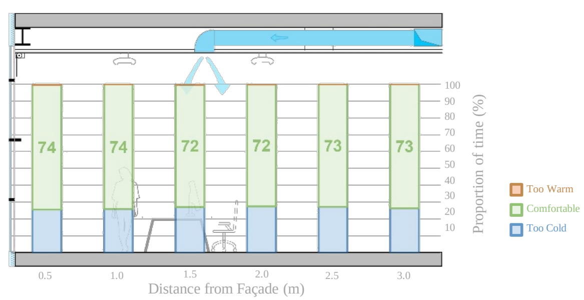
For a given building within its specific context, the size, angle and shape of these shading devices can be tuned to maximise performance. Some designers incorporate shading as a integral part of the building's aesthetic, which is evident is buildings such as ARM's Barak Building, pictured below.

One notable disadvantage of fixed shading is its impact on views and daylight, particularly due to the fact that fixed shades cannot be retracted when solar gain is not an issue.

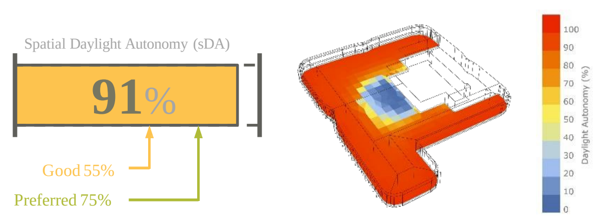
Energy Use Intensity



Thermal Comfort



Daylight Performance



Perceived Innovation Limited innovation impact as widely used approach	★☆☆☆☆
Market Tested Standard practice in Australian market	★★★★★
Capital Cost Additional façade package costs	★★★☆☆
Energy Cost Score based on EUI calculation	★★☆☆☆
Maintenance Costs Significant annual outlay, but equipment likely to last longer than baseline system	★★★☆☆
Ease of Operations Easy to maintain, unlikely to cause operational issues	★★★★☆
Flexibility/Adaptability No impact / minimal impact	★★★★★
Long Term Rental Return No impact / minimal impact	★★★☆☆
Daylight & Views Fixed external shading can interrupt views and remain in place even when solar control is not required	★☆☆☆☆
Thermal Comfort External shading controls solar gain before it reaches the glazing, improving near-façade comfort	★★★★☆
Indoor Air Quality No impact / minimal impact	★☆☆☆☆
Impact on Certification Impacts associated with energy reduction due to reduced cooling requirements and reduced glare risk	★★★☆☆
Net Zero Emissions Impact Score based on EUI calculation	★★☆☆☆

Technology Appraisal

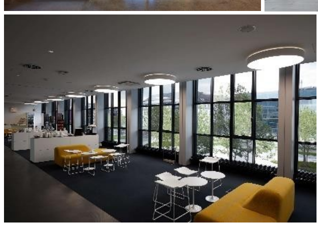
#5 Dynamic Glass

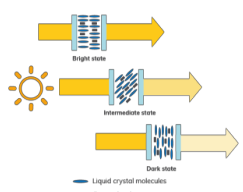
Architectural

Feasibility

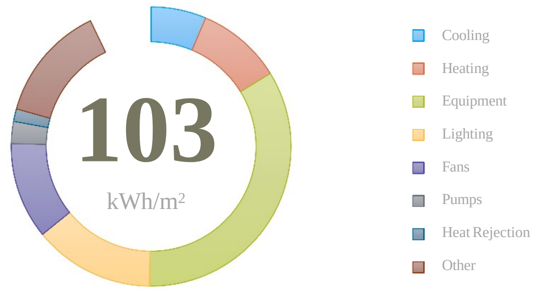
Dynamic glass has been in use for decades, but has seen an increase in popularity in recent years. The technology allows the performance of the glass to vary in response to external conditions, BMS operation, or occupant control. The dynamicism of the technology means the glass can tint to control solar gain or sky brightness when required, but then increase its transparency when control is no longer required. In this way, dynamic glass can provide an optimal balance between energy savings and occupant satisfaction.

There are a number of dynamic glass technologies available in the market, most notably the electrochromic variants (produced by Sage, View and Halio) and the liquid crystal glazing (produced by Merck). The products vary substantially with regards to glass colour, switching speed and capital cost. As such, a project-specific assessment should be conducted when appraising the use of the technology.

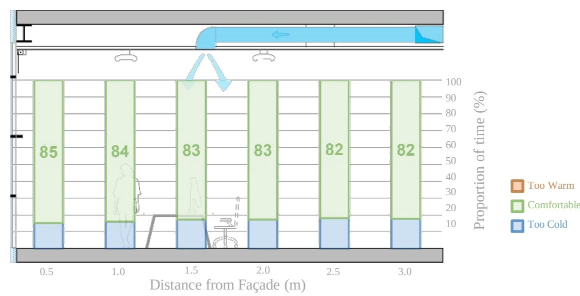




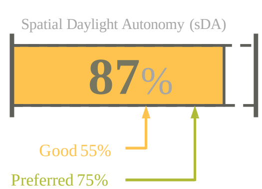
Energy Use Intensity

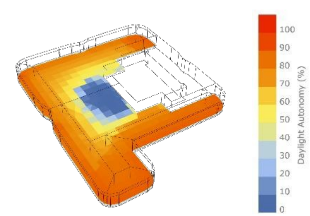


Thermal Comfort



Daylight Performance





Perceived Innovation Technology is not new, but still signifies innovation	★★★★☆
Market Tested Not common in Australia	★☆☆☆☆
Capital Cost Additional cost associated with glass technology	★★☆☆☆
Energy Cost Score based on EUI calculation	★★★★★
Maintenance Costs Significant annual outlay, but equipment likely to last longer than baseline system	★★☆☆☆
Ease of Operations May cause operational issues if system is down	★★☆☆☆
Flexibility/Adaptability Depending on control strategy, zoning may have impacts on flexibility	★★★★☆
Long Term Rental Return Dynamic performance may command higher rent, without sacrificing NLA (as per CCF option)	★★★★☆
Daylight & Views Dynamicism maximises daylight and views while solar control is not needed. Glass is still transparent when shaded.	★★★★★
Thermal Comfort Dynamic glazing provides solar control when it is required, improving near-façade comfort	★★★★☆
Indoor Air Quality No impact / minimal impact	★☆☆☆☆
Impact on Certification Impacts associated with energy reduction due to reduced cooling requirements and reduced glare risk	★★★★☆
Net Zero Emissions Impact Score based on EUI calculation	★★★★★

Technology Appraisal

#5 Dynamic Glass

Aggressively Manage Solar Gain…

- Smart glass
- Utilize Daylight
- Vegetation for Shading and Evapo-Transpiration
- Address Local Heat Island Effects with Plantings

Incorporate exterior solar control

- Stepped building designs
- Overhangs

Technology Appraisal

#6 Closed-Cavity Façade (CCF)

Architectural

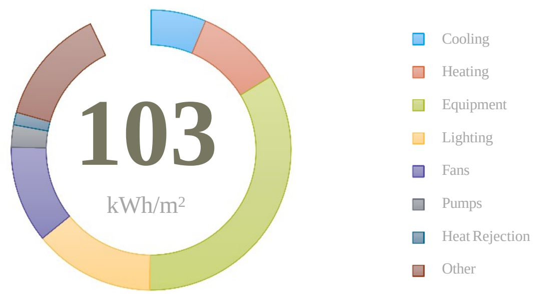
Feasibility ✓

The Closed-Cavity Façade, or CCF, has been popular in Europe for a number of years, but has recently gained traction in the Australian market through the use on projects such as 200 George St and 100 Mount St. The facade system is made up of an exterior single pane and interior double pane, with an interstitial automated shade (typically a venetian blind). The cavity is constantly positively pressurised by a small quantity of supply air, which helps to prevent ingress of dust.

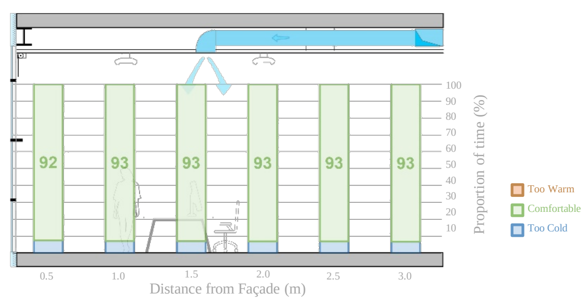
The performance benefits of the CCF are a function of its automated shading system, which can control solar gain when necessary but also retract when suitable to maximise daylight and views. The third pane of glazing also helps to improve the thermal performance of the system, reducing heating demand and increasing near-façade thermal comfort.

The CCF's main disadvantages are capital cost and increased façade depth, which can impact net lettable area.

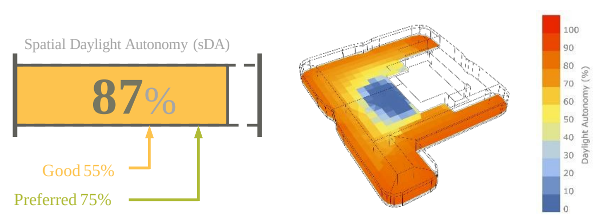
Energy Use Intensity



Thermal Comfort



Daylight Performance



Perceived Innovation ★★★★☆
Relatively new to Australian market, but becoming more mainstream

Market Tested ★★★☆☆
New in Australia but market exists and is growing rapidly

Capital Cost ★★☆☆☆
Additional cost associated with complex façade build-up and control system

Energy Cost ★★★★★
Score based on EUI calculation

Maintenance Costs ★★☆☆☆
Significant annual outlay, but equipment likely to last longer than baseline system

Ease of Operations ★★★☆☆
Well established technology that is designed to be maintained easily

Flexibility/Adaptability ★★★★☆
Depending on control strategy, zoning may have impacts on flexibility

Long Term Rental Return ★★☆☆☆
Depth of façade may impact NLA and resulting rental yield

Daylight & Views ★★★★☆
Dynamicism maximises daylight and views while solar control is not needed.

Thermal Comfort ★★★★☆
Automated blinds provide solar control when it is required, improving near-façade comfort

Indoor Air Quality ★☆☆☆☆
No impact / minimal impact

Impact on Certification ★★★★☆
Impacts associated with energy reduction due to reduced cooling requirements and reduced glare risk

Net Zero Emissions Impact ★★★★★
Score based on EUI calculation

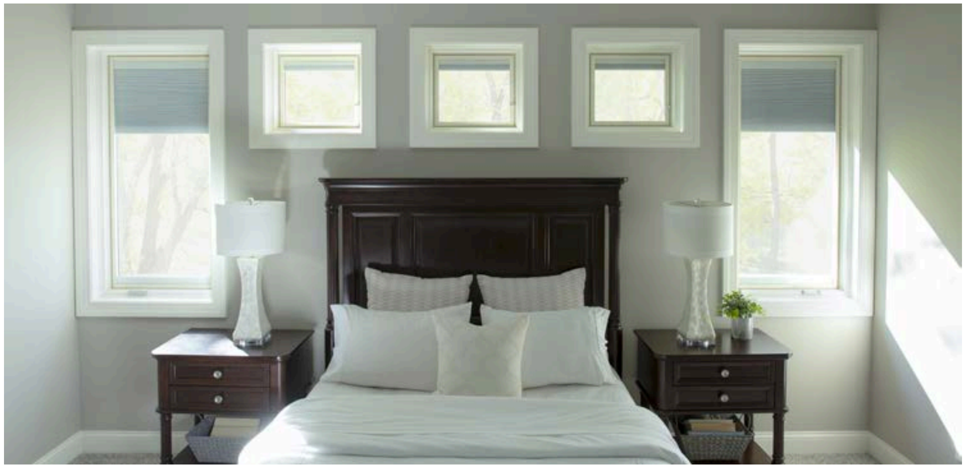
Technology Appraisal

#7 Integrated Shading Glazing Units

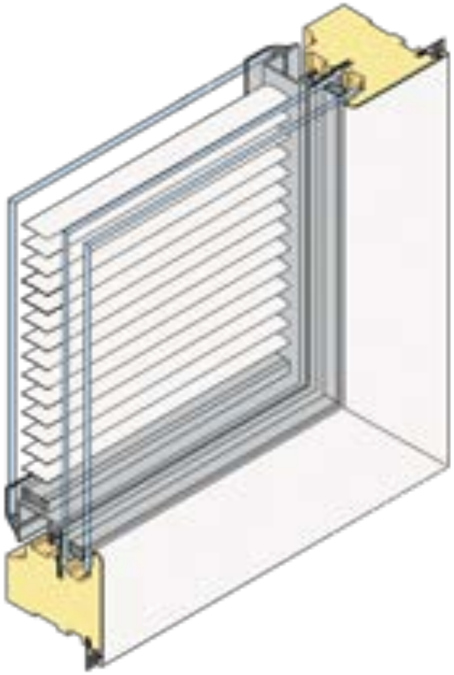
Interior blinds and shades are not enough!

Exterior solar control is critical for energy reduction and comfort

- High performance glazing, including low-emissivity
- Thermal breaks
- Integrated between glass shades and blinds
- → envelope commissioning important



Source – Pella windows.



Technology Appraisal

#15 Rooftop Photovoltaics

Renewables

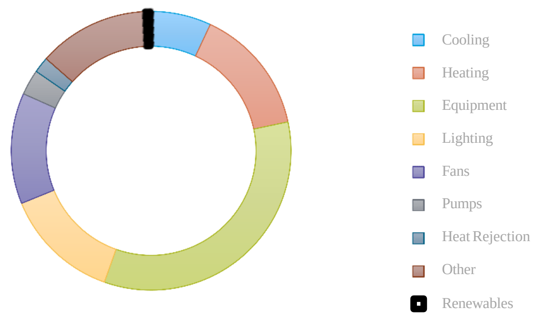
Feasibility ✓

Rooftop photovoltaics are the most common implementation of a renewable energy technology in the building industry. Photovoltaic (PV) panels convert the energy of the sun into useful electrical energy, and therefore are most commonly positioned on rooftops where a building's exposure to sunlight is greatest.

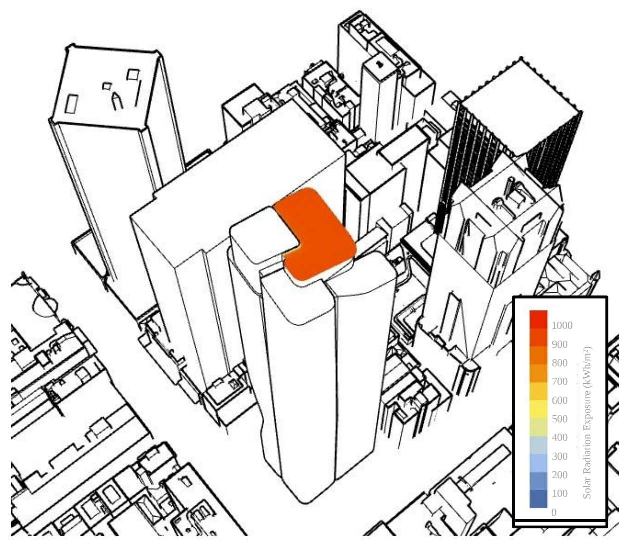
In the last decade the price of PV panels has drastically reduced, making rooftop PV one of the most cost effective methods of generating energy on site and reducing a building's overall energy footprint.

In buildings that have a large roof area in comparison to overall floor space, energy generated by rooftop PV has the potential to offset the entire building's energy demand. In practice, this scenario is typically restricted to buildings of at most four or five storeys. In tall towers such as 435 Bourke St, the proportionally small roof area available for PV means that the energy generated has a modest impact on overall building energy footprint.

Energy Use Intensity



Solar Radiation Yield



Perceived Innovation Limited innovation impact as widely used technology	★☆☆☆☆
Market Tested Standard practice in Australian market	★★★★★
Capital Cost Standard panels have minimal cost impact	★★★★☆
Energy Cost Score based on EUI calculation	★☆☆☆☆
Maintenance Costs Significant annual outlay, but equipment likely to last longer than baseline system	★★★☆☆
Ease of Operations Easy to maintain, unlikely to cause operational issues and building can continue to operate if system is down	★★★★☆
Flexibility/Adaptability No impact / minimal impact	★★★★★
Long Term Rental Return No impact / minimal impact	★★★☆☆
Daylight & Views No impact / minimal impact	★★★☆☆
Thermal Comfort No impact / minimal impact	★★☆☆☆
Indoor Air Quality No impact / minimal impact	★☆☆☆☆
Impact on Certification Assists with peak load reduction and incorporation of renewable energy. Impact is proportional to generation.	★★☆☆☆
Net Zero Emissions Impact Score based on EUI calculation	★☆☆☆☆

Technology Appraisal

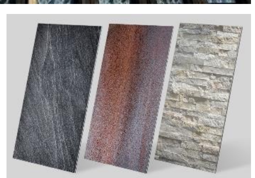
#7 Building Integrated Photovoltaics (static)

Renewables

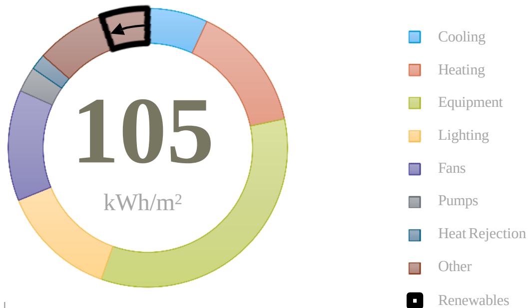
Feasibility ✓

For buildings that have a proportionally small roof area, such as tall towers, generating electricity using the building's façade can significantly reduce overall energy consumption. Exposed vertical surfaces will generate less solar energy than their horizontal counterparts, but for buildings with large amounts of exposed façade, the energy generated can be significant.

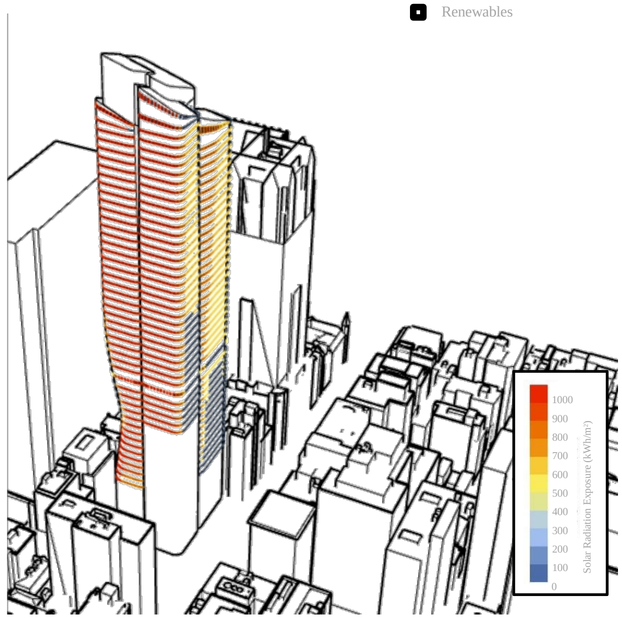
Traditionally, building integrated photovoltaic (BIPV) panels have been implemented using the typical photocell aesthetic, which has led many designers to shy away from the technology unless it is applied out of sight (on rooftops). Recent advances in PV design, including those highlighted by the EU *Construct PV* initiative, have shown that energy can be generated from facades while contributing to the architectural aesthetic. BIPV panels can be screen printed with custom patterns, or be produced to imitate materials such as stone or Corten steel.



Energy Use Intensity



Solar Radiation Yield



Perceived Innovation Still uncommon to see this technology used extensively	★★★★☆
Market Tested Gaining traction internationally	★★☆☆☆
Capital Cost Designer panels command a higher cost than standard PV modules	★★★☆☆
Energy Cost Score based on EUI calculation	★★★★☆
Maintenance Costs Significant annual outlay, but equipment likely to last longer than baseline system	★★★☆☆
Ease of Operations Unlikely to cause operational issues and building can continue to operate if system is down	★★★☆☆
Flexibility/Adaptability No impact / minimal impact	★★★★★
Long Term Rental Return No impact / minimal impact	★★★☆☆
Daylight & Views No impact / minimal impact	★★★☆☆
Thermal Comfort No impact / minimal impact	★★☆☆☆
Indoor Air Quality No impact / minimal impact	★☆☆☆☆
Impact on Certification Assists with peak load reduction and incorporation of renewable energy. Impact is proportional to generation.	★★★☆☆
Net Zero Emissions Impact Score based on EUI calculation	★★★★☆

Technology Appraisal

#8 Building Integrated Photovoltaics (tracking)

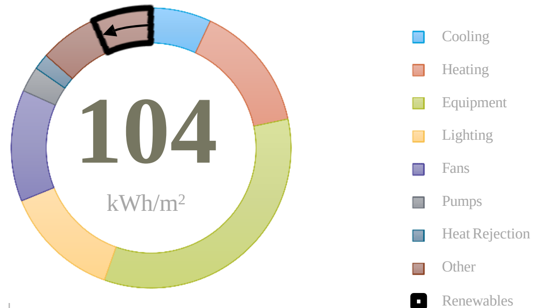
Renewables

Feasibility ✕

In order to boost the energy generated by building integrated photovoltaics, it is possible to implement them in a more dynamic way. Wellsun is a start up firm in the Netherlands who have developed a façade solution that utilises high-efficiency PV modules that track the movement of the sun. Boasting a panel efficiency of 30% (significantly higher than standard static PV systems), the technology is mounted within a double-skin façade. The number of cells can be customised to allow designers to balance energy generation, daylight and external views.

Given the system's impact on façade transparency, it is unlikely that the technology would be applied to the entirety of a building's envelope. For the purposes of this assessment, the system has been applied to the exposed sections of the north and west facades of 435 Bourke Street.

Energy Use Intensity



Solar Radiation Yield

Perceived Innovation Highly visible, new renewable technology	★★★★★
Market Tested Technology is very new to market	★☆☆☆☆
Capital Cost Significant cost as technology is new and requires double skin façade	★☆☆☆☆
Energy Cost Score based on EUI calculation	★★★★★
Maintenance Costs Significant annual outlay, but equipment likely to last longer than baseline system	★☆☆☆☆
Ease of Operations Technology is new and relies on a control system, but building can continue to operate if system is down	★★☆☆☆
Flexibility/Adaptability Potential impact on internal flexibility due to specific façade appearance	★★★★☆
Long Term Rental Return No impact / minimal impact	★★☆☆☆
Daylight & Views Despite being transparent, tracking cells will impact external views	★★☆☆☆
Thermal Comfort No impact / minimal impact	★★☆☆☆
Indoor Air Quality No impact / minimal impact	★☆☆☆☆
Impact on Certification Assists with peak load reduction and incorporation of renewable energy. Impact is proportional to generation.	★★★☆☆
Net Zero Emissions Impact Score based on EUI calculation	★★★★★

Technology Appraisal

#9 Transparent Photovoltaics

Renewables

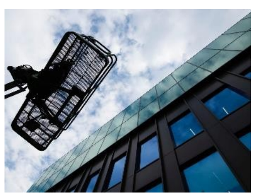
Feasibility ✕

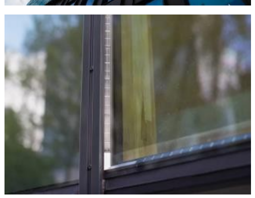
Another relatively recent technology, transparent photovoltaics provide an opportunity to generate electrical energy from a typical commercial building's predominant envelope material - glass. There are a number of transparent PV products and technologies on the market, and most work by redirecting solar energy that strikes the glass towards photocells located at the perimeter of the window.

ClearVue are an Australian firm developing transparent PV technology in association with researchers at Edith Cowan University. It is estimated that $4m^2$ of ClearVue window can generated as much energy as $1m^2$ of "standard" PV.

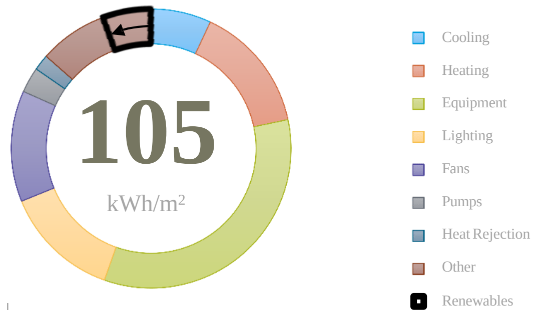
It should be noted that generally, the higher the efficiency of a transparent PV module, the lower the visible light transmittance of the glass.

For this assessment, it has been assumed that the transparent PV technology has been applied on all highly exposed windows on the east, north and west facades.

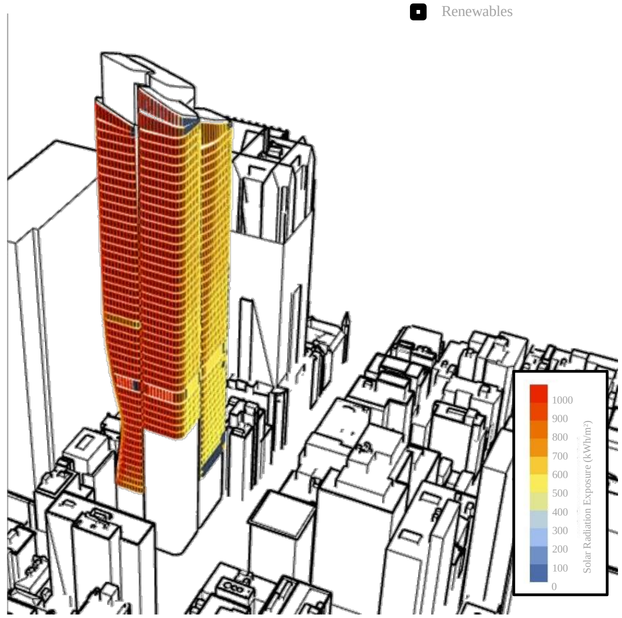




Energy Use Intensity



Solar Radiation Yield



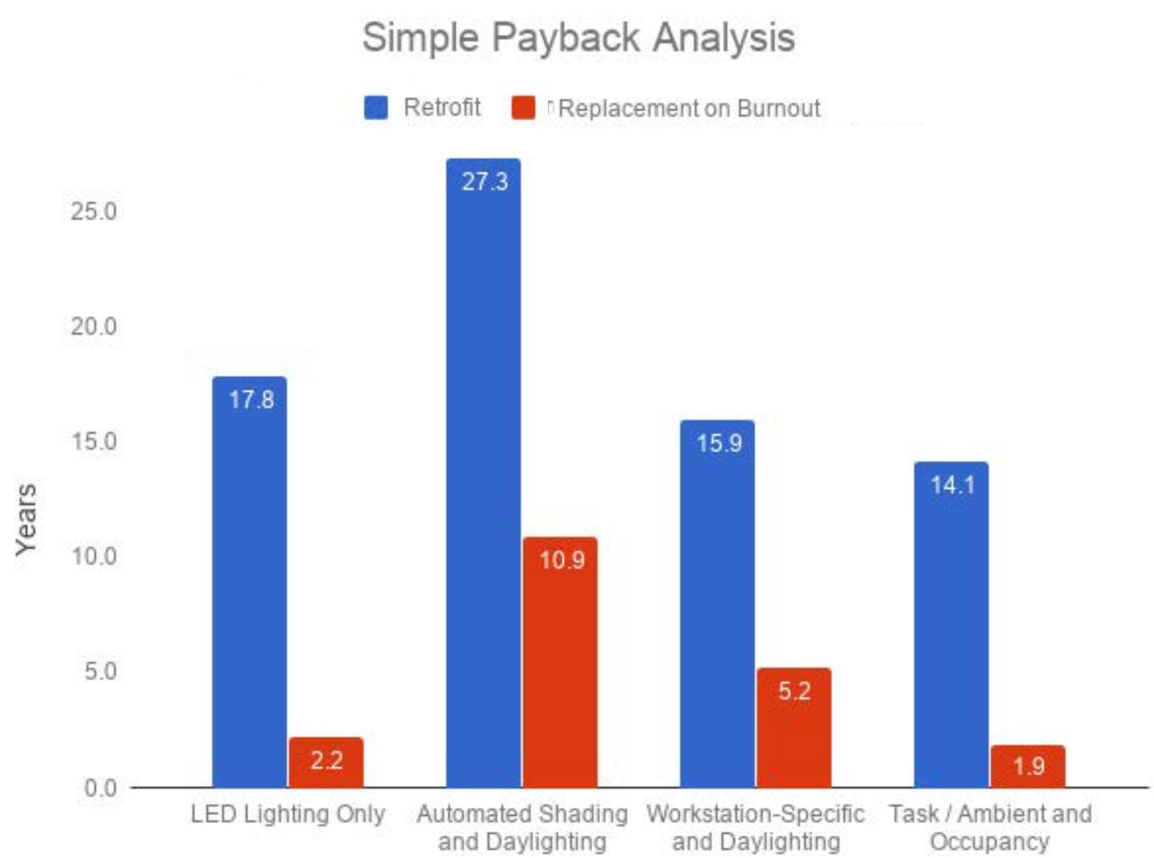
Perceived Innovation New innovative product with development within Australia (Perth)	★★★★★
Market Tested Technology is very new to market	★☆☆☆☆
Capital Cost Additional expense related to glass product	★★☆☆☆
Energy Cost Score based on EUI calculation	★★★★☆
Maintenance Costs Significant annual outlay, but equipment likely to last longer than baseline system	★★★☆☆
Ease of Operations Technology is new, but building can continue to operate if system is down	★★☆☆☆
Flexibility/Adaptability No impact / minimal impact	★★★★★
Long Term Rental Return No impact / minimal impact	★★★☆☆
Daylight & Views Daylight performance is inversely proportional to energy yield	★★☆☆☆
Thermal Comfort No impact / minimal impact	★★☆☆☆
Indoor Air Quality No impact / minimal impact	★☆☆☆☆
Impact on Certification Assists with peak load reduction and incorporation of renewable energy. Impact is proportional to generation.	★★★☆☆
Net Zero Emissions Impact Score based on EUI calculation	★★★★☆

Lighting

Lightings Systems Save More Than LED Fixture Upgrades

Two systems outperform the component based approach as a retrofit. One system pays back for new construction or replace on burnout quicker than the LED retrofit.

"Energy Cost Savings of Systems-Based Building Retrofits: A Study of Three Integrated Lighting Systems in Comparison with Component Based Retrofits" (Regnier, 2018)



Lighting EUI (kWh/sf/yr) (Baseline Fluorescent 4.02 EUI)	1.48	0.61	0.27	0.75
Lighting Energy Savings relative to Baseline	63.1%	84.8%	93.3%	81.3%
Lighting Energy Savings relative to Component-based Retrofit	-	58.8%	81.9%	49.3%

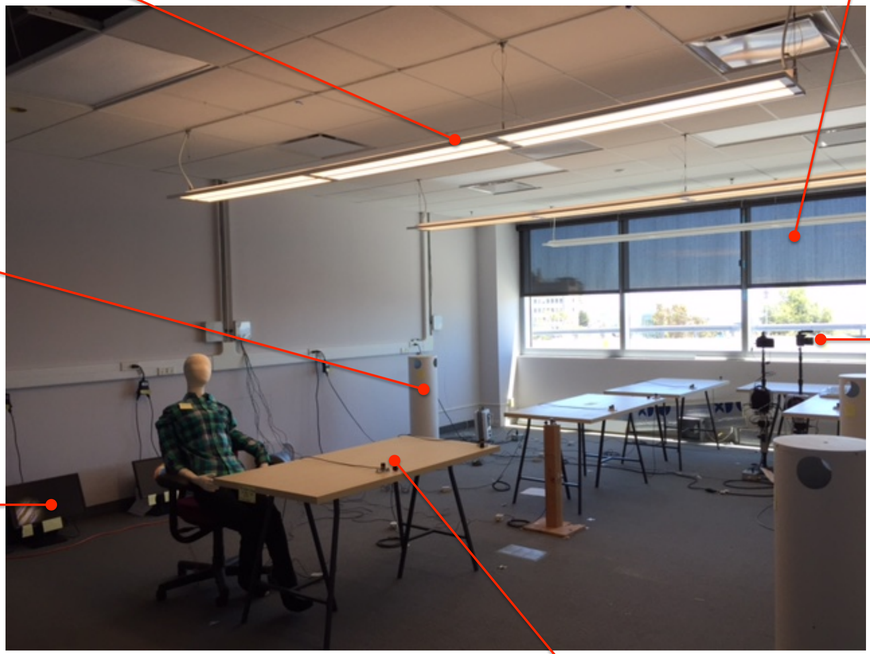
Technology Appraisal

#10 Automated Shading with Daylight Dimming

ComEd
An Exelon Company

Market:
Med-large office
K-12 Educational

ComEd
519–633 GWh savings potential, simple payback for shading and lighting controls only (no light upgrade) >20 years; simple payback w/ lighting upgrade 10.9 years



Source: FLEXLAB, LBNL Berkeley CA USA

Annual Energy Savings Potential:
20%+ Lighting Savings
4-10% Whole Bldg Savings

Technology Appraisal

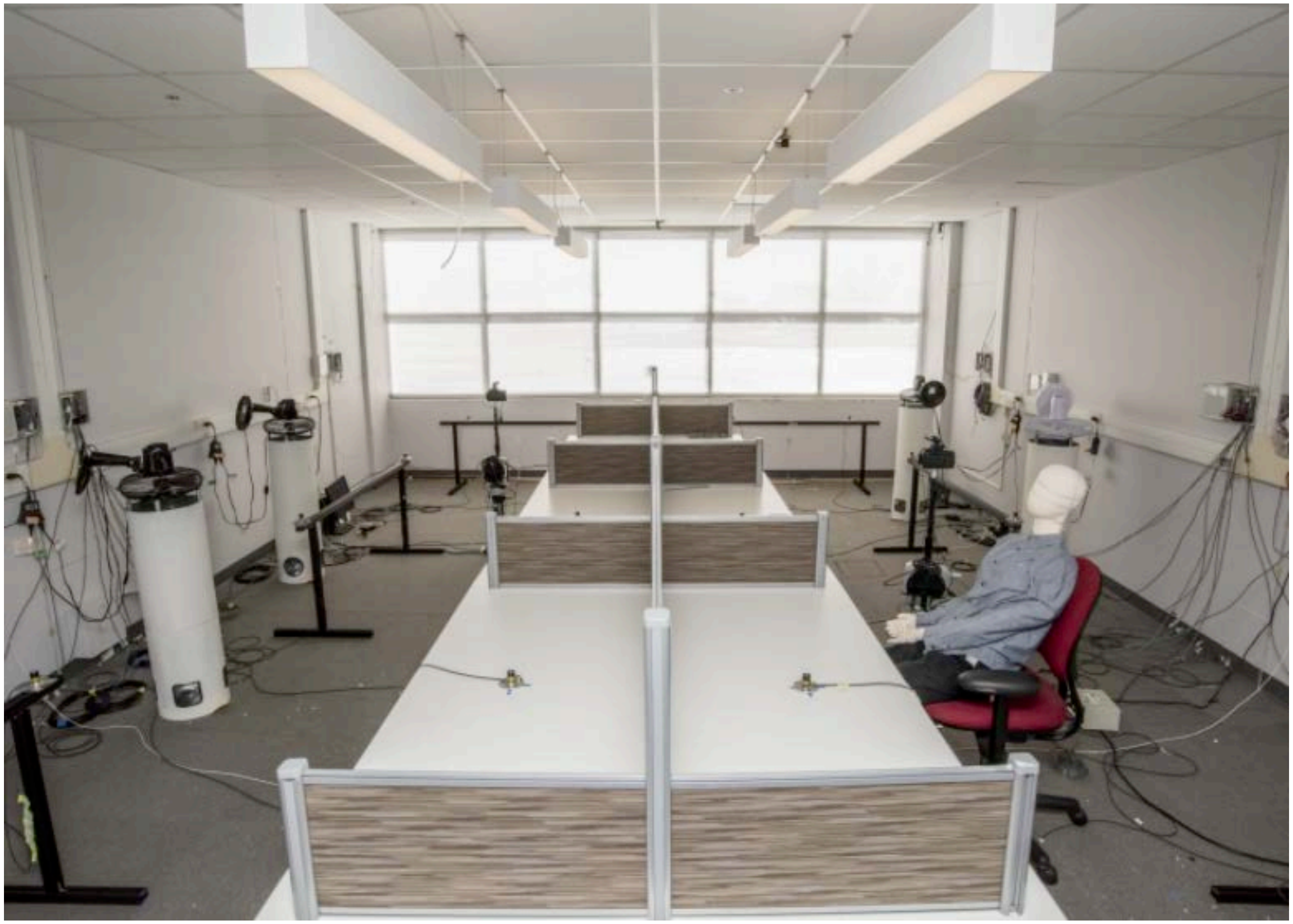
#11 Workstation Specific Lighting with Daylight Dimming

Xcel Energy℠

Market:
Med-large office

Colorado 120–672 GWh savings potential, 8 to 12 years simple payback* at $0.12/kWh

Annual Energy Savings Potential:
90%+ Lighting Savings
5-11% Whole Building Savings (applied S, SW, SE only)



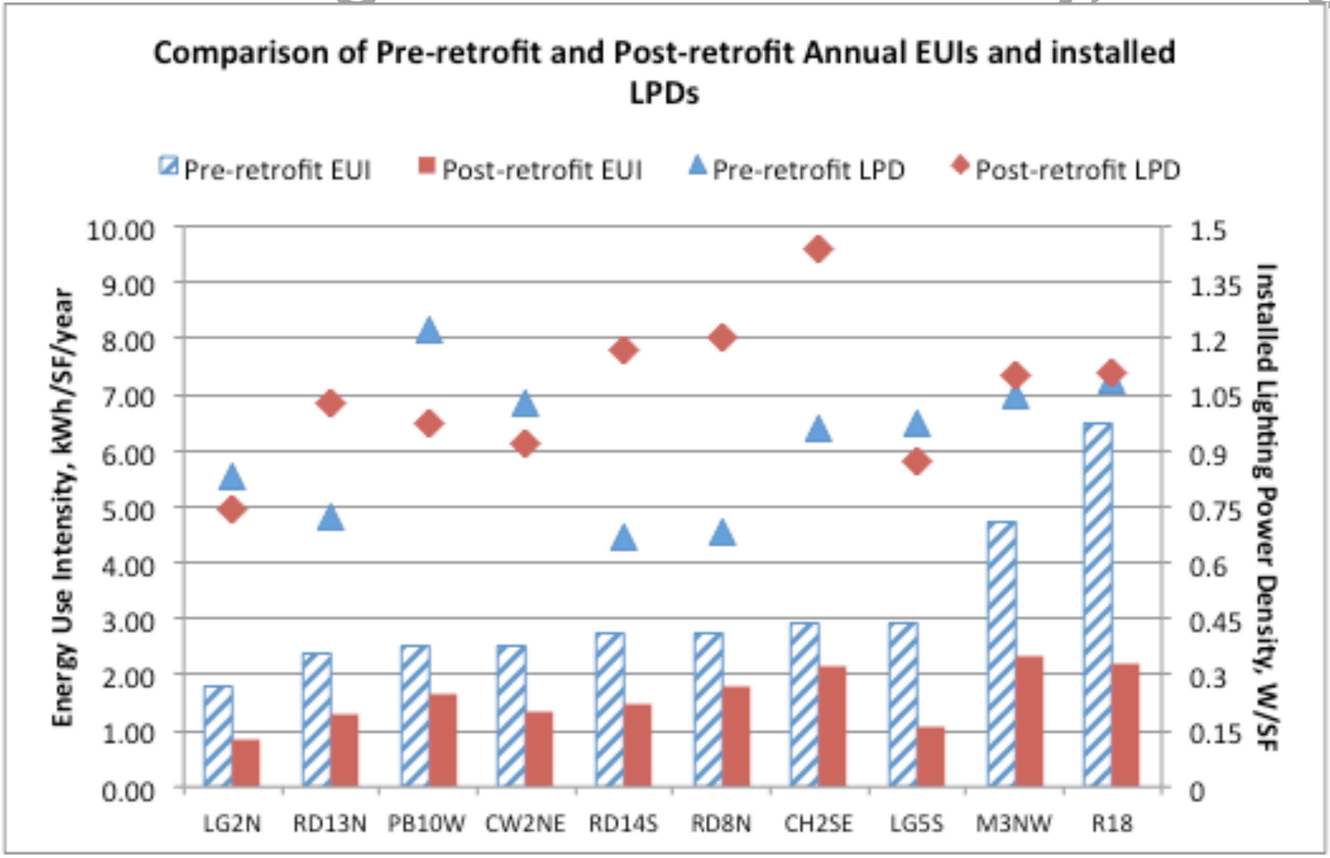
Source: FLEXLAB, LBNL Berkeley CA USA

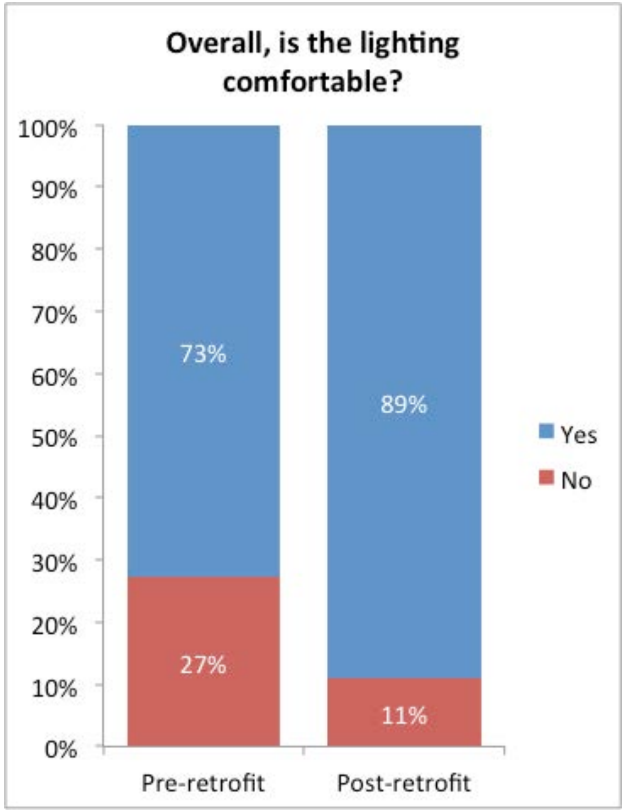
FLEXLAB Setup, Workstation Specific Lighting, 100sf/person

Configurations studied: Light output levels of 500 & 300 lux, Workstation layouts for 100 and 150sf/person occupancy

Technology Appraisal

#11 Workstation Specific Lighting with Daylight Dimming - GSA Case Study, 7 bldgs. CA & NV



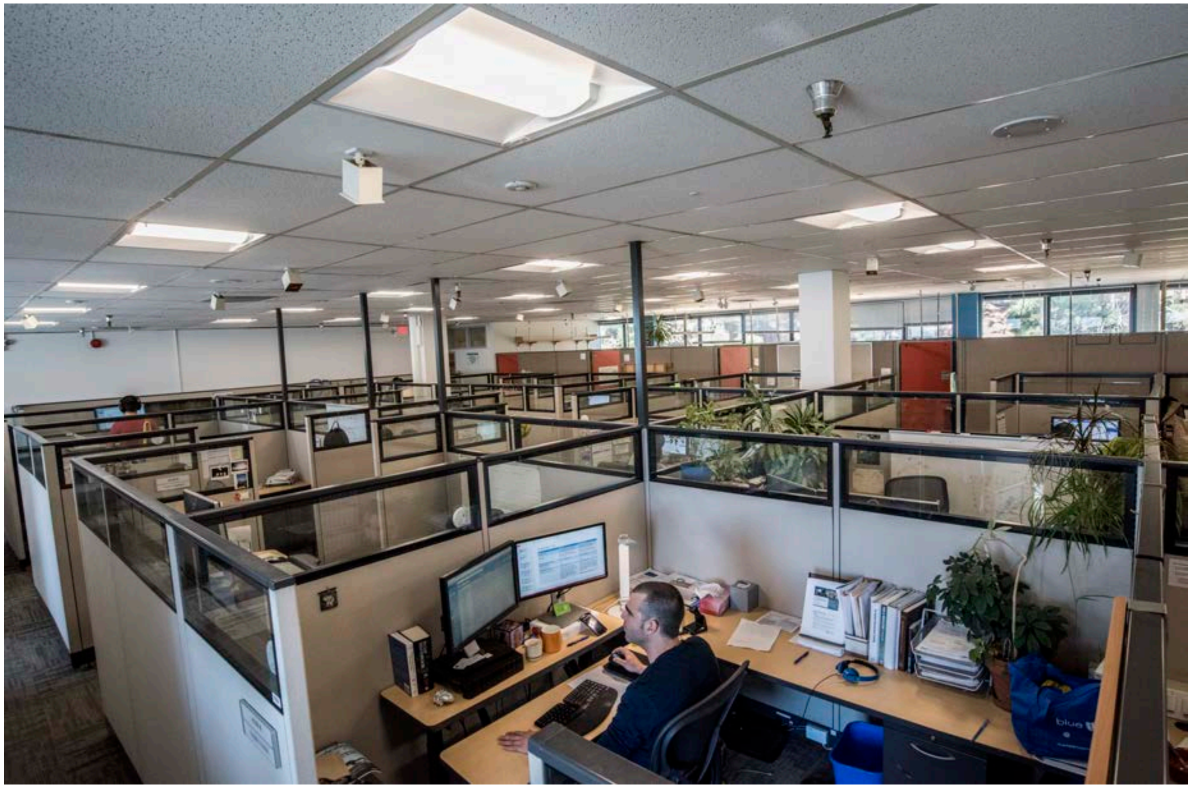


- Achieved energy savings ranging from 26-66%
- Provided comparable or greater light levels to pre-retrofit conditions
- Typically improved occupants' satisfaction with lighting environment
- Adoption throughout GSA is achievable

Technology Appraisal

#12 Task/Ambient Lighting with Plug Load Occupancy Controls

Integrated task/ambient lighting with plug load occupancy-based controls



Market:
Small-large office

NCPA/SCPPA 319/372 GWh savings potential, 6-9 years simple payback at $0.16/kWh

Annual Energy Savings Potential:
30%+ Lighting Savings
11-23% Whole Building Savings

Technology Appraisal

#13 Lighting Integration with ACMV

Use of granular occupancy data provided by lighting systems to enhance ACMV operations

Enables advanced controls interactions

- Zone level ACMV setpoint setback, combined with occupancy sensing
- Zone level ACMV demand controlled ventilation, combined with occupancy sensing

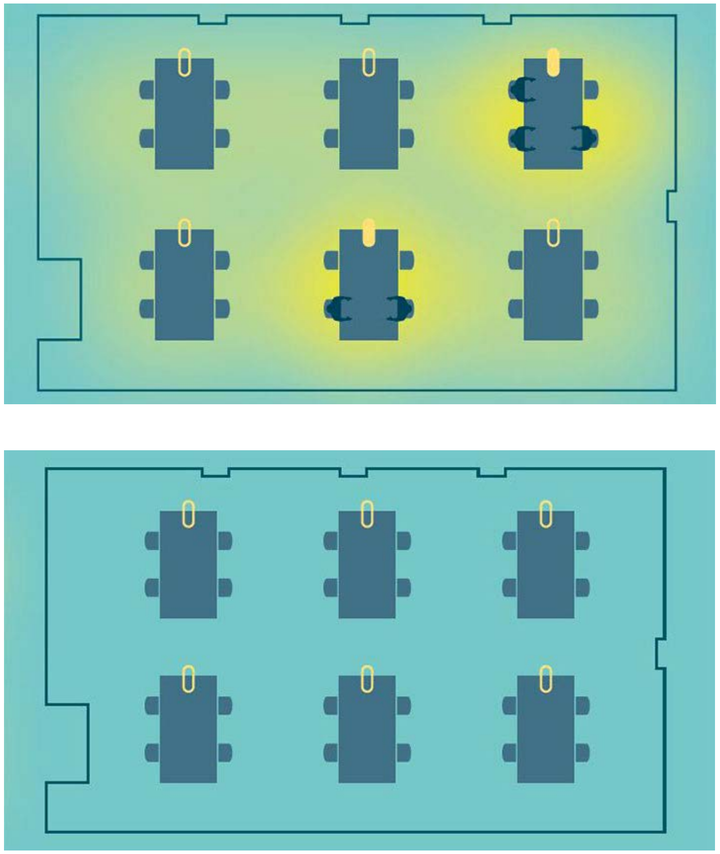


Figure – Granular occupancy sensing and lighting control (Source Philips SpaceWise)

Technology Appraisal

#14 Organic Response Lighting

Load Reduction

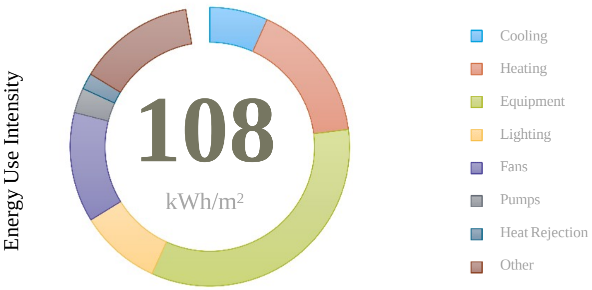
Feasibility ✓

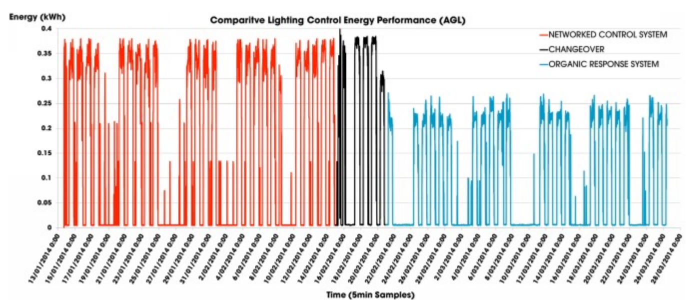
Organic response technology was developed and manufactured in Australia by Organic Response. It uses distributed intelligence, rather than centralised control to provide peer-to-peer wireless communications allowing standalone fittings to work together as a system. Sensor nodes, either discreet or integrated into luminaires, comprise motion sensors, ambient light sensors, a microprocessor and infrared transmitters / receivers to communicate with their immediate neighbours.

Upon occupant detection, the activated luminaire operates at full output and communicates with surrounding luminaires in a cascading manner, to provide zones of descending brightness in the surrounding area to balance visual comfort with energy efficiency. As the occupant moves through the space, luminaires in the proximity respond by adjusting their output while luminaires where no occupancy is detected return to partial dimming. Dimming levels, dwell times and many other programming options are available.

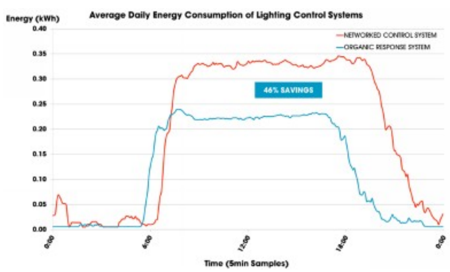
The light sensor allows for daylight harvesting and lumen maintenance operations for dimmable luminaires. Daylight harvesting dims luminaires to maintain a predetermined light level when natural light is present. Lumen maintenance allows dimming of the luminaires to a pre- adjusted lighting level to prevent a space being overlit.

The system provides high resolution lighting control, improving energy efficiency possibilities. Being wireless and decentralised, it allows for easier modification in the event of spatial or furniture changes. The control platform can be used to monitor system utilisation, performance and history plus certain control functions.





PROJECT DETAILS	
INDUSTRY	Commercial Office
OFFICE TYPE	Activity-based working
LUMINAIRES	75 x 2x28W T5 Luminaire
EXISTING NETWORKED CONTROL SYSTEM	Interior Occupancy Switching Perimeter Daylight Harvesting
ORGANIC RESPONSE CONTROL SYSTEM	Distributed Intelligence: - per luminaire control of light level & dwell time - per luminaire response to daylight and occupancy
ENERGY SAVINGS	~46%



Above: Data from case study of Commercial Office Floor in Melbourne, Australia

Perceived Innovation — ★★★★★
Recent innovation in lighting controls

Market Tested — ★★☆☆☆
New in Australia with limited supplier options, but strong support from industry

Capital Cost — ★★★☆☆
Cost can be similar to centralised DALI dimming equipment and commissioning

Energy Cost — ★★☆☆☆
Score based on EUI calculation

Maintenance Costs — ★★★☆☆
Significant annual outlay, but equipment likely to last longer than baseline system

Ease of Operations — ★★★☆☆
Manual and auto operation similar to centralised controls. Tenant & FM education will resolve initial unfamiliarity

Flexibility/Adaptability — ★★★★★
No impact / minimal impact

Long Term Rental Return — ★★★★★
Innovative lighting technology may be more desirable / offset tenant energy costs

Daylight & Views — ★★★☆☆
No impact / minimal impact

Thermal Comfort — ★★☆☆☆
No impact / minimal impact

Indoor Air Quality — ★☆☆☆☆
No impact / minimal impact

Impact on Certification — ★★★☆☆
Proportional energy savings will be small. Ease of system monitoring & reporting may assist in Green Star submission.

Net Zero Emissions Impact — ★★☆☆☆
Score based on EUI calculation

BREAK

Plug Loads

Technology Appraisal

#15 Smart Plug Controls

Load Reduction

Feasibility

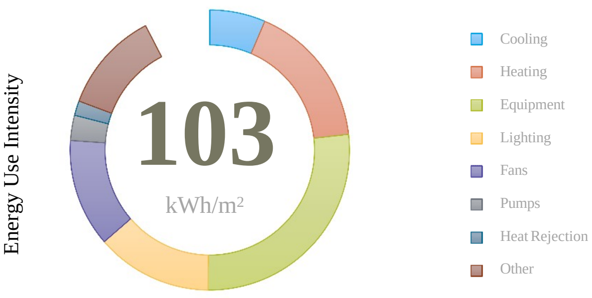
Historically, plug loads have not been targeted as an energy savings measure in the same way as lights or HVAC. However, there are significant opportunities in understanding and managing these loads. Not only do they save electrical energy directly, but cooling energy is also reduced due to reduced heat generated by equipment.

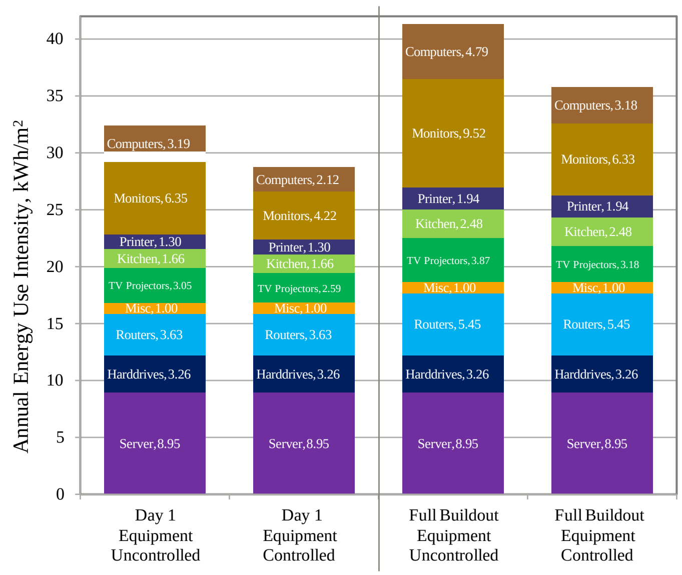
Based on the current estimates, plug loads represent about a third of the total energy consumption of the baseline building. As plug loads can be highly variable depending on the occupancy and the type and use of equipment, the actual building could use more or less than this estimate.

The reduction of plug loads is a multi-faceted process, primarily comprising a detailed assessment of user equipment power requirements, e.g. servers, PCs, monitors, printing, audio visual, kitchen, etc. to ensure that the most energy efficient equipment is selected and that equipment matches the users' requirements rather than exceeding them.

Furthermore, the control of these items via smart plugs can further reduce energy consumption by energising attached equipment only when being used.

Smart plug control technologies include but are not limited to master / slave outlet arrangements whereby slave outlets (monitors, etc.) switch off when the master outlet senses that the PC has been switched off, timed energisation / de-energisation and proximity sensing outlets which can de-energise outlets when no presence is detected.



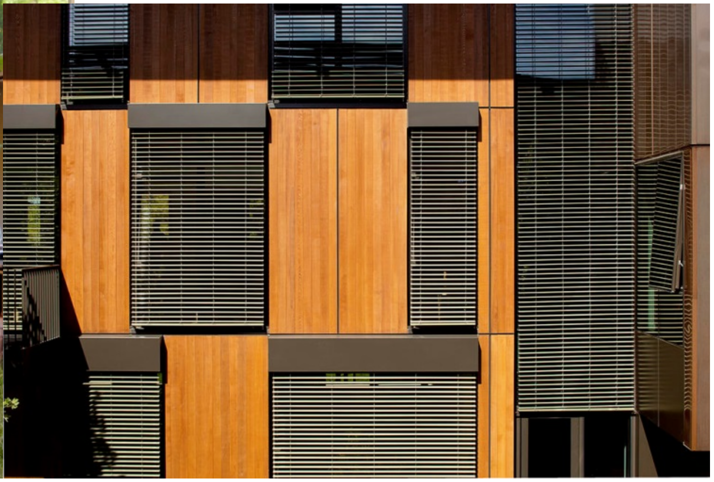


Above: Plug load analysis and measurement for US construction firm headquarters

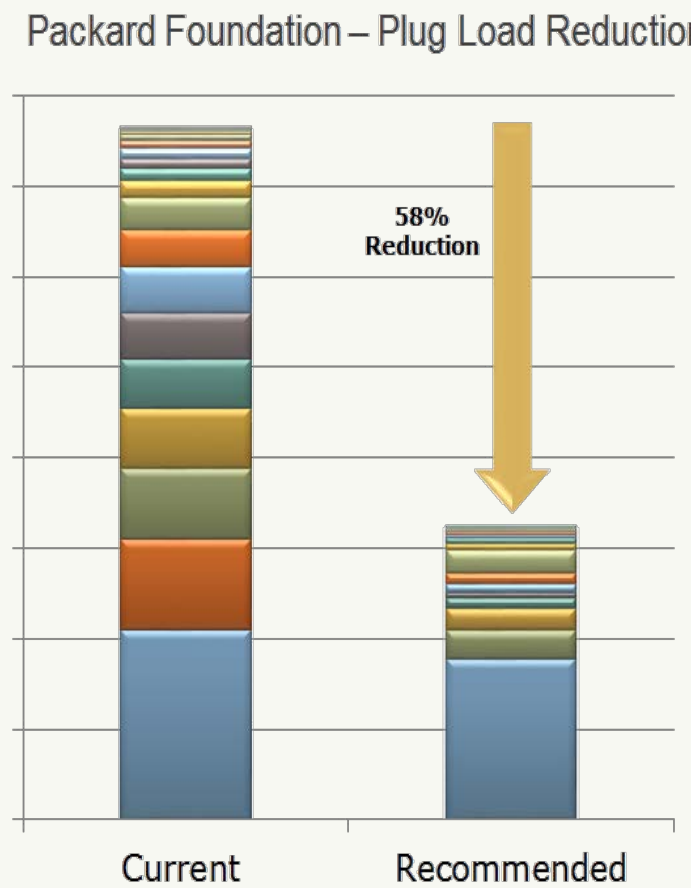
Perceived Innovation Not particularly innovative, but also not implemented often enough	★★☆☆☆
Market Tested Established technologies exist, but are not mainstream yet	★★★☆☆
Capital Cost Minimal cost impact	★★★★☆
Energy Cost Score based on EUI calculation	★★★★★
Maintenance Costs Significant annual outlay, but equipment likely to last longer than baseline system	★★★☆☆
Ease of Operations Unlikely to cause operational issues if system is down - more likely to impact energy consumption	★★★☆☆
Flexibility/Adaptability No impact / minimal impact	★★★★★
Long Term Rental Return Innovative technology may be more desirable / offset tenant energy costs	★★★★★
Daylight & Views No impact / minimal impact	★★★☆☆
Thermal Comfort No impact / minimal impact	★★☆☆☆
Indoor Air Quality No impact / minimal impact	★☆☆☆☆
Impact on Certification Potential to exceed benchmark reductions to earn Green Star points, but savings are dependant on tenant adoption	★★★☆☆
Net Zero Emissions Impact Score based on EUI calculation	★★★★★

Plug Loads Case Studies

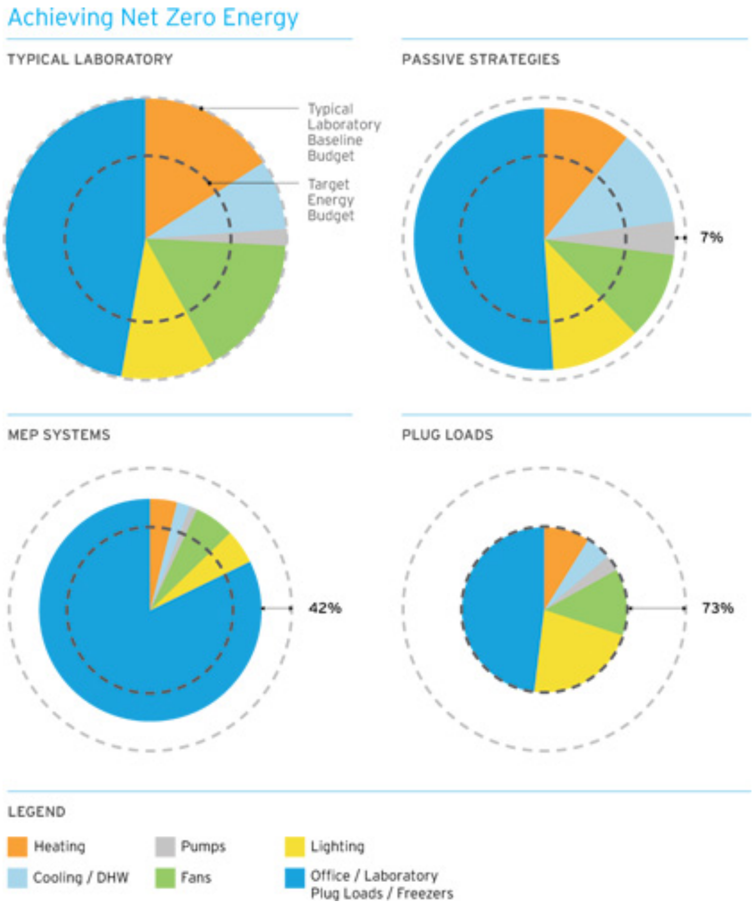
Packard Foundation, California



Packard Foundation – Plug Loads Matter



J Craig Venter Institute – Whole Systems Thinking



Technology Appraisal

#16 Low Energy Lifts

Load Reduction

Feasibility ✓

The most energy efficient elevators now have:

software- and microprocessor-based controls instead of electromechanical relays

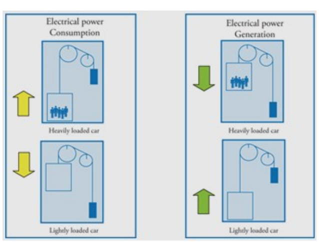
in-cab sensors and software that automatically enter an idle or sleep mode, turning off lights, ventilation, music, and video screens when unoccupied

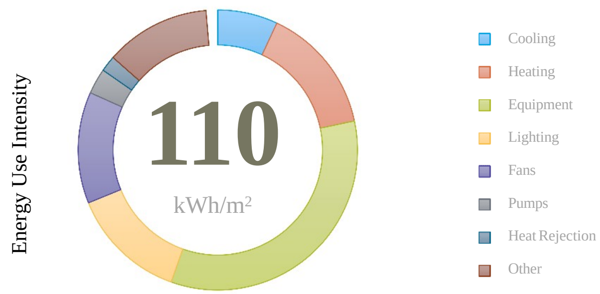
destination dispatch control software that batches elevator stop requests, making fewer stops and minimizing wait time, reducing the number of elevators required

personalized elevator calls used with destination dispatch controls that eliminate the need for in-cab controls.

Lift are programmed to go into hibernate/standby mode when demand is low

Regenerative drive systems that feed energy back to the network





Perceived Innovation Not particularly innovative, but also not implemented often enough	★★☆☆☆
Market Tested Well established technologies internationally, starting to become more prevalent in Australia	★★★☆☆
Capital Cost Moderate cost increase for vertical transportation	★★★☆☆
Energy Cost Score based on EUI calculation	★★☆☆☆
Maintenance Costs Significant annual outlay, but equipment likely to last longer than baseline system	★★★★☆
Ease of Operations Unlikely to cause operational issues and building can continue to operate one lift is down	★★★☆☆
Flexibility/Adaptability No impact / minimal impact	★★★★★
Long Term Rental Return No impact / minimal impact	★★★☆☆
Daylight & Views No impact / minimal impact	★★★☆☆
Thermal Comfort No impact / minimal impact	★★☆☆☆
Indoor Air Quality No impact / minimal impact	★☆☆☆☆
Impact on Certification Limited energy impacts, no impact on other certification requirements	★☆☆☆☆
Net Zero Emissions Impact Score based on EUI calculation	★★☆☆☆

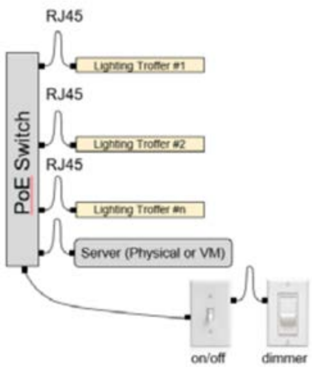
Technology Appraisal

#17 Power Over Ethernet, Case Study MN CEE

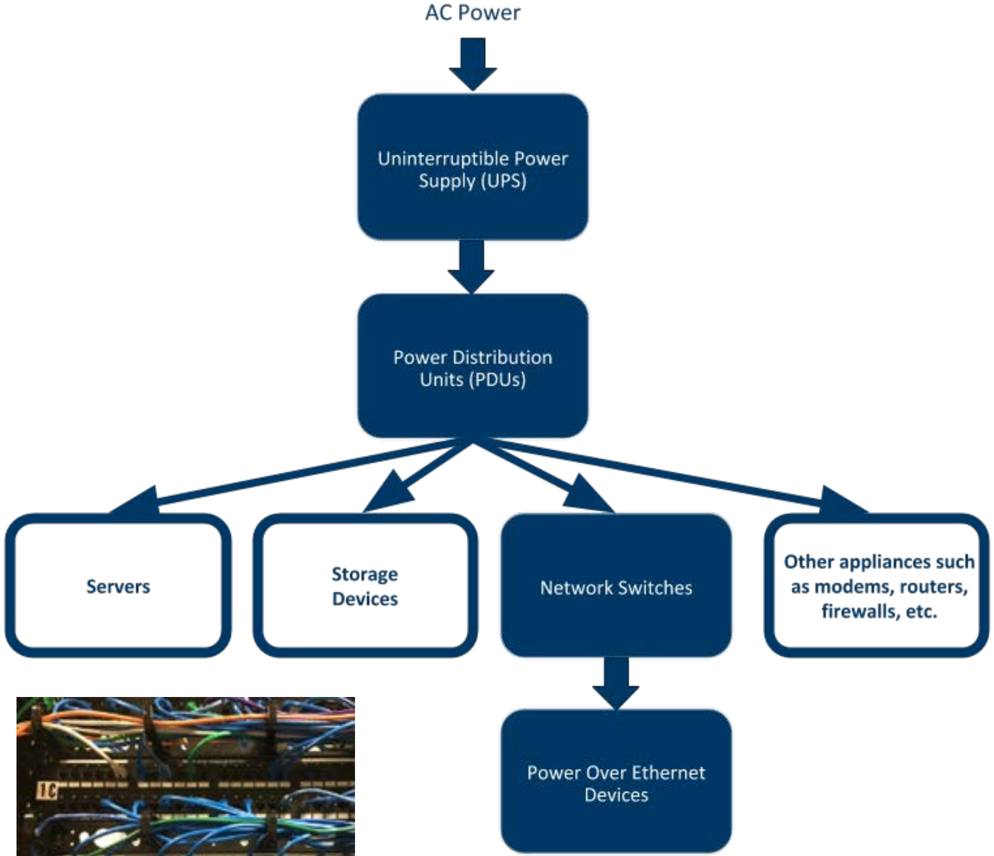
Minneapolis, MN USA

Focus on M&V of performance of use of IT network switches to power and control lighting and plug loads. Conducting energy and cost savings analysis. Demonstrates energy management opportunities where not typically available.

- New IEEE Standard 802.3bt Type 4 will allow up to 100W loads



Figures – Cree 2x2 LED troffer directly connected via RJ45 (Source: MN CEE)



Figures – POE Architecture (Source: MN CEE)

Ref: https://www.mncee.org/resources/projects/power-over-ethernet/

ACMV Strategies

Technology Appraisal

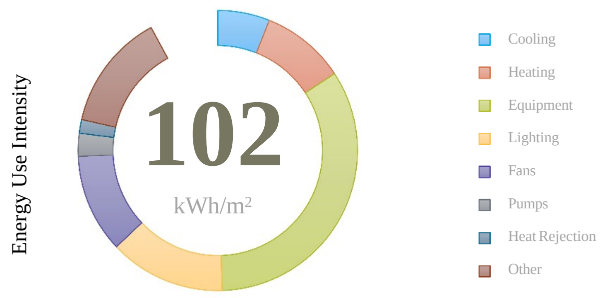
#18 Expanded Setpoints

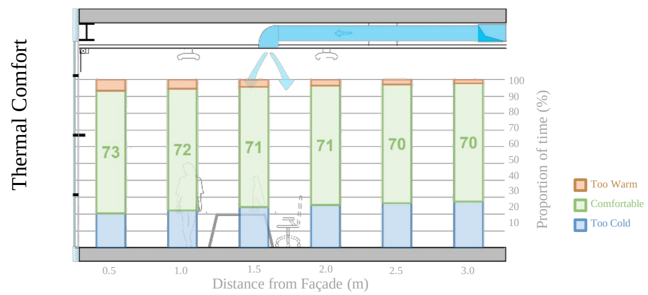
Feasibility

Adjusting internal air temperature setpoints slightly within the occupied areas has a significant impact on energy use within buildings. Setpoints can be adjusted by half to a full degree higher than the typical 24° C design limit in summer and half to a full degree lower than the typical 21° C limit in winter.

Where this strategy has been implemented in operational buildings, it has been noted that there has been no significant increase in occupant comfort complaints. This is believed to be due to the majority of comfort complaints arising from issues associated with air movements (draughts) and surfaces temperatures, eg. as a result of poor building fabric design.

There is also an opportunity for seasonal space temperature setpoints to be implemented within buildings to prevent over cooling in summer and overheating in winter.





Perceived Innovation Not particularly innovative, but also not implemented often enough	★★☆☆☆
Market Tested Easy to implement, but some briefs require design to standard setpoints	★★★☆☆
Capital Cost Minimal cost impact	★★★★☆
Energy Cost Score based on EUI calculation	★★★★★
Maintenance Costs Significant annual outlay, but equipment likely to last longer than baseline system	★★★★☆
Ease of Operations Unlikely to impact operations, minor risk of increased comfort complaints if not commissioned appropriately	★★★★☆
Flexibility/Adaptability No impact / minimal impact	★★★★★
Long Term Rental Return No impact / minimal impact	★★★☆☆
Daylight & Views No impact / minimal impact	★★★☆☆
Thermal Comfort Allows for greater fluctuation in space conditions	★☆☆☆☆
Indoor Air Quality No impact / minimal impact	★☆☆☆☆
Impact on Certification Impacts associated with energy reduction due to reduced cooling and heating requirements	★★★★☆
Net Zero Emissions Impact Score based on EUI calculation	★★★★★

Technology Appraisal

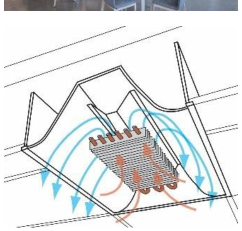
#19 Radiant Systems

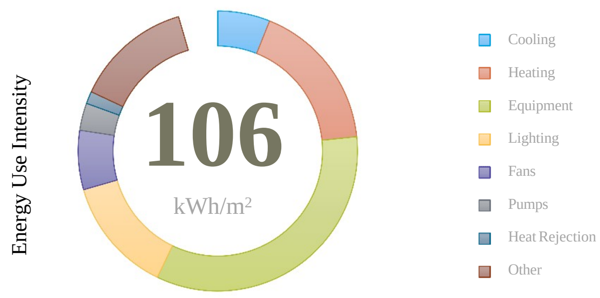
Feasibility ✓

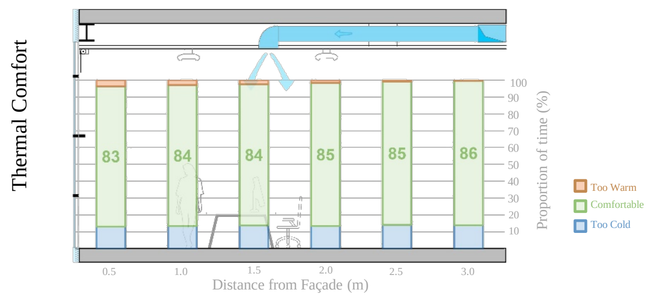
Radiant systems work by utilising passive (draught-free) convection and radiation from the ceiling or floor to the occupied space, with the majority of conditioning being delivered by water, which has a significantly higher heat capacity than air. When using chilled beams there is no fan, filter or condensate drain required. The temperature difference of the coil surface temperature and space drives a convective loop to move heat to the beam. Radiant systems offer improved thermal comfort, can reduce floor to floor heights, reduce riser sizing and reduce fan energy.

Radiant systems include; passive chilled beams, active chilled beams and radiant ceiling panels, as well as radiant slabs.

Passive chilled beams are self-regulating, where as the active beam system integrates with a ventilated air system to magnify the convective process.







Perceived Innovation Can still provide marketing differentiation compared to standard VAV design	★★★☆☆
Market Tested Chilled beams are well establish in Australia, but radiant slabs are less established	★★★☆☆
Capital Cost Additional cost associated with hydronic systems	★★☆☆☆
Energy Cost Score based on EUI calculation	★★★☆☆
Maintenance Costs Significant annual outlay, but equipment likely to last longer than baseline system	★★★☆☆
Ease of Operations Once commissioned and balanced system operation is straight forward	★★★☆☆
Flexibility/Adaptability If delivered through radiant slab, zoning of control may be less flexible	★★☆☆☆
Long Term Rental Return Improved thermal comfort may command higher rental yield	★★★★☆
Daylight & Views No impact / minimal impact	★★★☆☆
Thermal Comfort Radiant systems are consistency rated better for thermal comfort	★★★★★
Indoor Air Quality Hydronic heating/cooling reduces supply air volumes and associated pollutants	★★☆☆☆
Impact on Certification Impacts associated with energy reduction due to reduced cooling and heating requirements	★★★★☆
Net Zero Emissions Impact Score based on EUI calculation	★★★☆☆

Technology Appraisal

#20 Displacement Ventilation

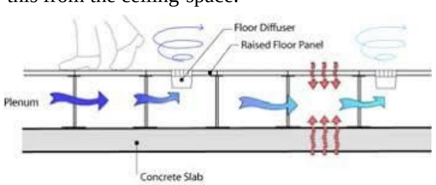
HVAC Strategies

Feasibility

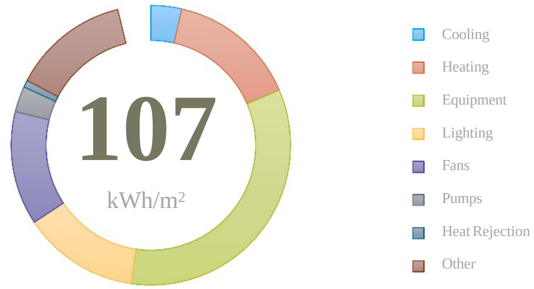
Displacement ventilation (DV) systems deliver air at low level rather than from overhead. The benefit of this is that air can be introduced at a slower speed and more moderate temperature, reducing the risk of cold draughts and reducing energy consumption. The progression of air from low level to the top of a space, where it is returned to air handling equipment, means pollutants are taken away from the occupied space and indoor air quality is improved.

A common implementation of DV is the Underfloor air distribution (UFAD) system, which supplies air through grilles on the floor and returns/exhausts at high level. A raised floor void is required (400 to 450mm) and zones are split into separate plenums with supply air being distributed within ductwork to each of the plenums.

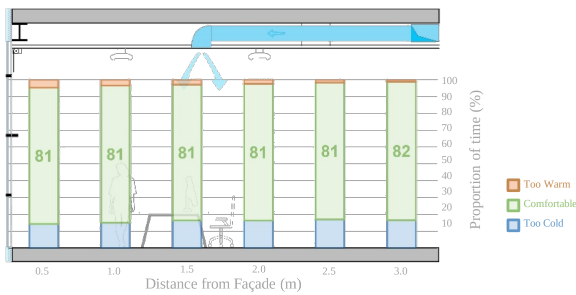
DV systems have a higher economy cycle working range, local adjustable air supply control, minimal space recirculation, quiet operation and provide great flexibility for fitouts. A raised floor can also double up for use with cable distribution, which removes this from the ceiling space.



Energy Use Intensity



Thermal Comfort



Perceived Innovation Can still provide marketing differentiation compared to standard VAV design	★★★☆☆
Market Tested Market is less mature than traditional VAV	★★★☆☆
Capital Cost If raised access floor is included then cost increases comparable to chilled beam system	★★☆☆☆
Energy Cost Score based on EUI calculation	★★★☆☆
Maintenance Costs Significant annual outlay, but equipment likely to last longer than baseline system	★★★★☆
Ease of Operations Once commissioned and balanced system operation is straight forward	★★★☆☆
Flexibility/Adaptability DV system is flexible in rasied access floor plenum system. Floor grilles can be relocated to suit tenancy layouts.	★★★★☆
Long Term Rental Return Improved air quality may command higher rental yield	★★★★☆
Daylight & Views No impact / minimal impact	★★★☆☆
Thermal Comfort Reduced risk of draught complaints	★★★★☆
Indoor Air Quality Air movement through space takes pollutants away from occupants	★★★★★
Impact on Certification Impacts associated with energy reduction due to reduced cooling and heating requirements and improved air quality	★★★★☆
Net Zero Emissions Impact Score based on EUI calculation	★★★☆☆

Technology Appraisal

#21 Natural Ventilation

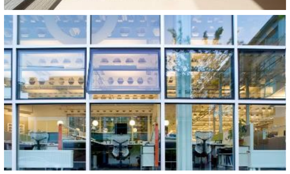
HVAC Strategies

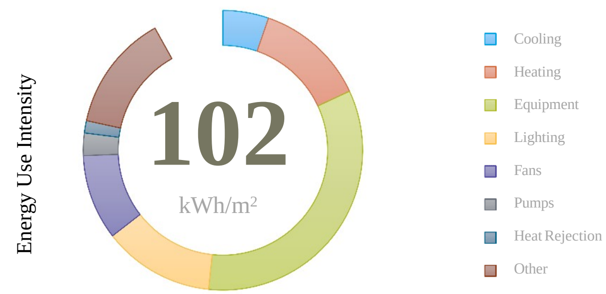
Feasibility

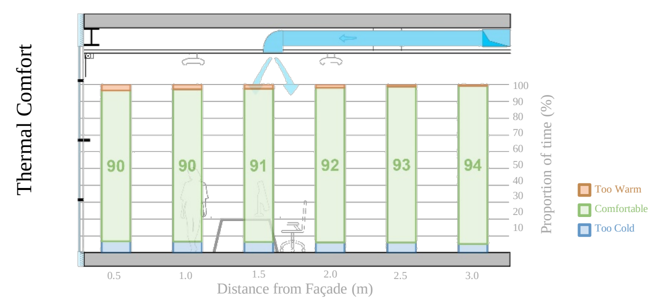
Natural ventilation can be implemented when the outside ambient conditions are within certain temperature and humidity ranges.

This system relies on the air conditioning system being turned off with the cooling and ventilation being provided from outside via operable windows. The system provides energy savings in cooling compressor energy and fan energy.

This system requires operable windows with actuators, a weather monitoring station to confirm ambient temperatures/conditions and that the air conditioning system be turned off through integrated reed switches and related controls.







Perceived Innovation ★★★☆☆
Depending on building typology, it's not common to see outside of the residential sector

Market Tested ★★☆☆☆
Uncommon in Australian market for non-residential buildings

Capital Cost ★★☆☆☆
Additional costs associated with operable façade elements, sensors, BMS interlocks

Energy Cost ★★★★★
Score based on EUI calculation

Maintenance Costs ★★☆☆☆
Significant annual outlay, but equipment likely to last longer than baseline system

Ease of Operations ★★☆☆☆
Likely to require additional maintenance if using integrated control. Can be implemented simply using winter gardens

Flexibility/Adaptability ★☆☆☆☆
Interlocked mixed-mode systems can be less adaptable to updated layouts

Long Term Rental Return ★★★★☆
Improved thermal comfort and occupant control may command higher rental yield

Daylight & Views ★★★☆☆
No impact / minimal impact

Thermal Comfort ★★★★☆
Occupant control improves perception of thermal comfort

Indoor Air Quality ★★★☆☆
Opportunity for higher levels of fresh air, provided openable windows are closed when outdoor air quality is low

Impact on Certification ★★★★☆
Impacts associated with energy reduction due to reduced cooling and heating requirements and localised controls

Net Zero Emissions Impact ★★★★★
Score based on EUI calculation

Case Study – Passive + Active Chilled Beams

Case Study – Passive + Active Chilled Beams

NOAA

Design for Discovery

1 — Wind Pressure

Automated modulating dampers enable intakes to function as windscoops tracking prevailing wind direction.

2 — Gravity

When outside air temperature is greater than 65 degrees, the incoming air is cooled by a cooling coil in the shaft. The colder, denser air leaving the coil creates a downdraft in the supply shaft.

3 — Buoyancy

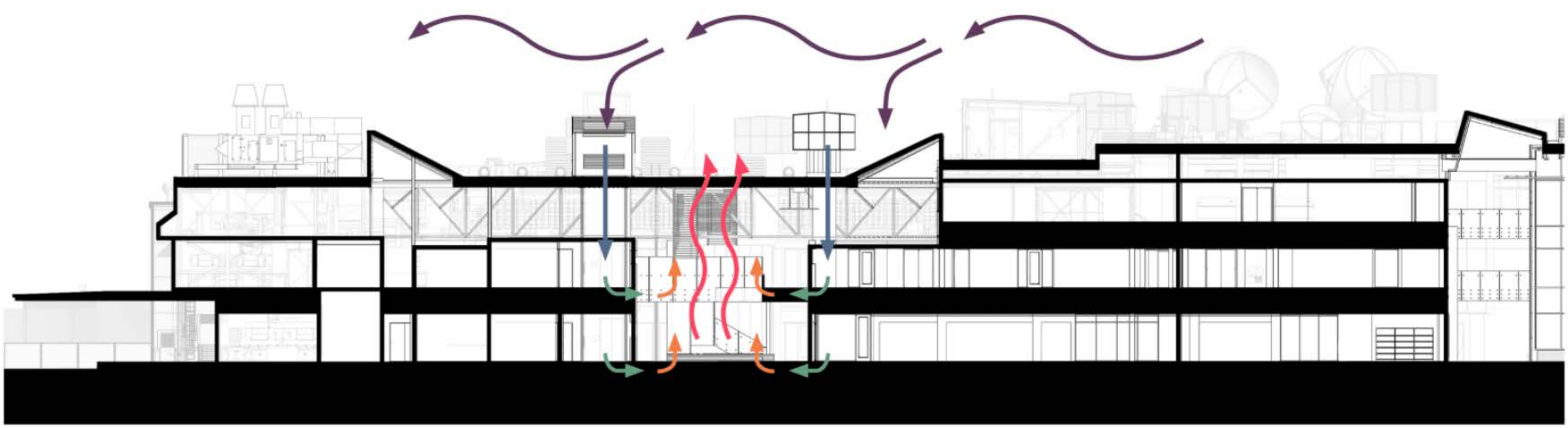
When outside air temperature is less than 65 degrees, air is heated by a heating coil at the foot of the supply shaft. This warmer, more buoyant air moves upwards into the occupied space through floor diffusers.

4 — More Buoyancy

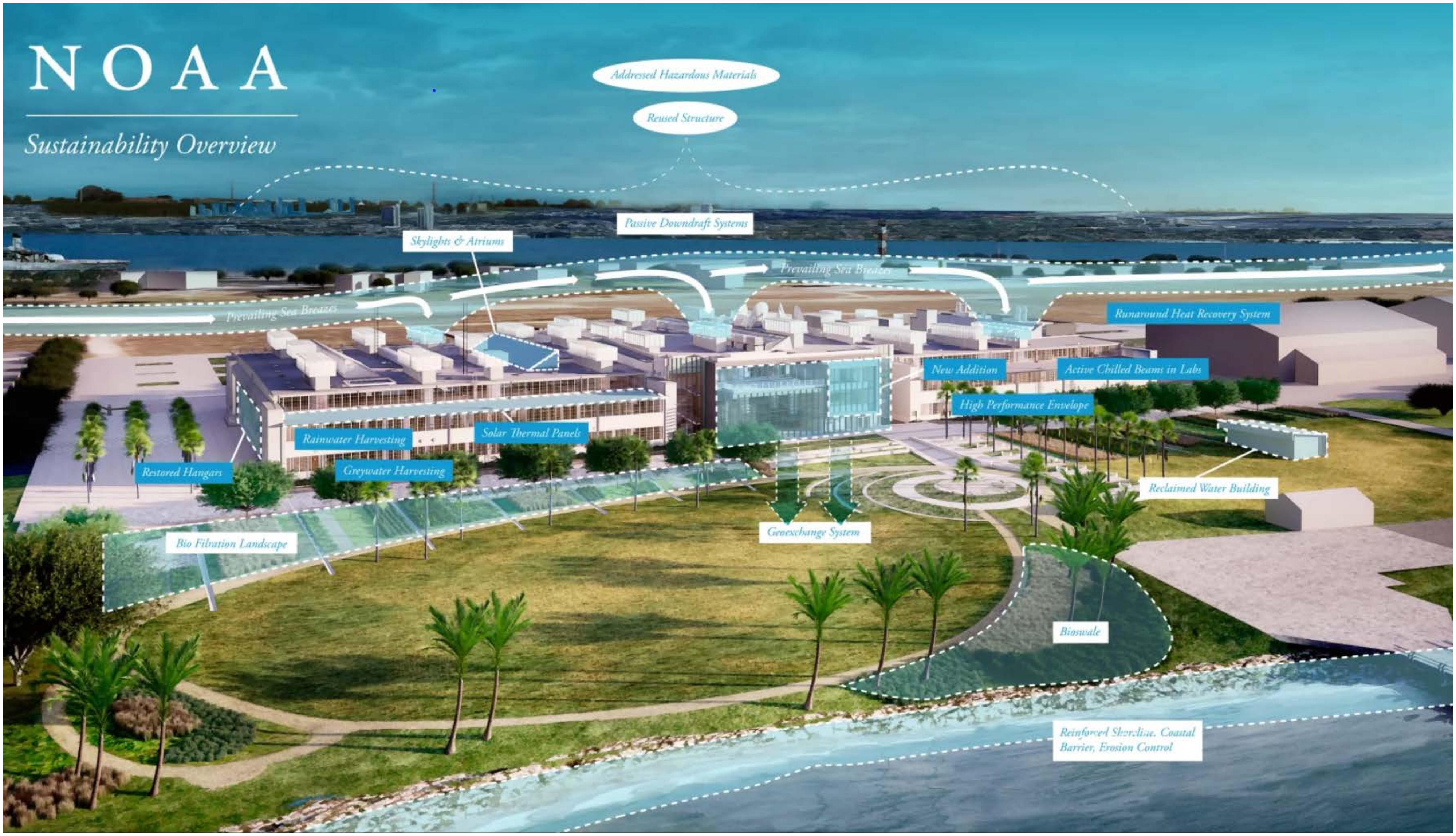
Heat gain from occupants, equipment and lighting adds heat to the air. This warmer polluted air rises to the ceiling, drawing fresh air through the system to replace it. The greater the heat load, the more air is drawn through the system.

5 — Stack & Venturi Effect

Warm relief air rises up the atria towards the skylights. Solar heat gain through the skylight increases the temperature at roof level. Wind flowing over the skylight openings creates suction, assisting exhaust.



Case Study – Passive + Active Chilled Beams



Case Study – University of Hawaii at Manoa

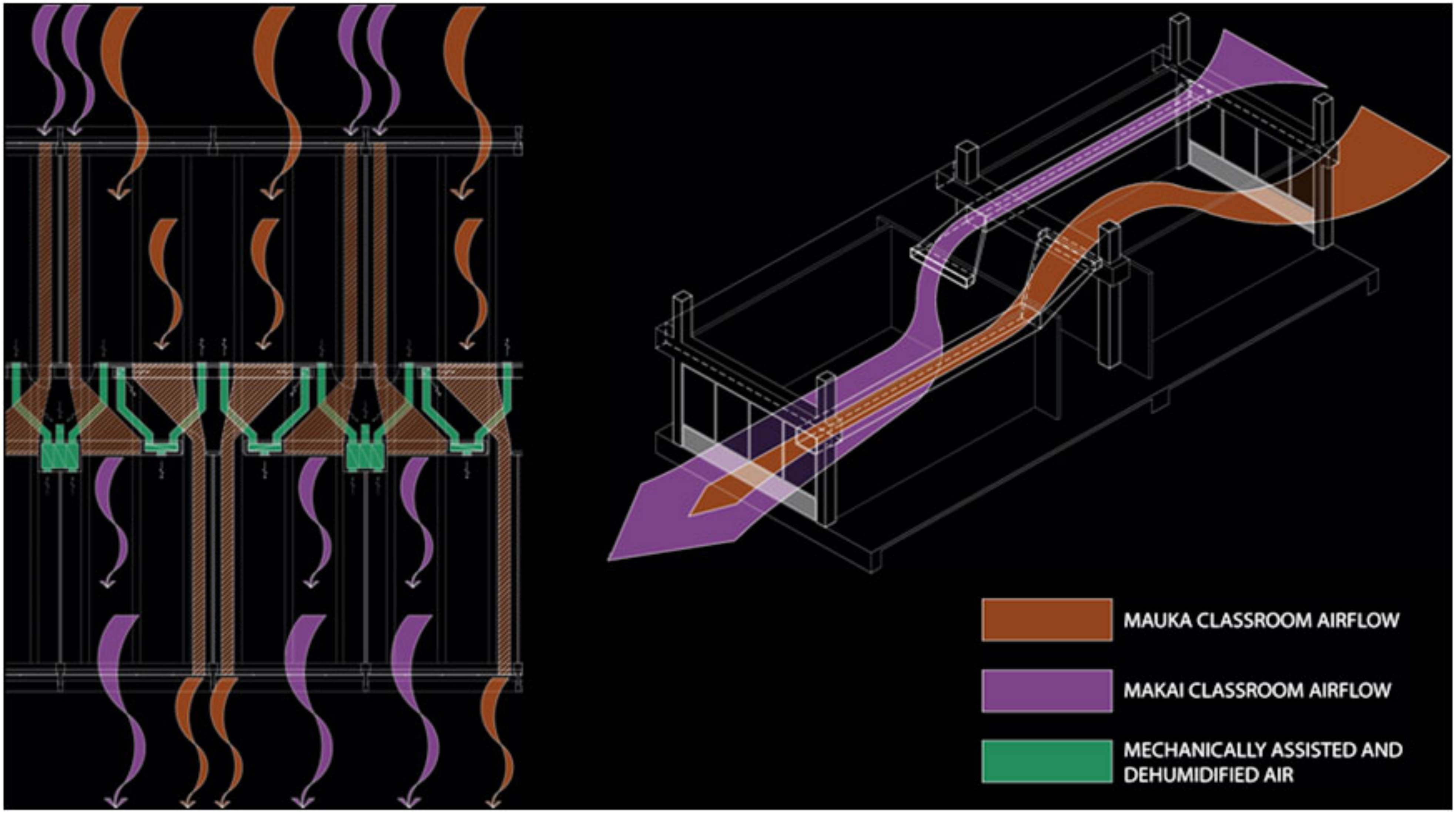
Source– Loisos & Ubbelohde, University of Hawaii at Manoa

Case Study – UHM Envelope Retrofit

Source – Loisos and Ubbelohde

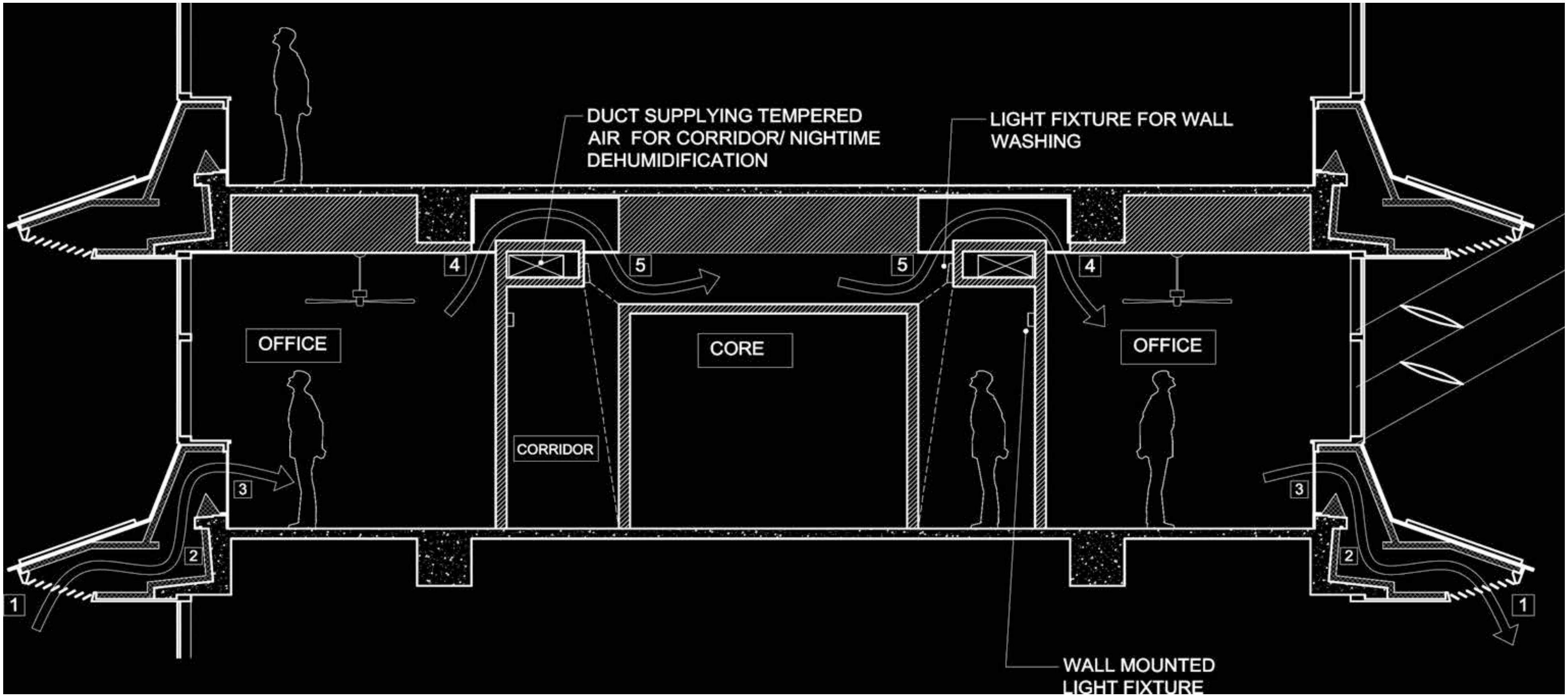
Direct solar gain control while providing daylight and views

Case Study – UHM Cross-flow Natural Ventilation



Source– Loisos & Ubbelohde, University of Hawaii at Manoa

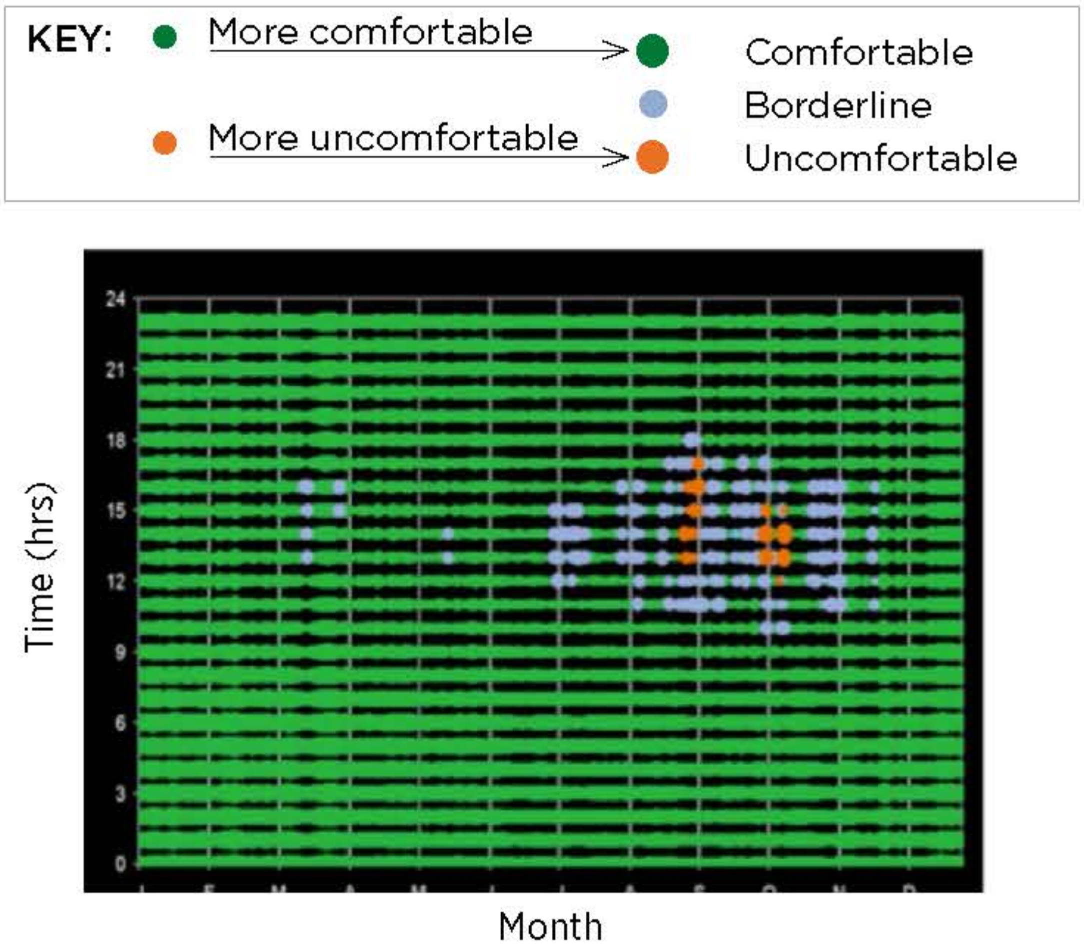
Case Study – UHM Cross-flow Natural Ventilation



Source – Loisos & Ubbelohde, University of Hawaii at Manoa

Section through faculty offices wing with PV awning and sound attenuation from outside.

Case Study – UHM Thermal Comfort



Annual thermal comfort results — A visual tool used to assess hourly thermal comfort performance over the course of a year.

Source: Loisos and Ubbelohde

Provide 'transitional' thermal comfort zones in corridors, atria, creates increased setpoint and deadband

Make use of air movement to enhance comfort with natural ventilation

Case Study – Fort Osage, Missouri, Radiant Heating and Cooling, Enthalpy Recovery

Education Center
High humidity environment (35C DB/23.3C MCWB 0.4% ASHRAE Design Conditions)
Operational 2007

- In-slab radiant heating and cooling system
- Ground source heat pumps
- Dedicated outside air system with enthalpy heat recovery
- 57% energy savings compared to conventional construction

Figures – Fort Osage exterior and interior, exposed thermal mass for radiant heating and cooling (Source: BNIM Architects)

DC Power and Grid Integration Emerging Technology

California's 'Duck' Curve – Increased PV Generation Causes Utility Issues

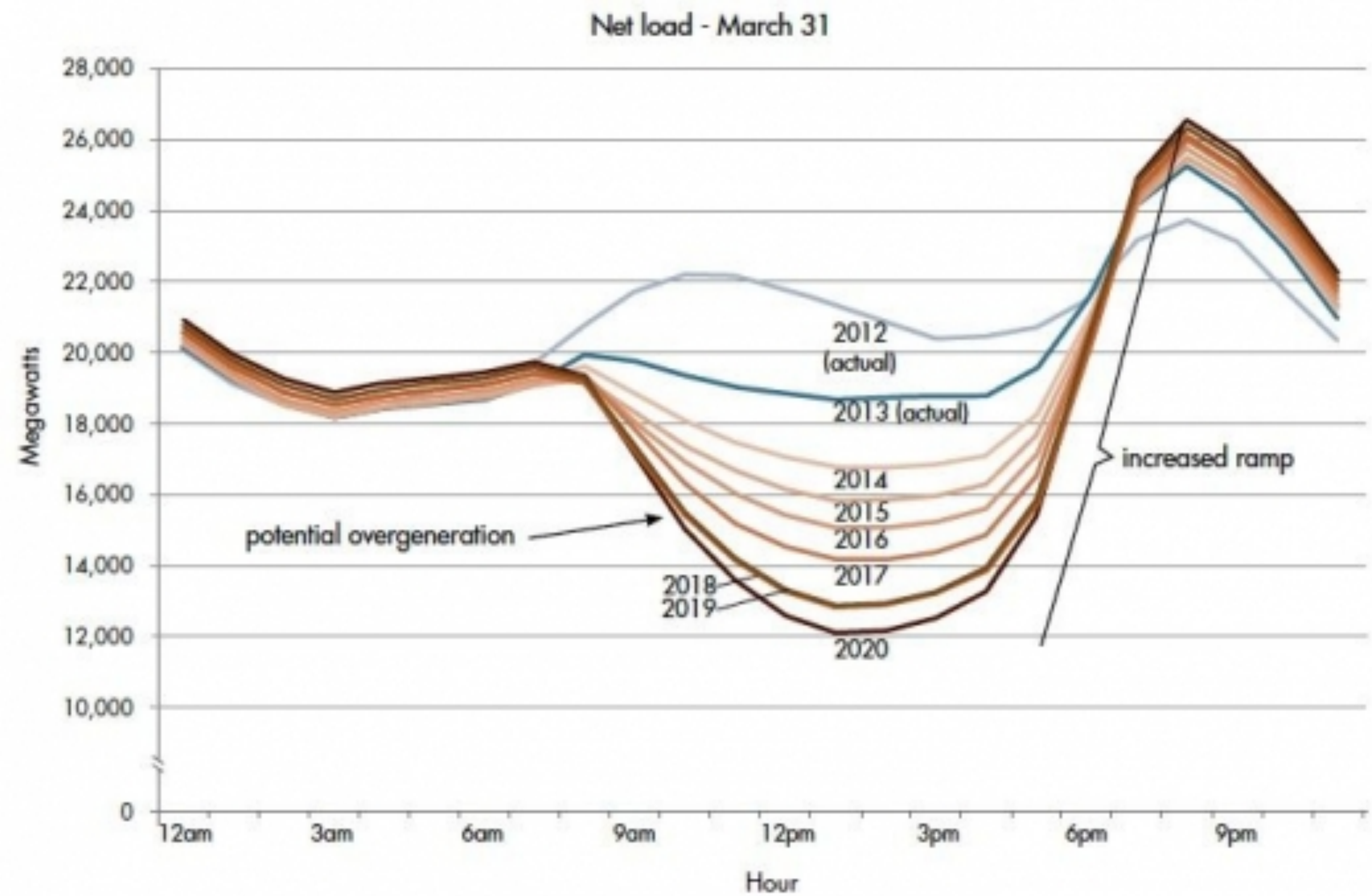


Figure – Typical Spring Day in California, Utility Generation Needed to meet Demand for Increasing Annual PV Penetration

(Source: U.S. Dept of Energy, CALiSO)

Technology Appraisal

#22 DC Power, Case Study – Fraunhoffer Institute for Integrated Systems and Devices

DC System Application, Fraunhoffer Institute, Germany

Office building, operational 2014/15
15kW PV, 3 kW micro CHP

380V for car charging, lighting
24V for laptops, monitors, mobile equipment
Uses DC/DC converter to translate PV DC to stable 380V DC

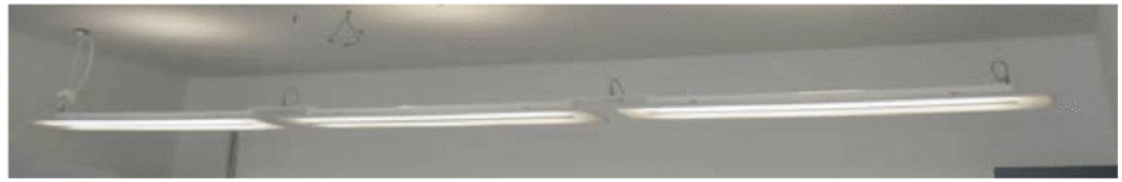


Figure – Philips smartbalance 380V DC lighting (Source: Fraunhoffer)

Figure – Emerson Integrated Solar MPPT (Maximum Power Point Tracker) DC/DC converter (Source: Fraunhoffer)

- Full monitoring and evaluation showed 2.7 – 5.5% savings over a traditional AC system
- Energy conversion from PV system calculated to be 7% more cost effective than traditional PV system
- Less conversion losses, higher distribution efficiency
- More info at https://ieeexplore.ieee.org/document/7152030

Case Study – DC Power at American Geophysical Union

American Geophysical Union, Washington DC USA

Retrofit of existing 6-story commercial office building to NZE. Includes 250 kW PV. Includes microgrid.

- DC Office Lighting and Plug Loads
- Targeting Aug 2019 completion

Source: American Geophysical Union, Washington DC

Case Study – DC Power at Alliance Center

Alliance Center, Denver CO USA

Retrofit of 6-story all-electric building. Includes 26.4 kW PV. Project implemented in 3 stages, stage 1 is 1st floor DC lighting, plugs. Stage 2 is upper floors DC lighting, plugs. Stage 3 is HVAC on DC.

- 24V Office Lighting and Plug Loads
- DC power represents ~17% of the total building load
- Li-ion batteries, 84 kWh, 50 kW
- In operations since Dec 2017

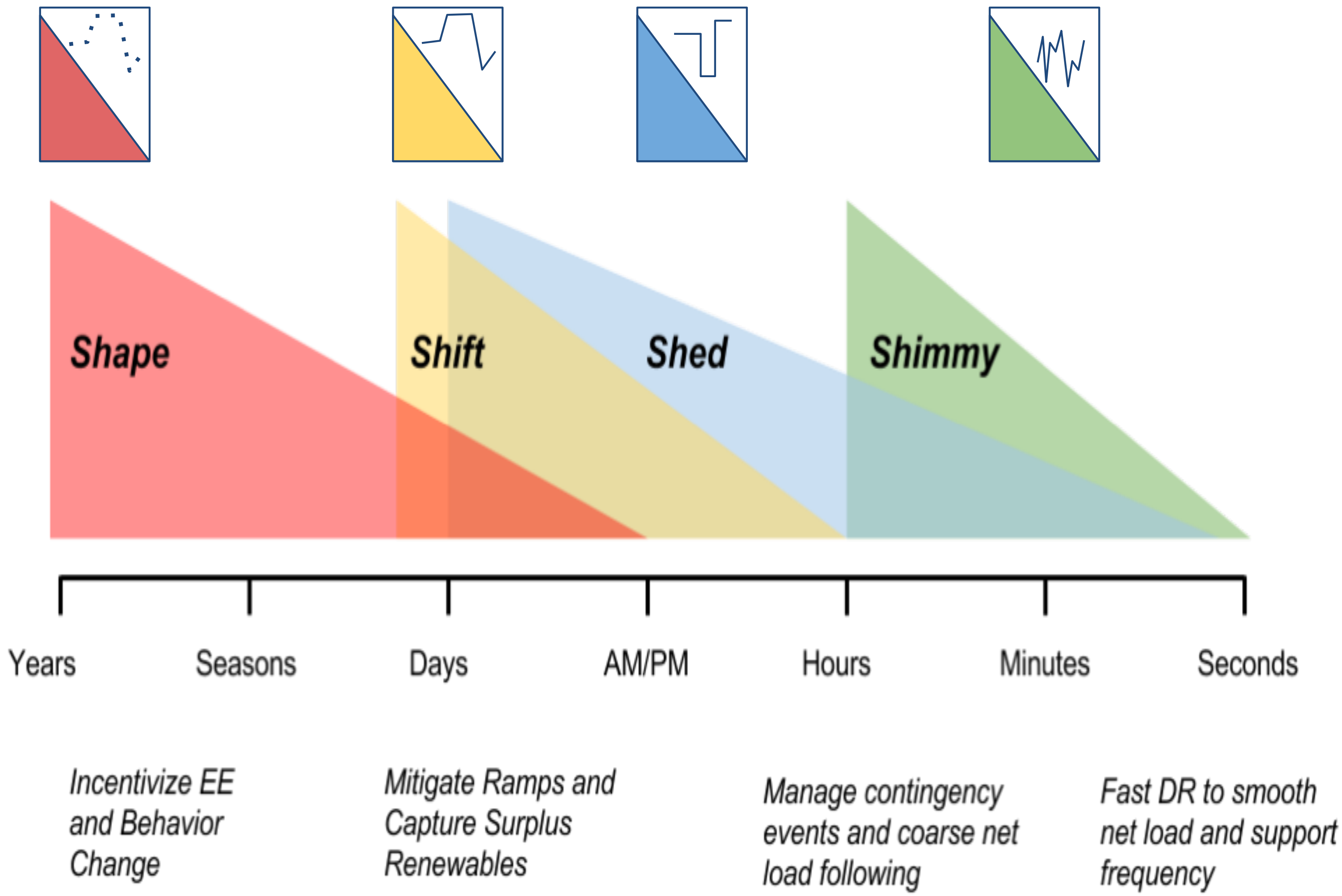
Source: Alliance Center, Denver CO USA

Grid Integrated Building Controls – Using Available PV Power Wisely

The best use of renewable energy is to use it directly when it's produced!

→ Avoid battery storage losses and costs
→ Reduces utility scale distribution and transmission inefficiencies
  → Important for considering ZNE when using source energy
→ Use of DC power produced by PV directly can reduce transformer and distribution losses

Grid Integrated Building Controls – Demand Response Building Controls to Reduce Grid Power

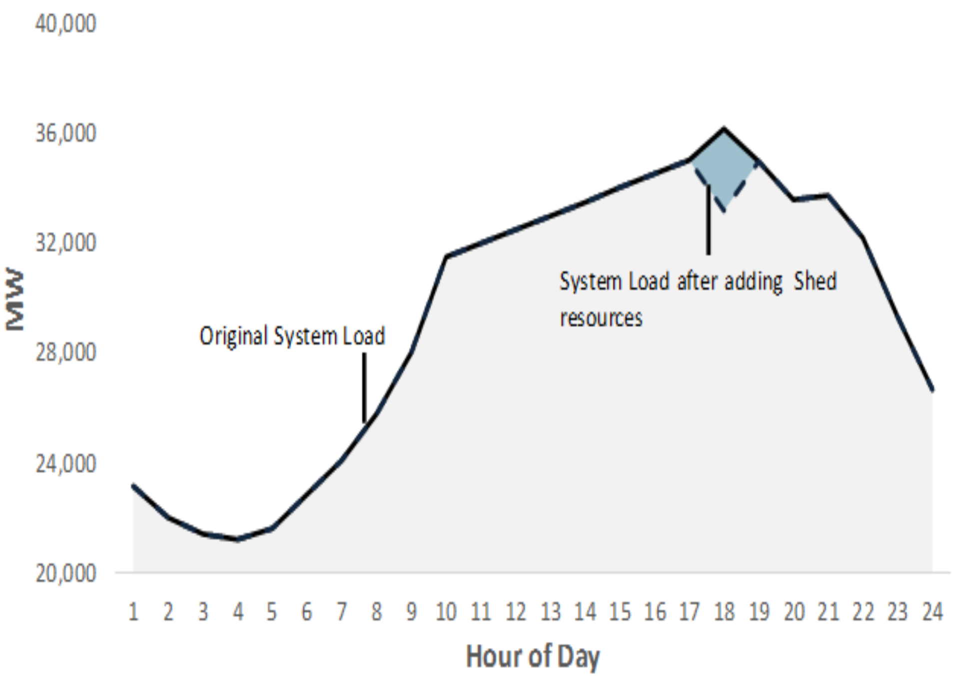


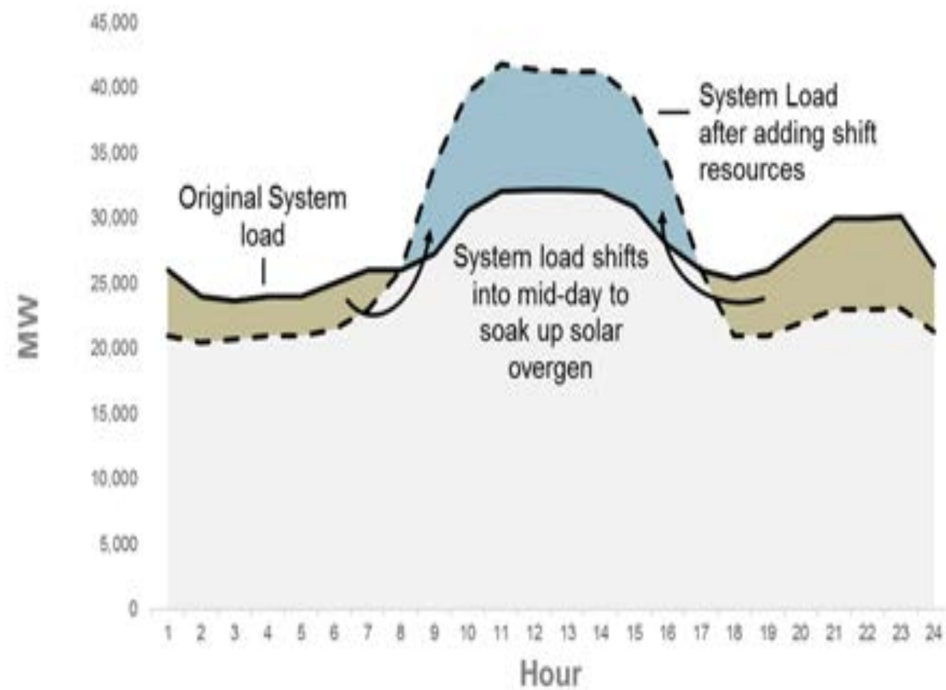
Source: Piette, Phase 2 Results: 2025 California Demand Response Potential Study. 2017 LBNL

Grid Integrated Building Controls – Shed and Shift

Shed Service Type: Peak Shed DR

Shift Service Type: Shifting load from hour to hour to alleviate curtailment/ overgeneration





Source: Piette, Phase 2 Results: 2025 California Demand Response Potential Study. 2017 LBNL

Technology Appraisal

#23-6 Grid Integrated Building Controls for PV Overgeneration

Strategies During PV Overgeneration Periods:

- Lower temperature setpoint in refrigerated cases, commercial grocery
- Lower temperature setpoint in chilled water storage tank
- Increase cooling to select areas
  - Ensure within a desirable deadband
- Increase temperature setpoint of domestic hot water storage

SolarEdge Three Phase Inverters for the 208V Grid for North America

SE9KUS / SE14.4KUS

Select inverters that report net power supply or install power meters to provide net metering signal to EMS

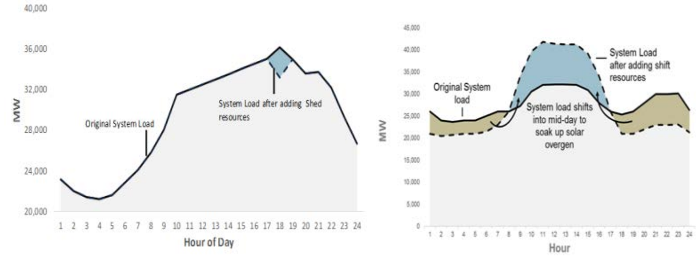
Technology Appraisal

#27-9 Grid Integrated Building Controls for Demand Reduction

Strategies to Reduce Peak Power Demands beyond Available PV Generation:

- Staged AHUs, plant equipment to prevent peak coincident load
- Engage 'hybrid' cooling strategies during peak demand events
  - E.g. ceiling fans, with cooling setpoint increase 6F
- Engage intermittent ventilation controls

Source: Haiku by Big Ass Fans, haikuhome.com



Source: Piette, LBNL

Thank You!!

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