City of Tempe Sustainable Design Guidelines 2022

Contents

01 Intent

Design Guideline Intent

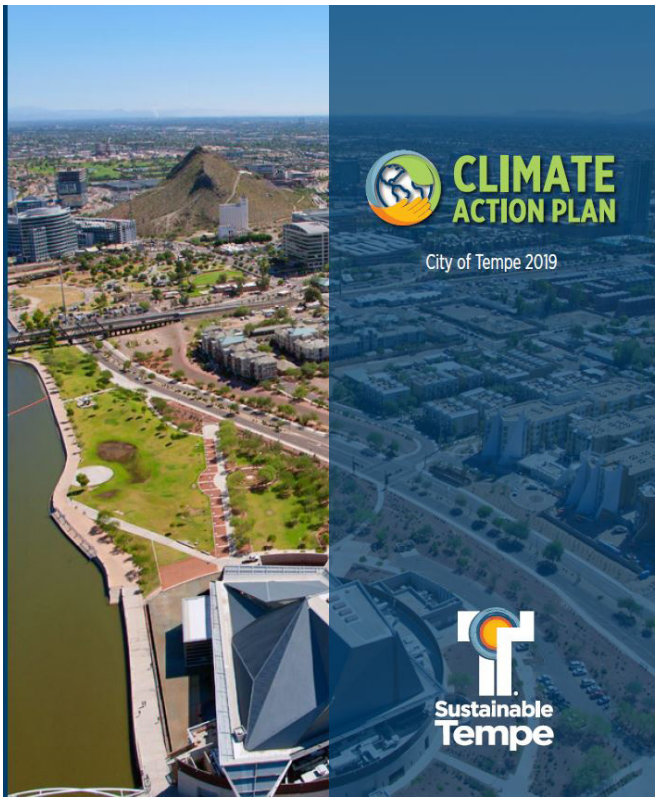
In order to meet the Sustainable targets established in the City of Tempe Climate Action Plan, the following Sustainable Design Guidelines have been developed. With roughly 30% of the Municipal greenhouse gas (GHG) emissions coming from Buildings and Facilities, it will be imperative achieve significant reductions in operational carbon over the next few years for both new construction, retrofits, and major renovations within the City.

Areas of Focus

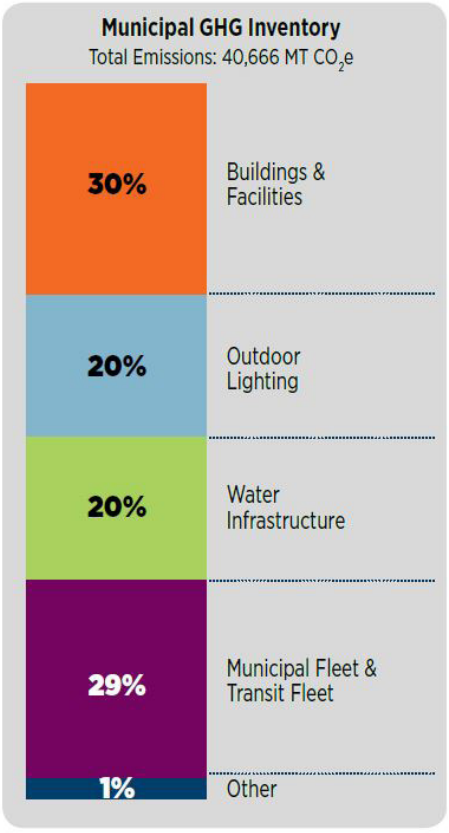
It was determined that these guidelines would focus on the immediate facility needs of the City over the next 3-5 years. This focus includes particular building projects that are planned within this time frame. This focus includes the following projects:

- Community Services, Fire Stations, Historic Buildings, Office Spaces, Police / Courts, Sports Facilities, Utility Buildings, and Water Management Buildings.

It was also determined that specific design strategies would focus on Energy and Water reduction. Many of these strategies have synergies with Ecology and Wellness, but the Energy Efficiency Measures (EEMs) identified are specific to Energy and Water savings.



City of Tempe Climate Action Plan



City of Tempe Municipal GHG inventory

How to Use the Guidelines

Within this document are a list of energy and water efficiency strategies that are applicable to future Tempe building projects. Project teams should plan for and follow the Holistic Design process outlined in Section 2 for various building projects defined below:

Project Size

The following project scopes and size are addressed. These various project types should follow the designated Holistic Design process and consider EEMs that have that project type designation.

- **Under 50,000 square feet or $2M in construction cost (Modernization Fit-out only) -** Follow the streamlined Holistic Design Process #1
- **Under 50,000 square feet or $2M in construction cost (New Construction, Major Renovation)-** Follow the streamlined Holistic Design Process #2
- **Over 50,000 square feet or $2M in construction cost (New Construction, Major Renovation) -** Follow Holistic Design Process #3

Project Type

The project designations below will help a project team determine which EEMs should be considered and modeled for implementation and payback analysis. An “X” marked within the cell indicates that the EEM should be considered and potentially modeled for the project.

- **New Construction -** Projects that include brand new site, structure, envelope and MEP systems.
- **Major Renovation -** Projects that include major changes to an existing building envelope or MEP system.
- **Modernization -** Projects that are simple renovations to existing space that do not include any changes to the envelope or base building MEP systems. Mostly focussed on interior fit-outs and system control changes.

	COMMUNITY SERVICES	FIRE STATIONS	HISTORIC BUILDINGS	OFFICE SPACES	POLICE / COURTS	SPORTS FACILITY	UTILITY	WATER MANAGEMENT
NEW CONSTRUCTION	X							
MAJOR RENOVATION								
MODERNIZATION								

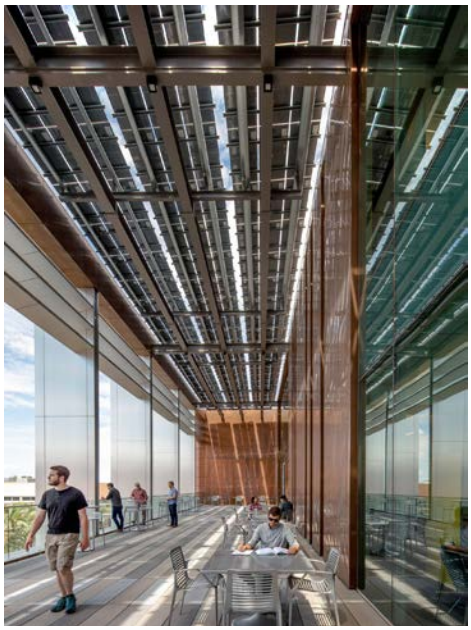
Sample Project designation matrix found in each EEM section

Implementation Schedule

Each EEM includes an associated project schedule indicating when analysis for that EEM should begin. Many of the analytics are recommended for early design stages to ensure that the analysis can inform the design process and not just verify what has already been designed. Project teams should plan for these early analytics in their work plans. Below is a sample time frame that is found in each EEM section.

SAMPLE - Project Timeline Application &

EXAMPLE STRATEGY



Strategy Image

Strategy Image

Strategy Title

Introduction text about the applicability and importance of this strategy for the given climate and building types

Strategy Description

Description text of the strategy and how it works

Technical Links

Online resources where the strategy is described in major detail with step by step technical operations and benefits

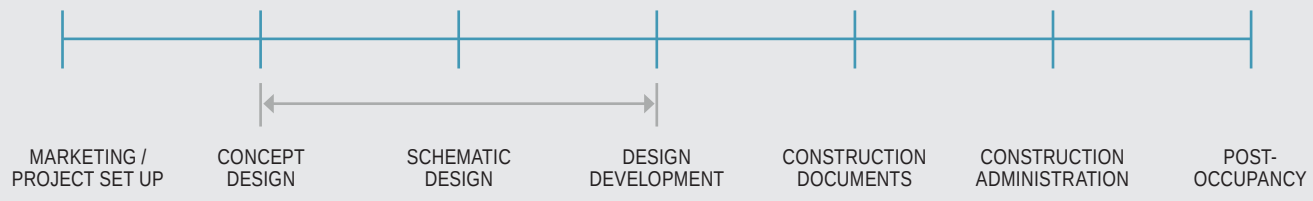
- *Source #1 - https://www.link1.net*
- *Source #2 - https://www.link2.com*

Building Typologies & Project Type

Applicable application to primary Tempe building typologies and project types.

	COMMUNITY SERVICES	FIRE STATIONS	HISTORIC BUILDINGS	OFFICE SPACES	POLICE / COURTS	SPORTS FACILITY	UTILITY	WATER MANAGEMENT
NEW CONSTRUCTION								
MAJOR RENOVATION								
MODERNIZATION								

SAMPLE - Project Timeline Application & Implementation



Holistic Design Implementation

Description of when the strategy should be considered and evaluated with analytics and payback to ensure that the right decisions are being made in an integrated and holistic manner

Operations and Maintenance

Description of particular operations and maintenance issues for the strategy that should be considered in the life cycle cost analysis and understood by the City of Tempe maintenance.

Relevant Codes & Standards

- *List of relevant codes and standards - https://www.link3.com*

Preferred Design & Analysis Tools

List of design software and tools that can be used to perform payback and life cycle cost analysis for the project.

- Software- *https://www.link4.com*
- Tool- *https://www.link5.com*

Case Study Image

CASE STUDY

Project Name

Location

Case Study description

Codes and Standards

The following codes and standards should be referenced when using these guidelines. At a minimum, all projects should meet the minimum requirements for “Required” codes and standards. “Recommended” codes and standards are listed that will improve the holistic, integrated design process for the City of Tempe projects and will allow for early analytics like simple payback and life cycle cost analysis to drive design decisions.

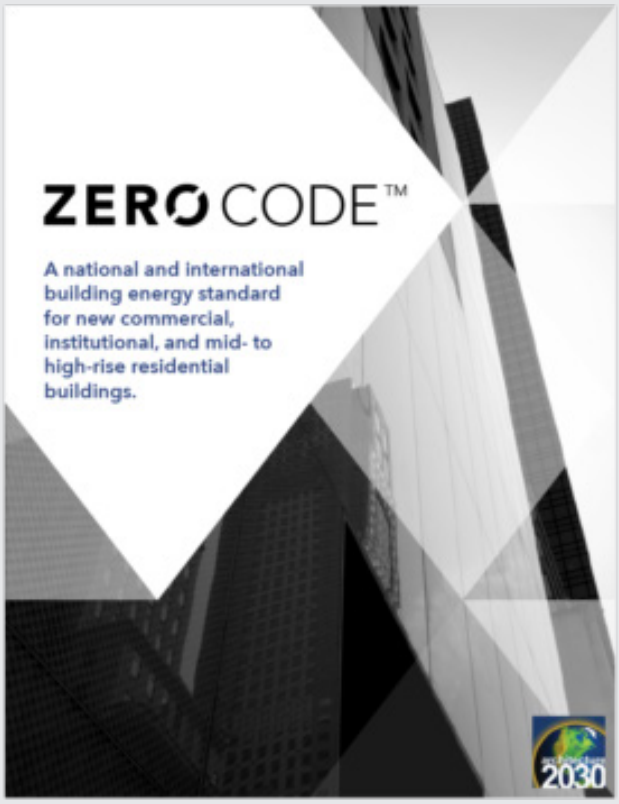
Required

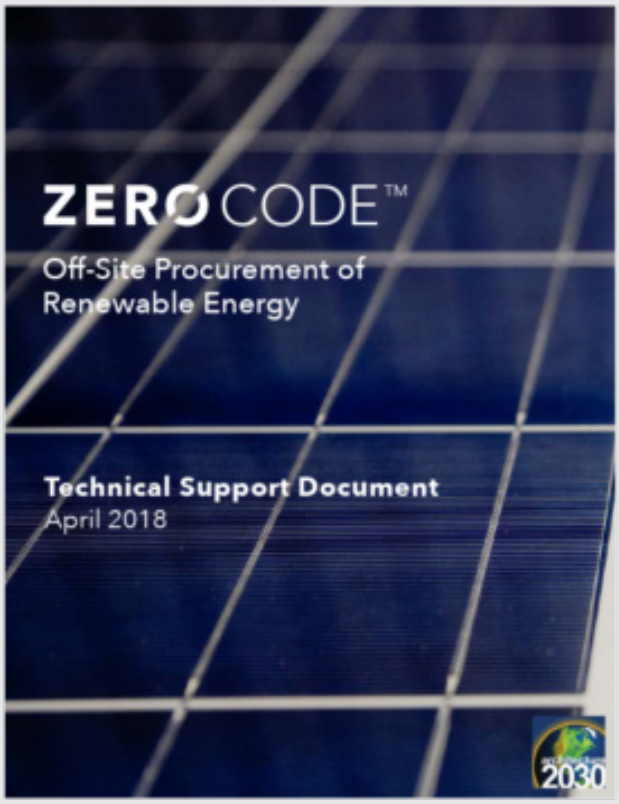
- 2018 Tempe Building Safety Administrative Code
- 2018 International Energy Conservation Code (IECC)
- 2018 International Residential Code (IRC)
- 2018 International Existing Building Code (IEBC)
- 2018 International Building Code (IBC)
- 2018 International Mechanical Code (IMC)
- 2017 National Electrical Code (NEC)
- 2018 International Plumbing Code (IPC)
- 2018 International Fuel Gas Code (IFGC)
- 2018 International Fire Code (IFC)

Codes and Standards

Recommended

- American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) 90.1-2019
- American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) 189.1-2017
- American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) 189.1-2020
- 2018 International Green Construction Code (IGCC)
- 2021 International Energy Conservation Code (IECC)
- Zero code Energy Efficiency Standard
- WBDG Federal Facility Criteria - https://www.wbdg.org/ffc/federal-facility-criteria
- Energy Policy Act of 2005





02 Holistic Design Approach

Holistic Design Process

As mentioned in Section 1, City of Tempe projects will follow a Holistic and Integrated design process to evaluate the applicability and impact of various sustainable design strategies. There are (3) Holistic processes that displayed on the following pages depending on the project size and typology. The details below provide details about the items in these processes.

Responsible Parties

Each task has as assigned “Responsible Party”. The “Responsible Party” is ultimately in charge of the execution of the task even though it is encouraged for them to collaborate and seek counsel from other pertinent project team members.

If a Sustainable Consultant is assigned to the project, it is still advised that the “Responsible Party” execute the action. The job of the Sustainable Consultant is to facilitate the process and offer expertise and advice when necessary to other project team members.

The following “Responsible Parties” have been identified:

- City of Tempe
- Architect / Interior Designer
- Mechanical, Electrical, Plumbing (MEP Engineer
- Civil Engineer
- Landscape Architect
- Lighting Designer
- Daylight Modeler
- Energy Modeler
- Sustainable Consultant

Planned Labor Costs

Project teams performing work for the City of Tempe should plan labor and fees to complete the tasks in the processes on the following pages.

- No additional labor hours or fees should be planned for responsible, high performance design solutions. This should be considered as a standard design deliverable.
- Labor hours and fees can be assigned to specific analytics and calculations that are above and beyond a typical design deliverable. Examples of analytics and calculations that fall into this category are:
  - Energy Modeling
  - Daylight Modeling
  - Full Water Cycle Calculations
  - Wellness Calculations
  - Stormwater and Irrigation calculations for capture, treatment, and reuse

Energy Analytics

Energy modeling and Lighting Power Density analysis should include (3) bundled design solutions of increasing performance that report the following:

- Predicted Energy Use Intensity (pEUI) measured in kBtu / square foot / year
- Predicted Lighting Power Density (LPD) measured in Watts / square foot

Daylight & Wellness Analytics

The type of wellness analytics to be performed should be prioritized by the project team and reported in the following manner:

- Daylight Analysis
  - Spatial Daylight Autonomy (sDA) percentage (%)
  - Useable Daylight Index (UDI) percentage (%)
  - Annual Solar Exposure (ASE) percentage (%)
- Views
  - Views to the Exterior (%)
  - Views to Nature / Beauty (%)

- Comfort
  - Adaptive Comfort Overheated (%)
  - Adaptive Comfort Underheated (%)
- Acoustics
  - Speech Privacy (SPC) (number)
  - Reverberation Time (seconds)
  - Noise level in dBA (number)

Water Cycle Analysis

The project team should calculate the following metrics if applicable for the project:

- Total Potable Water Use Reduction (gal)
- Total Process Water Use Reduction (gal)
- Total Irrigation Potable Water Use Reduction if applicable (gal)
- Rainwater Treatment if applicable (%)
- Wastewater treated on-site if applicable (%)

Simple Payback and Life Cycle Cost Analysis (LCCA) Requirements

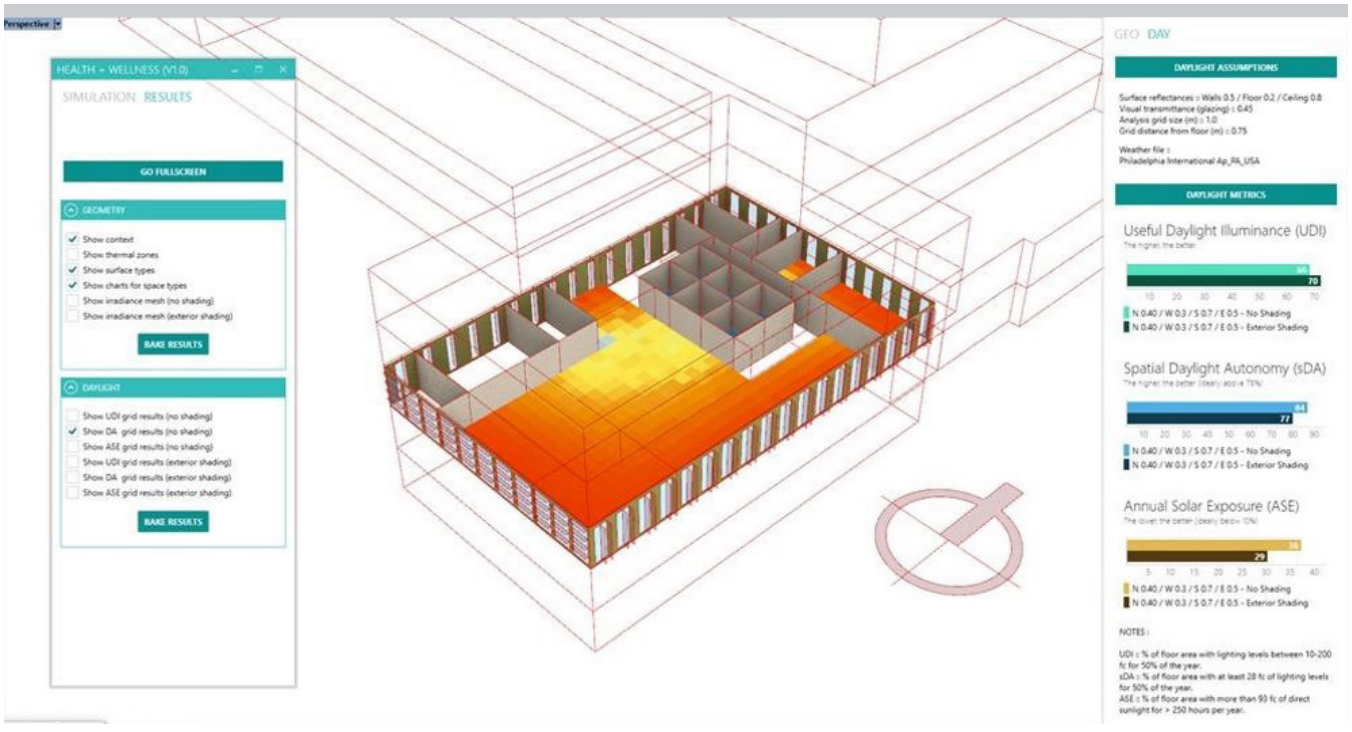
When trying to justify design strategies to be incorporated into the project to achieve high performance design, the project team should utilize the following methodologies:

- Simple Payback - While LCCA is preferred, simple payback can be assessed for individual strategies (ideally bundles of strategies together that have compounding effects)

Simple Payback =
Cost of Energy Efficient Strategy / Annual Utility Savings

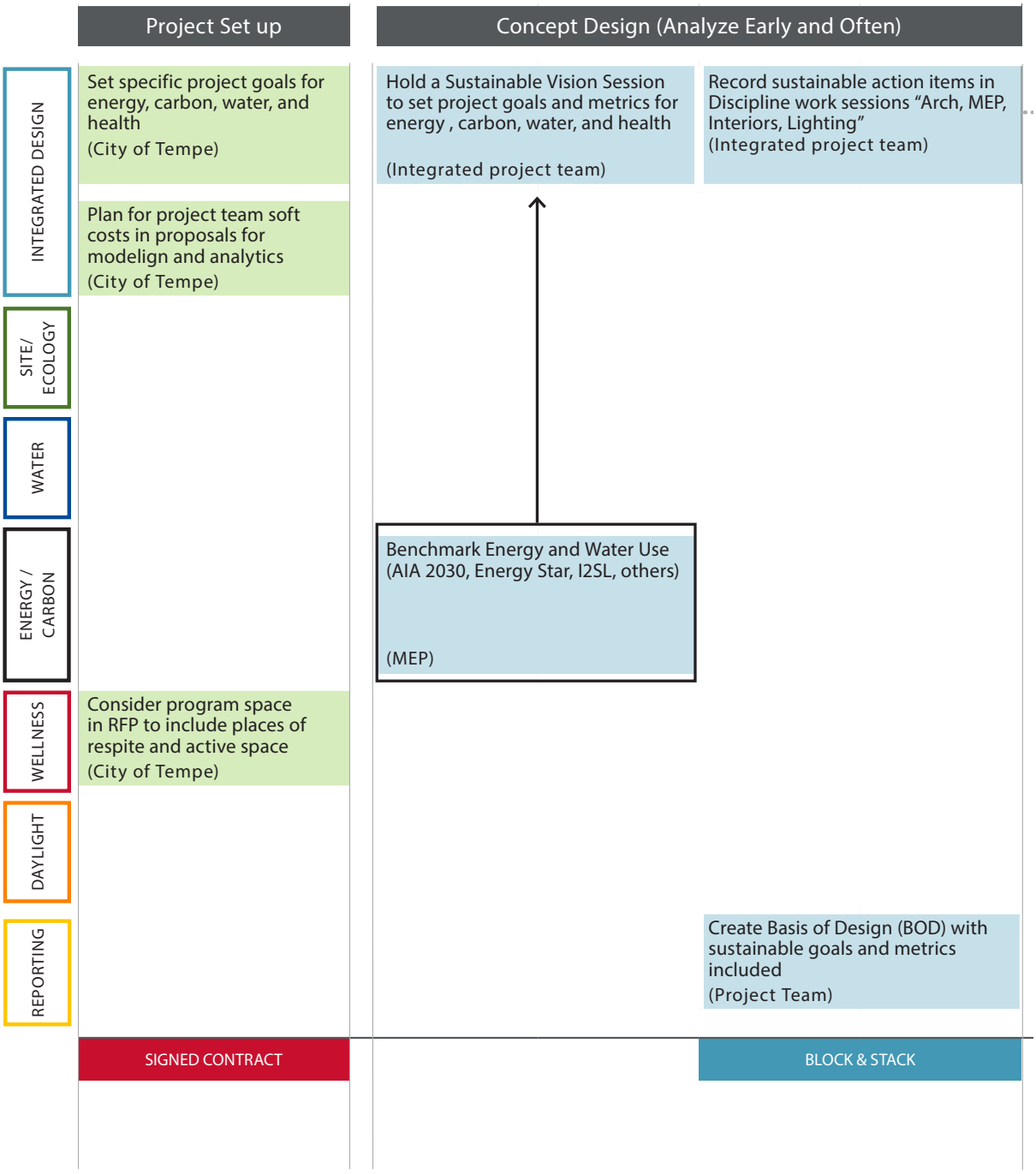
- LCCA - Use the Whole Building Design Guideline methodology for Life Cycle Cost Analysis (LCCA)
  - WBDG LCCA methodology

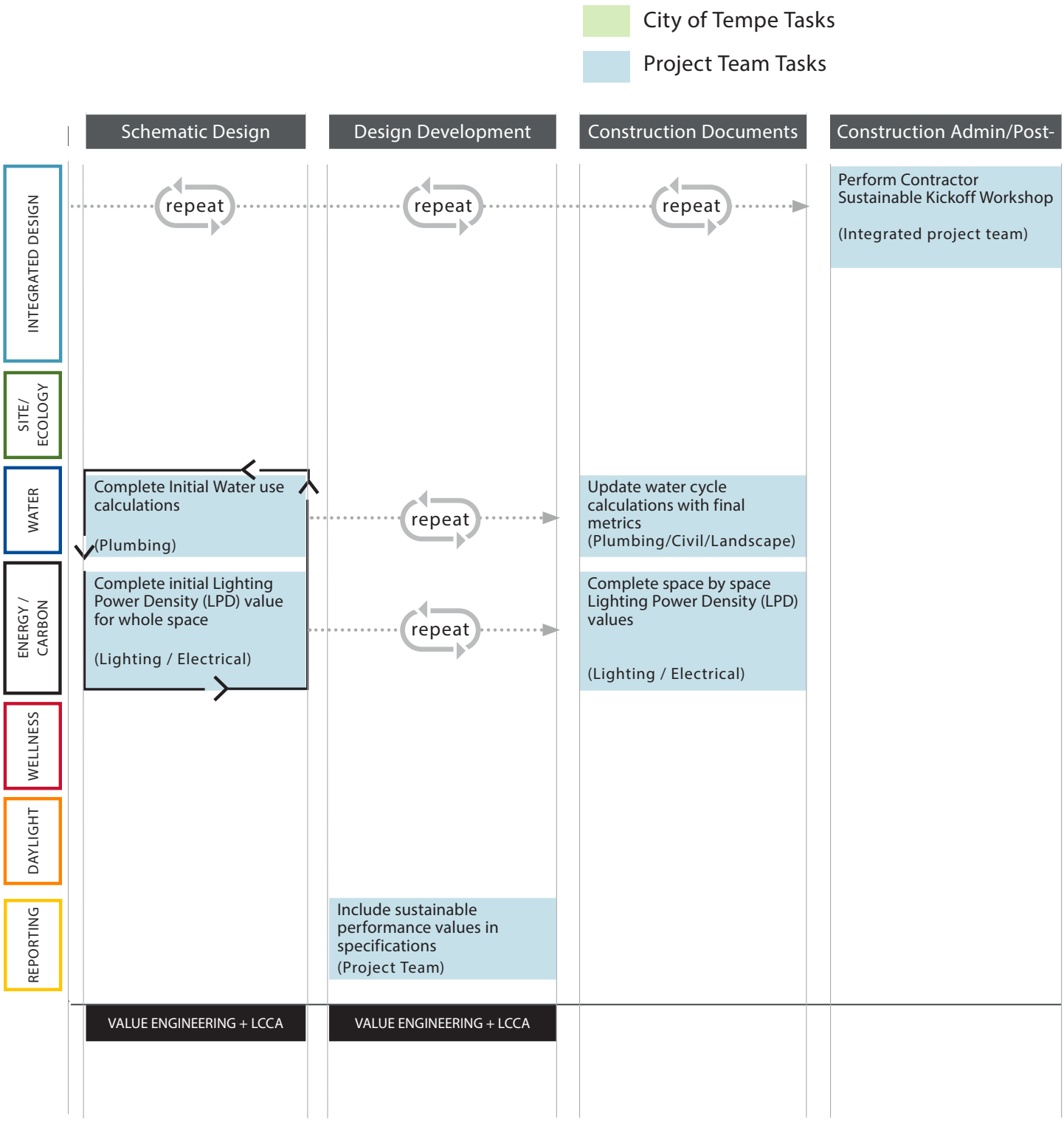
LCC = I + Repl — Res + E + W + OM&R + O



City of Tempe Holistic Design Process #1

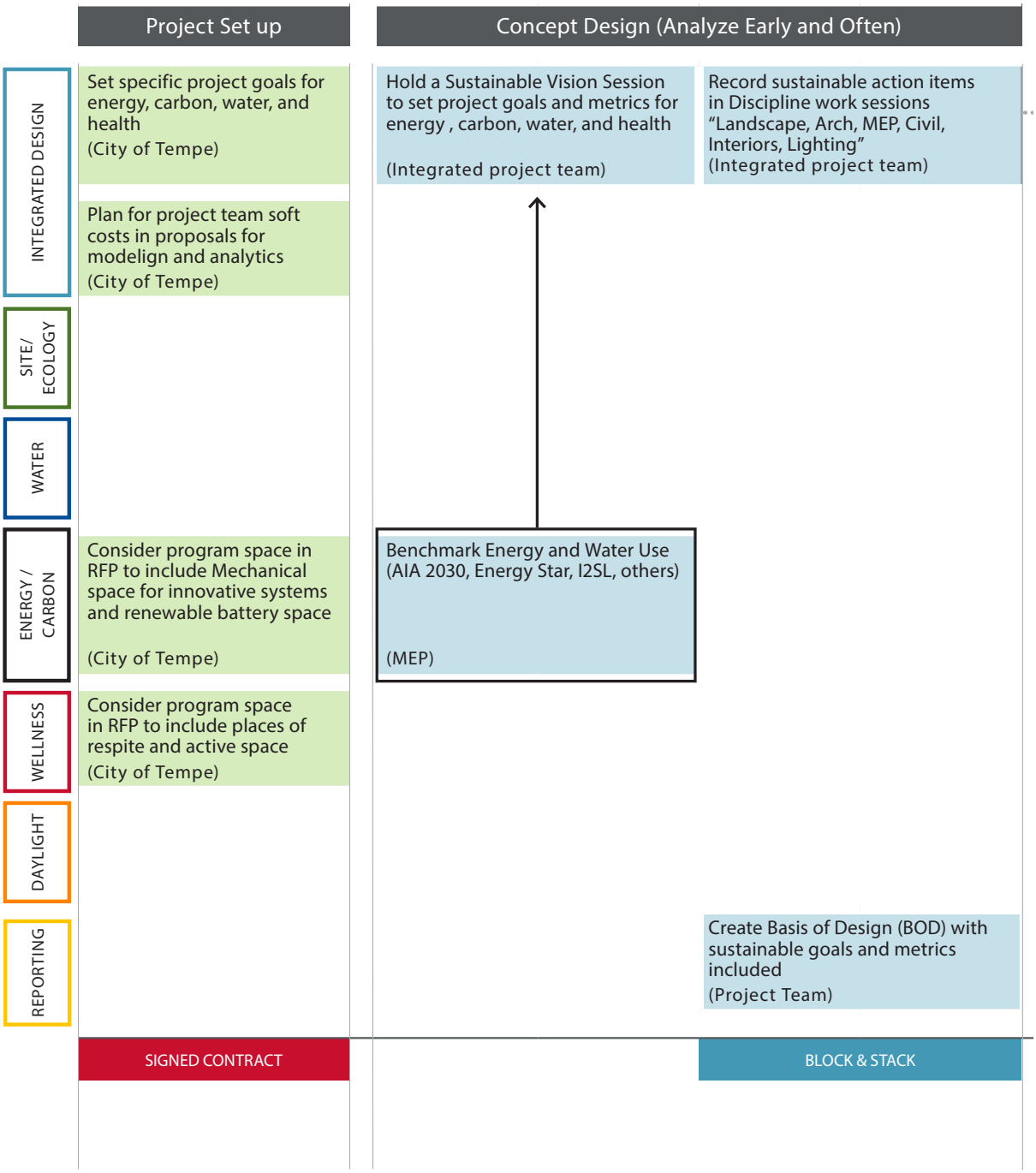
Project Size under 50,000 SF or $5M cost (Modernization (Fit-out only))

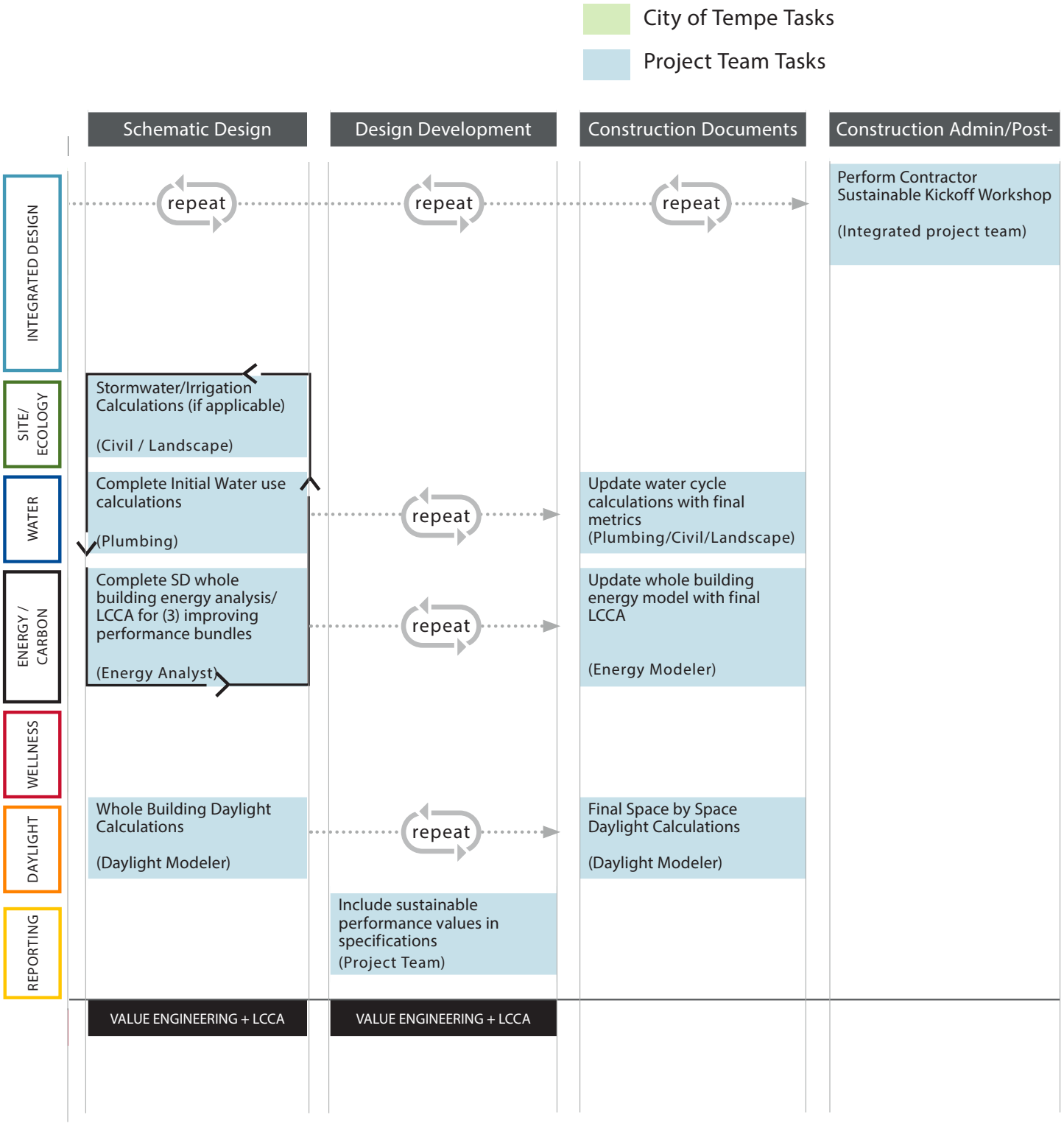



City of Tempe Tasks
Project Team Tasks
Schematic Design
Design Development
Construction Documents
Construction Admin/Post-
INTEGRATED DESIGN
SITE/ ECOLOGY
WATER
ENERGY / CARBON
WELLNESS
DAYLIGHT
REPORTING
repeat
repeat
repeat
Perform Contractor Sustainable Kickoff Workshop
(Integrated project team)
Complete Initial Water use calculations
(Plumbing)
repeat
Update water cycle calculations with final metrics
(Plumbing/Civil/Landscape)
Complete initial Lighting Power Density (LPD) value for whole space
(Lighting / Electrical)
repeat
Complete space by space Lighting Power Density (LPD) values
(Lighting / Electrical)
Include sustainable performance values in specifications
(Project Team)
VALUE ENGINEERING + LCCA
VALUE ENGINEERING + LCCA

City of Tempe Holistic Design Process #2

Project Size under 50,000 SF or $5M cost (New Construction, Major Renovation)

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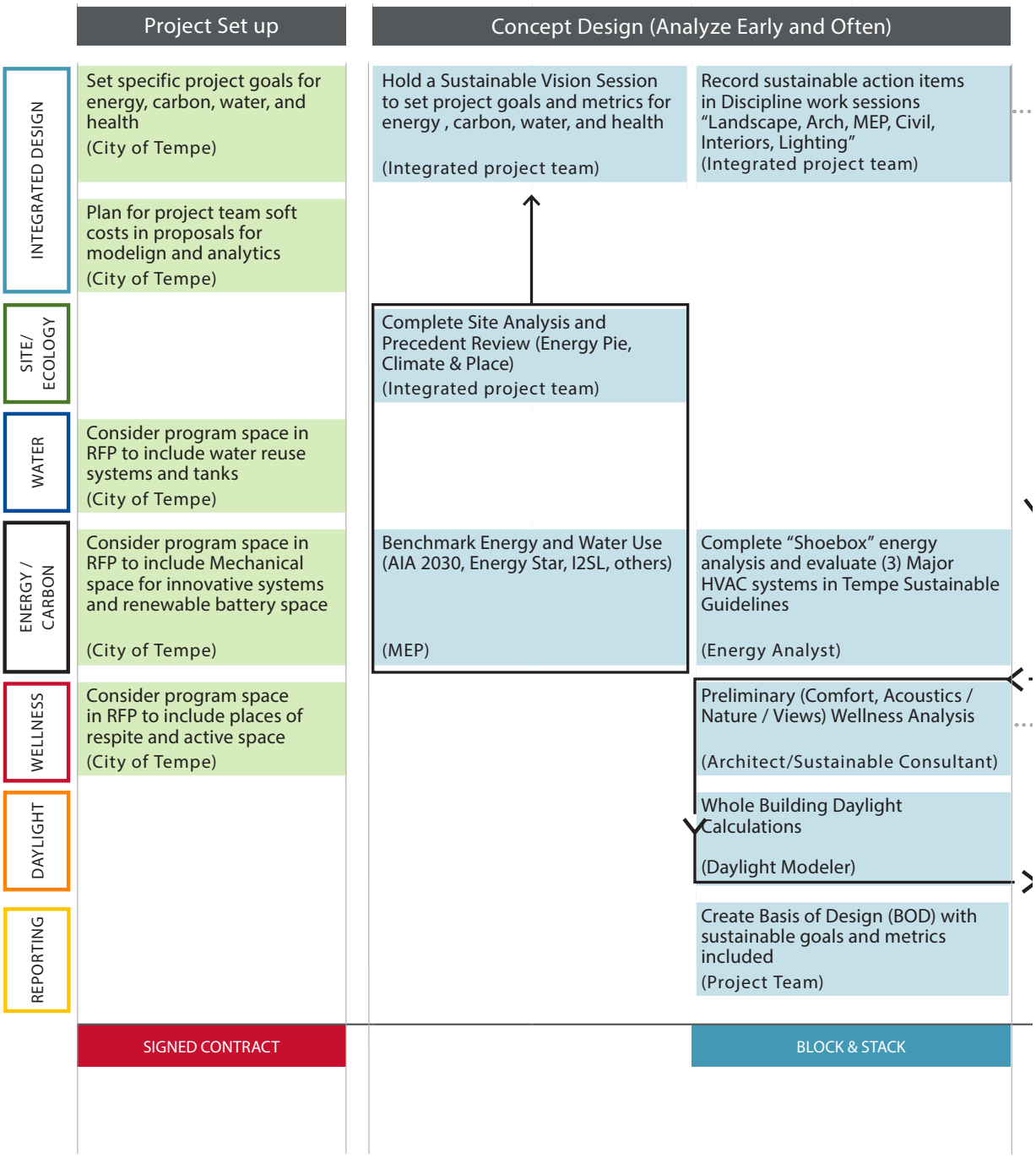
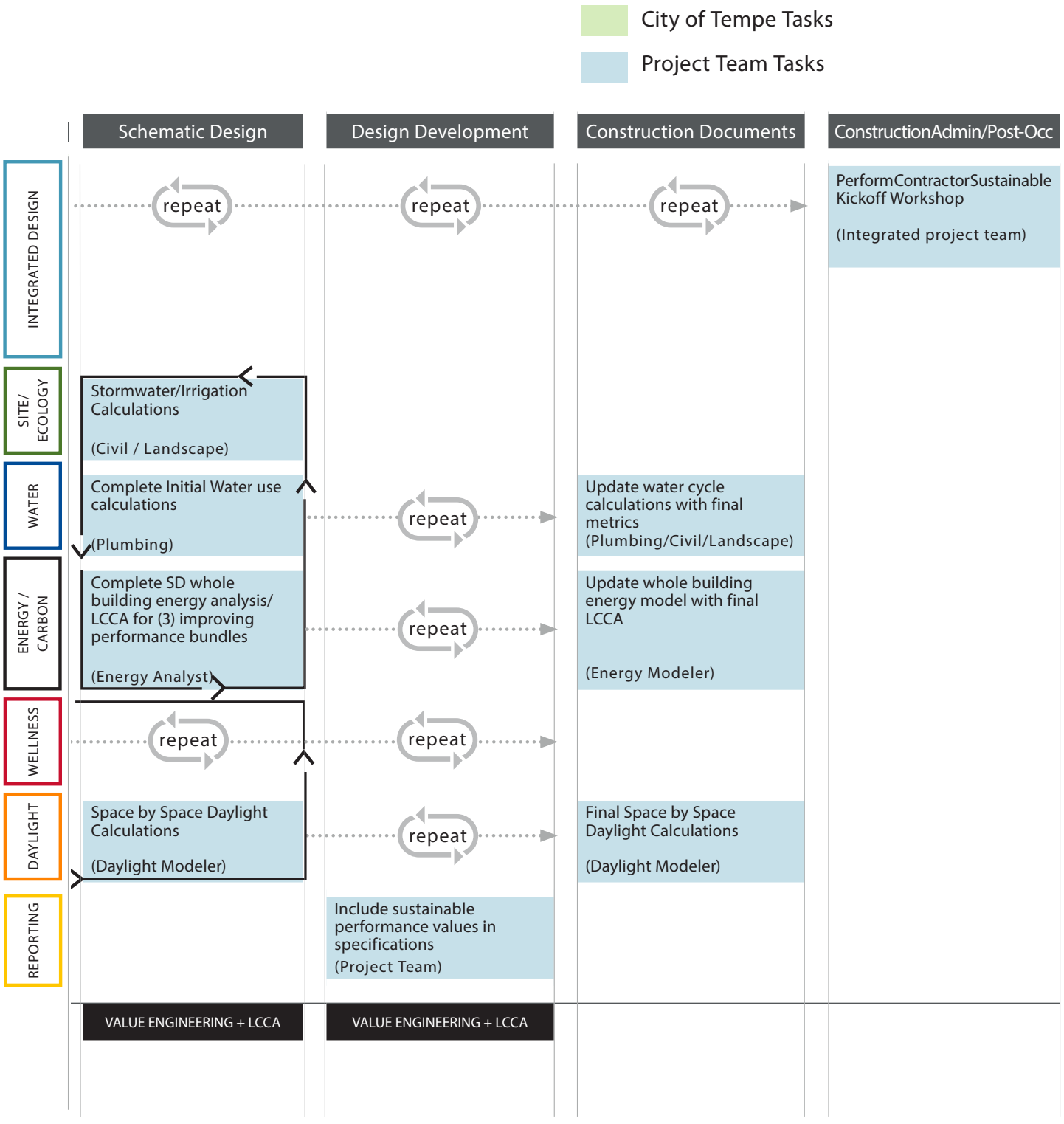
SITE/ ECOLOGY
WATER
ENERGY / CARBON
WELLNESS
DAYLIGHT
REPORTING
repeat
repeat
repeat
Perform Contractor Sustainable Kickoff Workshop
(Integrated project team)
Stormwater/Irrigation Calculations (if applicable)
(Civil / Landscape)
Complete Initial Water use calculations
(Plumbing)
repeat
Update water cycle calculations with final metrics
(Plumbing/Civil/Landscape)
Complete SD whole building energy analysis/ LCCA for (3) improving performance bundles
(Energy Analyst)
repeat
Update whole building energy model with final LCCA
(Energy Modeler)
Whole Building Daylight Calculations
(Daylight Modeler)
repeat
Final Space by Space Daylight Calculations
(Daylight Modeler)
Include sustainable performance values in specifications
(Project Team)
VALUE ENGINEERING + LCCA
VALUE ENGINEERING + LCCA

City of Tempe Holistic Design Process #3

Project Size 50,000 SF or $5M cost and up (New Construction, Major Renovation)

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repeat
repeat
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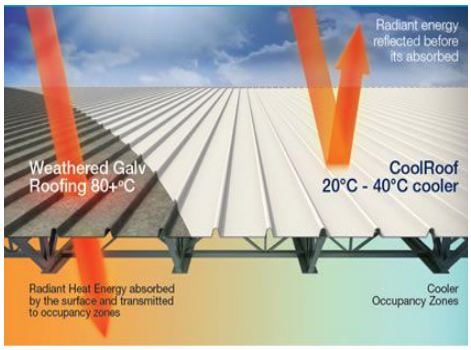
(Integrated project team)
Stormwater/Irrigation Calculations
(Civil / Landscape)
Complete Initial Water use calculations
(Plumbing)
repeat
Update water cycle calculations with final metrics
(Plumbing/Civil/Landscape)
Complete SD whole building energy analysis/ LCCA for (3) improving performance bundles
(Energy Analyst)
repeat
Update whole building energy model with final LCCA
(Energy Modeler)
repeat
repeat
Space by Space Daylight Calculations
(Daylight Modeler)
repeat
Final Space by Space Daylight Calculations
(Daylight Modeler)
Include sustainable performance values in specifications
(Project Team)
VALUE ENGINEERING + LCCA
VALUE ENGINEERING + LCCA

03 Energy

Envelope



Cool Roof Performance


Reflective Roof on a Walmart store, Las Vegas, NV

Cool Roof & Solar Reflective Index

With the recent heat waves and record breaking temperatures affecting much of the U.S., Cool roof technologies are emerging as an efficient and economical solution for lowering temperatures especially in a climate like Tempe. Solar reflectance and thermal emittance properties of cool roofs make them an effective strategy to reduce solar heat gain of the building compared to the standard types. According to the DOE, Standard or dark roofs can reach temperatures of 150 degrees F or more in the summer sun. A cool roof under the same conditions could stay more than 50 degrees F cooler and save energy and money by using less air conditioning.

Strategy Description

Cool roofs reflect incoming solar radiation and absorb less heat than the standard roofs thereby minimizing the solar heat gain. They achieve this through a wide range of technologies, like highly reflective paints / coatings, a sheet covering, highly reflective tiles or shingles depending on the type of application. A new generation of cool roof systems that can change their reflectance and thermal emittance properties seasonally using technologies like Phase Change Materials (PCM) and other smart coatings are being explored to maximize the resilience.

Technical Links:

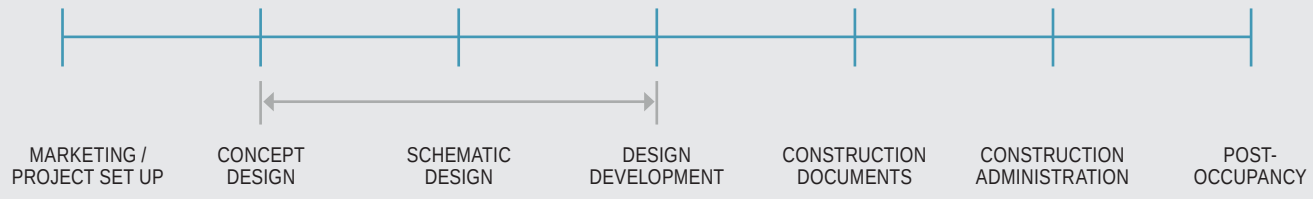
- ATAS Cool roofs: https://www.atas.com/products/
- Verisco roofing - https://www.versico.com/en/Roofing-Products/

Building Typologies & Project Type

Applicable application to primary Tempe building typologies and project types.

	COMMUNITY SERVICES	FIRE STATIONS	HISTORIC BUILDINGS	OFFICE SPACES	POLICE / COURTS	SPORTS FACILITY	UTILITY	WATER MANAGEMENT
NEW CONSTRUCTION	X			X	X	X	X	X
MAJOR RENOVATION	X			X	X	X	X	X
MODERNIZATION								

Project Timeline Application & Implementation



Holistic Design Implementation

Cool roofs for a project needs to be factored into the HVAC load calculations of the project. Hence it needs to be explored earlier in the design development phase of the project. Although it is relatively easy to retrofit buildings with cool roofs, cases where there are roof elements of the HVAC might prove challenging to do so, Considering this option while new construction gives the designers the opportunity to full take advantage of the energy savings achieved.

Operations and Maintenance

- Proper installation is important to the long-term success of a cool roof project. For example, when applied properly, many cool roof coatings have been shown to last more than 20 years. On the contrary, poorly applied cool roofs can peel or flake off the roof within a couple of years.
- A key concern for cool roofs is maintaining their high solar reflectance over time. Washing the roof according to the manufacturer's recommended maintenance procedures can help retain solar reflectance.

Relevant Codes & Standards

- City of Tempe Specifications
- City of Tempe current codes - ASHRAE 90.1 2016 / IECC 2018.
- Latest and Advanced codes - IECC 2021, IGCC 2021, ASHRAE 90.1 2019/Zero code, ASHRAE Standard 189 2020
- WBDG Federal Facility Criteria. Link to the source can be found here - https://www.wbdg.org/ffc/federal-facility-criteria
- Energy Policy Act of 2005

Chandler city hall, AZ

CASE STUDY

Chandler City Hall

Chandler, AZ

The entire facility employed cool roof technology, high performance glazing and well insulated walls and a roof with R-values of R-19 and R-30, respectively to minimize solar heat gain

Other References:

- ASU Student Pavilion, Tempe,AZ
- AIA Top ten:http://www.aiatopten.org/
- New Buildings Institute - https://newbuildings.org/case-studies/

Preferred Design & Analysis Tools

- Cove tool, ENERGY plus, eQuest can be used to compare variations in performance of different roofing systems.
- RoofNav - is a free Web-based tool developed by FM Approvals™ that provides fast access to the most up-to-date FM Approved roofing products and assemblies.
- SRI Calculator by LBNL- coolcolors.lbl.gov/assets/docs/SRI%20Calculator/SRI-calc10.xls
- DOE Cool Roof Calculator was developed by the U.S. Department of Energy's Oak Ridge Laboratory. This calculator provides an estimate of cooling and heating savings for small to medium size facilities that purchase electricity with a demand charge and an alternative version for larger facilities. http://www.ornl.gov/sci/roofs%2Bwalls/facts/CoolCalcEnergy.htm
- EPA Cool Roof Calculator is provided by ENERGY STAR- This calculator allows the designer to input specific details about a building, including heating and cooling systems as well as location and the cost of energy. http://www.roofcalc.com/RoofCalcBuildingInput.aspx

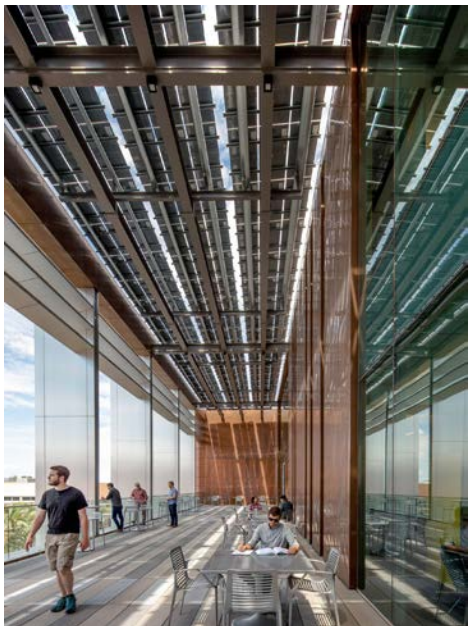
Rating Program

Cool Roof Rating Council (CRRC) Product Rating Program—The CRRC administers a rating program under which manufacturers can label various roof surface products with radiative property values.

Environmental Protection Agency (EPA) Energy Star Program Requirements for Roof Products —This federal program designates roof products that comply with the EPA requirements to assist consumers in making informed decisions with respect to energy conservation.

Design guidance:

- Whole Building Design guide (WBDG)- https://www.wbdg.org/resources/windows-and-glazing
- GSA Sustainable Facilities Tool (SFTool)- https://sftool.gov/
- AIA 2030 Palette - http://2030palette.org/
- AIA COTE Tool kit: https://network.aia.org/blogs/michael-w-lassel-aia-leed-ap1/2019/08/29/aia-cote-toolkit



Shading Structure on South Facade at ASU Student Pavilion

Static louver Shading Structure on West Facade at ASU Student Pavilion

External Shading

In cooling dominated climate, where excess solar gain may result in high cooling energy consumption, it is very important to control the amount of sunlight that is admitted into a building. Well designed sun control and passive shading devices helps in reduces the cooling load and also helps in capturing quality daylighting

Strategy Description

External shading can be implemented in various ways depending on the building orientation, opening locations and the design language. The primary function of shading is to block unwanted solar radiation and heat from entering into the building. As a passive strategy, it is easy to retrofit buildings with proper external shading mechanisms.

Technical Links

- Kovach Building Enclosures - https://www.kovach.net/
- Enclos Facades - https://enclos.com/

Building Typologies & Project Type

Applicable application to primary Tempe building typologies and project types.

	COMMUNITY SERVICES	FIRE STATIONS	HISTORIC BUILDINGS	OFFICE SPACES	POLICE / COURTS	SPORTS FACILITY	UTILITY	WATER MANAGEMENT
NEW CONSTRUCTION	X	X	X	X	X	X	X	X
MAJOR RENOVATION	X	X	X	X	X	X	X	X
MODERNIZATION	X	X	X	X	X	X	X	X

Project Timeline Application & Implementation

Holistic Design Implementation

Solar Shading strategies are particularly important for Tempe's climate. It is crucial to conduct an intensive sun shading analysis on all facade exposures very early in the design phase, since it is a strategy that has a potential to influence many design decisions down the line, including the HVAC systems, mechanical systems and building facade design. It should be coordinated with mechanical systems for their sizing and effects.

Operations and Maintenance

- Some shading systems may make it difficult to clean the building's windows, and may also attract bird life and the associated droppings.
- Bird nesting, window cleaning access requires proper assessment in the early stages of design is crucial to gain benefits from shading systems.

Relevant Codes & Standards

- City of Tempe current codes - ASHRAE 90.1 2016 / IECC 2018.
- Latest and Advanced codes - IECC 2021, IGCC 2021, ASHRAE 90.1 2019/Zero code, ASHRAE Standard 189 2020
- WBDG Federal Facility Criteria. Link to the source can be found here - https://www.wbdg.org/ffc/federal-facility-criteria
- Energy Policy Act of 2005

Preferred Design & Analysis Tools

Tools to evaluate shading strategies: Cove tool, Sefaira, Energy Plus, eQuest, DIVA, radiance, Ladybug, AGi32, Daysim, Facade

Design guidance:

- Whole Building Design guide (WBDG)- https://www.wbdg.org/
- GSA Sustainable Facilities Tool (SFTool)- https://sftool.gov/
- AIA 2030 Palette - http://2030palette.org/
- AIA COTE Tool kit: https://network.aia.org/blogs/michael-w-lassel-aia-leed-ap1/2019/08/29/aia-cote-toolkit

Vertical Fin Shading structure at Tooker Hall, ASU

CASE STUDY

Tooker House-Residence Hall

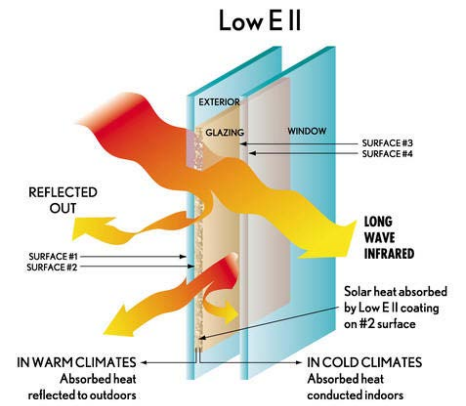
Arizona State University

Tempe, AZ

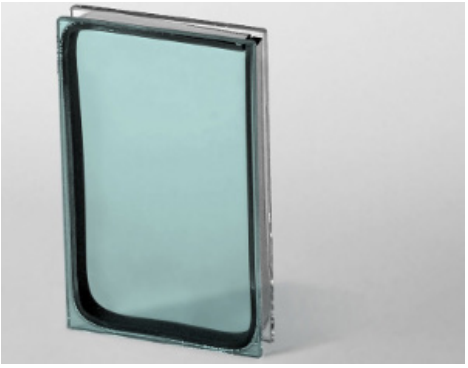
The southern facade of the building has a system of perforated aluminum vertical louvers that transition to a sandstone panel facade with punched aluminum windows. The facade design is based on a sun shading analysis to reduce the solar heat gain by 20-25%.

Other References:

- Phoenix Central Library, AZ
- ASU Student Pavilion, AZ
- AIA Top ten: http://www.aiatopten.org/



Shading Structure



Vitro- Solar ban90 Low E Glass

High Performance Glazing

Solar heat gain through windows is one of the major sources of cooling load for buildings in hot-arid climates like that of Tempe. Hence changing the type and performance of the glazing can have a significant impact, larger than any other single strategy, on the energy flow through the building. High performance glazing is one of the widely accepted measure that is seen as mandatory for hot-arid climates.

Strategy Description

High performance glazing has features like Low SHGC, Low Emissivity, and heat Reflection without compromising on the visibility This is usually achieved by specially treated glass or by the use of special coatings and films. Window systems with low-e and spectrally selective coatings can filter damaging UV wavelengths and increase the life of room furnishings. Optimized fenestration systems for daylighting in commercial/industrial buildings will reduce loads and save O&M costs.

Technical Links

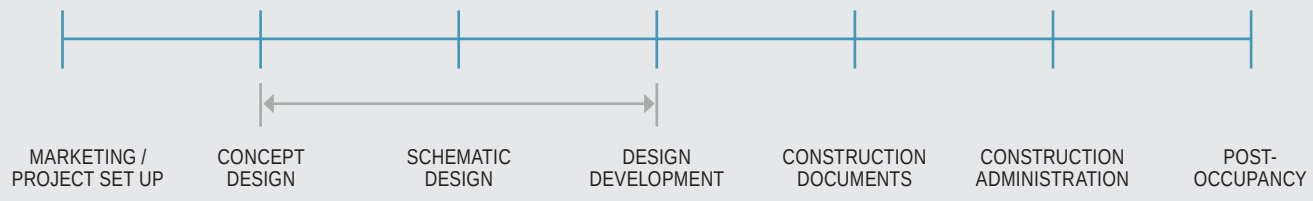
- Solar Ban Low-E glass: https://www.vitroglazings.com/
- Sun Guard Low-E Glass: https://www.guardianglass.com/

Building Typologies & Project Type

Applicable application to primary Tempe building typologies and project types.

	COMMUNITY SERVICES	FIRE STATIONS	HISTORIC BUILDINGS	OFFICE SPACES	POLICE / COURTS	SPORTS FACILITY	UTILITY	WATER MANAGEMENT
NEW CONSTRUCTION	X	X	X	X	X	X	X	X
MAJOR RENOVATION	X	X	X	X	X	X	X	X
MODERNIZATION								

Project Timeline Application & Implementation



Holistic Design Implementation

High performance glazing for a project needs to be factored into the daylighting analysis, HVAC load calculations of the project. Hence it needs to be explored earlier in the design development phase of the project. Although it is relatively easy to retrofit buildings with high performance glazing, considering this option while new construction gives the designers the opportunity to full take advantage of the energy savings achieved.

Operations and Maintenance

- Glare control, especially in commercial and industrial applications should be addressed. Limiting contrast ratios and providing visual comfort in the field of view is critical, particularly in daylighting applications.
- Condensation problems occurs when the glass surface temperature falls below the dew point of the room air. It can damage window and wall elements and obstruct views.

Relevant Codes & Standards

- City of Tempe current codes - ASHRAE 90.1 2016 / IECC 2018.
- Latest and Advanced codes - IECC 2021, IGCC 2021, ASHRAE 90.1 2019/Zero code, ASHRAE Standard 189 2020

Fenestration Energy Ratings:

- The North American Fenestration Standard (NAFS)
- National Fenestration Rating Council (NFRC).

Associations And Organizations

- American Architectural Manufacturers Association (AAMA) (http://www.aamanet.org/)
- Efficient Windows Collaborative (http://www.efficientwindows.org/)
- National Glass Association (http://www.glass.org/)
- Windows for High Performance Commercial Buildings, (http://www.commercialwindows.org)

Phoenix central library glazing on South Facade.

Phoenix central library glazing on North Facade.

CASE STUDY

Phoenix Central Library

Phoenix, AZ

Phoenix Central Library is one of the best examples to illustrate how the sun path and facade orientation can shape the design. The full glazed North facade is low e fitted with vertical fabric sails to admit light and views into the space. The south facade has computer controlled horizontal aluminum louvers to minimize the direct solar heat gain

Typical Glazing Properties:

- Green-tinted insulating low-E glass
- U-factor=0.31, SHGC=0.37, VT=0.65

Entry Glazing Properties:

- Clear insulating low-E glass
- U-factor=0.31, SHGC=0.53, VT=0.76

Preferred Design & Analysis Tools

Window properties :

- NRFC Certfied Products Directory-http://search.nfrc.org/search/searchDefault.aspx
- FACADE DESIGN TOOL - https://www.commercialwindows.org/fdt.php
- WINDOW, https://windows.lbl.gov/software/window
- Product selection tool - https://www.vitrum.ca/performance-data/
- Energy Star Windows: https://www.energystar.gov

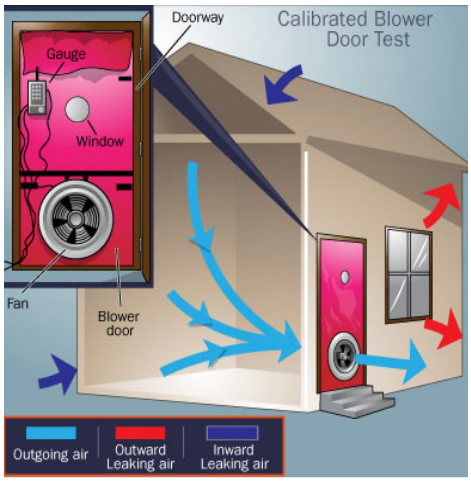
Window Strategy- Analysis :

- Cove tool, Energy plus, Sefaira, IES VE, eQuest
- Computational Fluid Dynamics (CFD)—This advanced computer-based analysis method can help analyze the effects of complex fenestration systems on air currents and interior ventilation patterns. For more information: http://www.cfd-online.com/

Design guidance:

- Whole Building Design guide (WBDG)- https://www.wbdg.org/resources/windows-and-glazing
- GSA Sustainable Facilities Tool (SFTool)- https://sftool.gov/
- AIA 2030 Palette - http://2030palette.org/
- AIA COTE Tool kit: https://network.aia.org/blogs/michael-w-lassel-aia-leed-ap1/2019/08/29/aia-cote-toolkit

Example of a Blower Door Test equipment



Blower Door Test Working principle

Blower Door Test for Infiltration reduction

Infiltration and ex filtration of air in buildings have negative consequences if left uncontrolled and untreated. They disrupt the air pressure creating additional load on the HVAC systems, entrain pollutants, moisture, disrupting air quality and comfort with in the space. Maintaining Air tightness in buildings improves energy efficiency, indoor air quality and thermal comfort. Blow door test is a standard procedure that determines airtightness of a building, it provides information about air leakage and energy loss that helps in identifying best sealing measures and choosing an efficient air barrier.

Strategy Description

Blower door testing is a process carried out to determine air infiltration rate of a building. A blower door device consists of three components - a series of calibrated fans that can both pressurize and depressurize a building to a prescribed pressure, a door panel system to temporarily seal an exterior doorway and a digital manometer to measure air flow and building pressure. This test combined with thermal imaging makes finding deficiencies in the building envelope easy.

Building Typologies & Project Type

Applicable application to primary Tempe building typologies and project types.

	COMMUNITY SERVICES	FIRE STATIONS	HISTORIC BUILDINGS	OFFICE SPACES	POLICE / COURTS	SPORTS FACILITY	UTILITY	WATER MANAGEMENT
NEW CONSTRUCTION	X	X	X	X	X	X	X	X
MAJOR RENOVATION	X	X	X	X	X	X	X	X
MODERNIZATION	X	X	X	X	X	X	X	X

Project Timeline Application & Implementation

Holistic Design Implementation

Blower door testing is a widely used measure undertaken as a part of retrofitting buildings with newer HVAC systems. In new construction buildings, blower door tests are typically conducted after the building envelope is completed, although it can be done right after completion of the continuous air barrier system.

Operations and Maintenance

To minimize disruption to subcontractors working in new buildings or tenants in occupied buildings, tests can be conducted at night or during weekends.

Relevant Codes & Standards

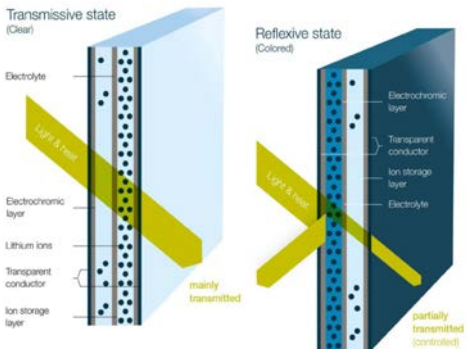
- City of Tempe current codes - ASHRAE 90.1 2016 / IECC 2018.
- Latest and Advanced codes - IECC 2021, IGCC 2021, ASHRAE 90.1 2019/Zero code, ASHRAE Standard 189 2020
- WBDG Federal Facility Criteria. Link to the source can be found here - https://www.wbdg.org/ffc/federal-facility-criteria
- Energy Policy Act of 2005

Demonstration of conducting a Blower Door Test

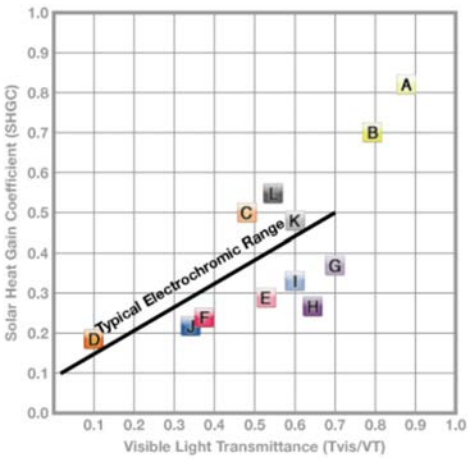
CASE STUDY

Blow Door Testing

The International Energy Conservation Code (IECC) once required building envelope leakage of 7 ACH50 in 2009, but now 2018 code requires 3 and 5 ACH50 in most of the country. This downward trend in leakage requirements indicates building codes will continue to get more stringent over time as builders get used to the standards, and as products and technologies improve. Achieving an ACH50 of 3-5 is more than doable.



Electrochromic Process



Electrochromic Peformance

Electrochromic Glazing

The sun is dynamic moving across the sky throughout the day and annual cycle. It is not possible to block the direct glare of the sun with static shading through all times of the year on the East, South and West facades. Electrochromic provides the opportunity of a dynamic shading system to shade from the sun during different times of times of the year without the risk of physically kinetic shading systems which have a greater risk of failing due to the movement of the system.

Strategy Description

Electrochromic glazing is an active glass technology that uses electricity to control the transmissivity of the light through the glass. Depending on the amount of voltage applied, the glass changes its tint from clear to darker state.

Technical Links:

- Halio electrochromic glass: https://www.kinestral.com/
- Sage Glass electrochromic glass: https://www.sageglass.com/en
- View electrochromic glass: https://view.com/

Building Typologies & Project Type

Applicable application to primary Tempe building typologies and project types as shown in the table below

	COMMUNITY SERVICES	FIRE STATIONS	HISTORIC BUILDINGS	OFFICE SPACES	POLICE / COURTS	SPORTS FACILITY	UTILITY	WATER MANAGEMENT
NEW CONSTRUCTION	X			X	X	X	X	X
MAJOR RENOVATION	X			X	X	X	X	X
MODERNIZATION								

Project Timeline Application & Implementation

Holistic Design Implementation

Exploring electrochromic glazing early in the design process is critical to discern plausibility of implementation due to the unique characteristics of the glazing and cost considerations.

To effectively capitalize on the economic and energy savings of electrochromic glazing, the mechanical design must incorporate the values of the tinted glazing into their calculations. However this does create the difficulty that if the glazing is not tinted when it is designed to be tinted, the HVAC system may not successfully bring the zone down the design temperature as the load will then be higher than it was designed for. Coordination must be orchestrated between the design time and operations to ensure all parties concur to when the glazing will be tinted ensuring that the glazing will be able to operate as intended in the design.

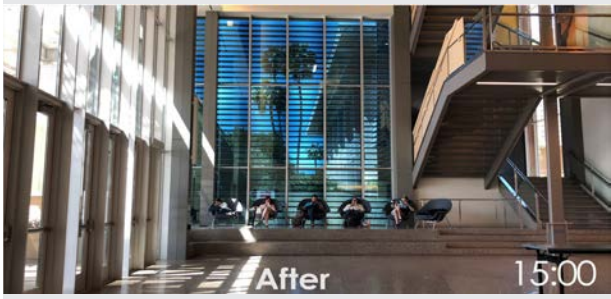
Operations and Maintenance

- Due to the dynamic components of electrochromic glazing, there is a increased risk that the switchable glazing component may fail. To mitigate this issue many manufacturers offer a warranty that will replace a failed unit for multiple years after completion of construction.
- While electrochromic glazing can bring the visible transmittance of the glass down to 1% in tinted phase, reducing most glare conditions, some occupants have identified to be experiencing glare from the point of the sun when the sun is within direct view. Depending on the angle of the sun, some alternate shading might be needed to prevent that.
- Can be challenging to install them as a part of older building retrofits, as electricity should be run to each window for the entire facade. It needs to be evaluated per case basis to understand the cost and advantage for the particular building.

Relevant Codes & Standards

- City of Tempe current codes - ASHRAE 90.1 2016 / IECC 2018.
- Latest and Advanced codes - IECC 2021, IGCC 2021, ASHRAE 90.1 2019/Zero code, ASHRAE Standard 189 2020
- WBDG Federal Facility Criteria is the source for the full text of all federal construction documents including Department of Defense Unified Facilities Guide Specifications (UFGS), Unified Facilities Criteria (UFC) and Federal Publications and Standards. Link to the source can be found here - https://www.wbdg.org/ffc/federal-facility-criteria
- Energy Policy Act of 2005

ASU Pavilion Clear Glazing



ASU Pavilion Tinted Glazing

CASE STUDY

Student Pavilion

Arizona State University

Tempe, AZ

Electrochromic glazing is located at the lobby and first floor conference halls of the ASU Student Pavilion. Within 15 minutes the lobby can go from clear glazing to full-tint blocking 99% of visible light. When the tinting is no longer needed it can be switched to off and be clear again within 15 minutes. Not only does this tint reduce the solar heat gain impacts on the Pavilion but also facilitates a more comfortable environment by reducing glare and radiant heat experienced by occupants.

Other Case studies for Reference:

- Chabot College Community and Student Services Center, Hayward, CA,

STRATEGY 5 (CONTINUED)

Fenestration Energy Ratings:

- The North American Fenestration Standard/Specification for windows, doors and skylights (AAMA/WDMA/ CSA 101/I.S.2/ A440) provides a method for rating the structural performance, water resistance and air leakage of fenestration products.
- The International Glazing Database (IGDB) is a collection of optical data for glazing products. LBNL maintains and publishes the IGDB. Ratings are available through the National Fenestration Rating Council (NFRC).

Associations And Organizations

- American Architectural Manufacturers Association (AAMA) (http://www.aamanet.org/)—Trade association of firms engaged in the manufacture and sale of building fenestration components and related products.
- Efficient Windows Collaborative (http://www.efficientwindows.org/)—Provides information on the benefits of energy-efficient windows in houses throughout the US. Now a part of NRFC.
- National Fenestration Rating Council (NFRC) (http://www.nfrc.org/) - A non-profit public/private collaboration of manufacturers, builders, designers, specifiers, code officials, consumers, utilities, and regulators working towards a national energy performance rating system for fenestration products.
- National Glass Association (http://www.glass.org/)

Other Resources and Links:

- Guidance for NFRC dynamic glazing rating system and label:
  - See Section 4.3.4.4 Dynamic glazing products, Page 27 of https://cdn.ymaws.com/nfrccommunity.site-ym.com/resource/resmgr/2017_program_docs/NFRC_700-2017_E0A0.pdf
  - https://cdn.ymaws.com/www.nfrccommunity.org/resource/resmgr/factsheets_2013/dynamicglazing2.pdf,
- NRFC Certfied Products Directory - http://search.nfrc.org/search/searchDefault.aspx,
- GANA - DYNAMIC GLAZING FOR HIGH PERFORMANCE BUILDINGS - https://sageglass.com/sites/default/files/gana-05-0911_dynamic_glazing_for_high_performance_buildings.pdf
- National Renewable Energy Laboratory's Research Support Facility, Denver, CO

Other Resources:

- Smart windows Simulation Study by LBNL: https://windows.lbl.gov/simulations-typical-office-installation Simulation of a typical office installations performed by Berkely lab (indicate that smart windows with lighting controls in arid climates can provide 30-40% energy savings over conventional windows).
- AIA Top ten:http://www.aiatopten.org/
- New Buildings Institute - https://newbuildings.org/case-studies/

Preferred Design & Analysis Tools

Window properties :

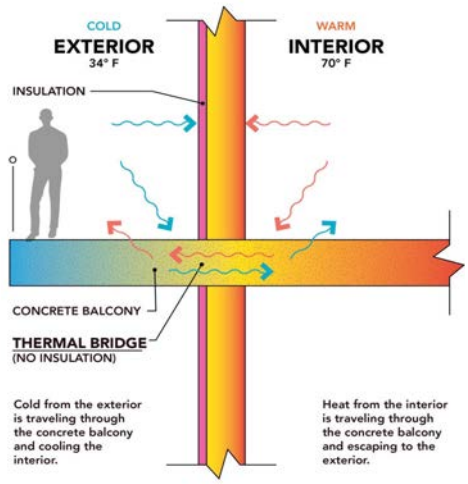
- NRFC Certfied Products Directory-http://search.nfrc.org/search/searchDefault.aspx
- FACADE DESIGN TOOL - https://www.commercialwindows.org/fdt.php - The Facade Design Tool provides options to choose the design conditions of a window and rank and compare the performance data in terms of annual energy, peak demand, carbon, daylight illuminance, glare, and thermal comfort.
- WINDOW, https://windows.lbl.gov/software/window a federally funded computer program developed by Lawrence Berkeley National Laboratory (LBNL), calculates U-values, SHGC, and Tvis of window systems constructed from glass and frames of known properties.
- Product selection tool - https://www.vitrum.ca/performance-data/ Helps to choose a specific or high performance glass by their performance parameters.
- Energy Star Windows: https://www.energystar.gov

Window Strategy- Analysis :

- Cove tool, Energy plus, Sefaira, IES VE, eQuest
- Computational Fluid Dynamics (CFD)—This advanced computer-based analysis method can help analyze the effects of complex fenestration systems on air currents and interior ventilation patterns. For more information: http://www.cfd-online.com/

Design guidance:

- Whole Building Design guide (WBDG)- https://www.wbdg.org/resources/windows-and-glazing
- GSA Sustainable Facilities Tool (SFTool)- https://sftool.gov/
- AIA 2030 Palette - http://2030palette.org/
- AIA COTE Tool kit: https://network.aia.org/blogs/michael-w-lassel-aia-leed-ap1/2019/08/29/aia-cote-toolkit



Thermal Bridging Diagram


Without Thermal Break


With Thermal Break

Thermal Breaks for Thermal Bridging

Current trends in energy codes are pushing the building construction industry towards greater energy efficiency. A big part of this shift is through reducing heat loss through the building envelope by minimizing thermal bridging. Hence thermal performance of the building envelope is a key design consideration in meeting today's stringent energy efficiency standards. Thermal bridging has a considerable impact on the performance of building envelope, thermal breaks will provide a solution to mitigate the impact.

Strategy Description

A thermal break is a material with low thermal conductivity, placed in an assembly, to reduce or prevent the flow of thermal energy between the inside and outside of a building.

Technical Links:

- Armadillo NV Inc- www.armadillonvinc.com
- Halfen Anchoring Systems - www.halfenusa.com
- Schoeck Canada Inc.- http://www.schock-us.com/

Building Typologies & Project Type

Applicable application to primary Tempe building typologies and project types.

	COMMUNITY SERVICES	FIRE STATIONS	HISTORIC BUILDINGS	OFFICE SPACES	POLICE / COURTS	SPORTS FACILITY	UTILITY	WATER MANAGEMENT
NEW CONSTRUCTION	X			X	X	X	X	X
MAJOR RENOVATION	X			X	X	X	X	X
MODERNIZATION								

Project Timeline Application & Implementation

Holistic Design Implementation

Design performance modeling prior to whole building energy modeling helps design teams to evaluate options and prioritize energy saving measures. As part of the early design stage evaluation process, thermal modeling will quantify thermal bridging heat loss and provide more accurate assembly U values. After identifying these values, thermal breaks might be deployed on a case-by-case basis to mitigate the thermal bridging effects. Collaboration at this stage with structural engineers is required to incorporate thermal breaks into the design and create high-performing, cost effective steel framed buildings with long-term energy savings in mind.

Relevant Codes & Standards

- City of Tempe current codes - ASHRAE 90.1 2016 / IECC 2018.
- Latest and Advanced codes - IECC 2021, IGCC 2021, ASHRAE 90.1 2019/Zero code, ASHRAE Standard 189 2020
- WBDG Federal Facility Criteria. Link to the source can be found here - https://www.wbdg.org/ffc/federal-facility-criteria
- Energy Policy Act of 2005

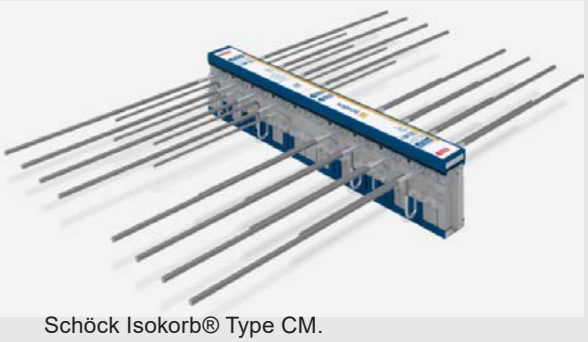
Other resources:

Research on details and thermal bridging challenges is being pursued by AISC. The updates, new findings, will be available at www.aisc.org/sustainability.

Preferred Design & Analysis Tools

- COMcheck, REScheck, WUFI and whole building energy modelling can be used to determine Building envelope performance.
- THERM- Heat transfer computer program. The program was developed by the Lawrence Berkeley National Laboratory, can be used to model two-dimensional details with thermal parameters of the various materials, and generate an average U-value of the area modeled

Candela Lofts building in NY/NJ Metro area.



Schöck Isokorb® Type CM.
For concrete-to-concrete balconies

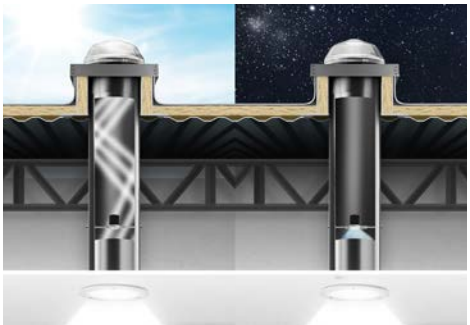
CASE STUDY

Candela Lofts

New York, NY

Candela Lofts in Metro area NY is a 30,000 sft 7 story structure which employed thermal break methods like Facade clips made of fiberglass. 9.5 in. thick mineral wool insulation. According to Schöck Isokorb, the manufacturer of thermal breaks used in Candela Lofts, structural thermal breaks reduce heat loss at balcony penetrations by up to 90% and up to 14% for a building overall.

Tubular Daylighting System



Roof Section with Architectural Lighting

Tubular Daylighting Devices

As the demand for renewable sources is increasing, harvesting natural light into the building has the potential to provide significant energy and cost savings. These benefits extend beyond savings, it helps improve comfort, health, mood and boosts productivity in a work/learning environment.

Strategy Description

Tubular Daylighting Devices (TDDs) is an energy efficient top lighting approach that harvests natural sunlight throughout the day. It employs a patented optical technology that captures the light and channels it into the interiors of the building through a series of reflectors and lenses, thereby delivering glare free light which makes it an ideal lighting strategy. The Infrared and UV rays are filtered out to prevent overheating of interiors and to make the light safer than direct sunlight.

Technical Links

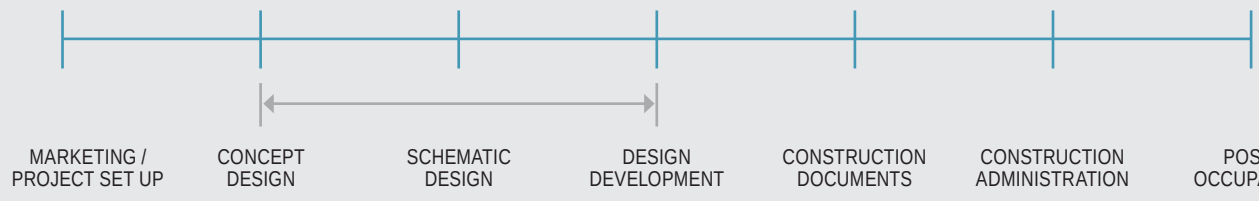
- Solatube Daylighting Device: https://www.solatube.com
- Sunoptics Daylighting system: https://sunoptics.acuitybrands.com
- Velux Light tubes: https://www.veluxusa.com/

Building Typologies & Project Type

Applicable application to primary Tempe building typologies and project types.

	COMMUNITY SERVICES	FIRE STATIONS	HISTORIC BUILDINGS	OFFICE SPACES	POLICE / COURTS	SPORTS FACILITY	UTILITY	WATER MANAGEMENT
NEW CONSTRUCTION	X			X	X	X	X	X
MAJOR RENOVATION	X			X	X	X	X	X
MODERNIZATION								

Project Timeline Application & Implementation



Holistic Design Implementation

Tubular Daylighting strategy is effective when integrated early in the design process to achieve the desired quality of lighting within each space. Its performance should be evaluated alongside other daylighting strategies that eventually influence the overall efficacy of daylighting. It is extremely critical to coordinate the design and installation with other disciplines (Structural, MEP, Interiors) right from the conception, to identify potential conflicts that may arise in future; for example,care should be taken while positioning the TDDs on the thermal boundary and make them airtight to prevent any ex-filtration or infiltration of unconditioned air, furthermore any other roof elements like HVAC rooftop systems or PV systems should be positioned not to obstruct / shadow the TDD.

Operations and Maintenance

Leaking concerns, internal dirt issues due to installation defects or overtime external eroding will effect the quality of light. Regular maintenance on exposed roof side components is required to minimize the degradation of performance.

Relevant Codes & Standards

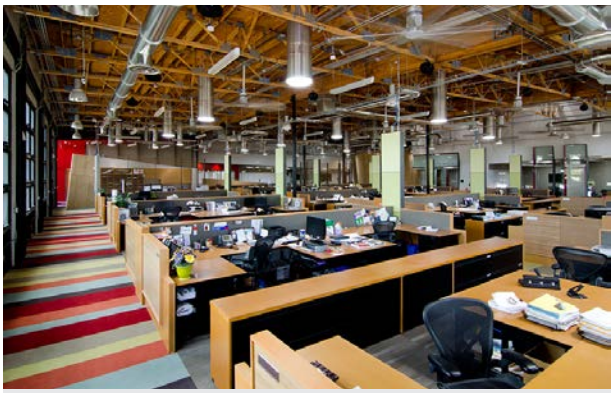
- City of Tempe current codes - ASHRAE 90.1 2016 / IECC 2018
- Latest and Advanced codes - IECC 2021, IGCC 2021, ASHRAE 90.1 2019/Zero code, ASHRAE Standard 189 2020.
- The Latest IECC 2021 code adds NFRC203 test procedure and minimum requirements for Tubular Daylighting Devices(TDD).
- WBDG Federal Facility Criteria. Link to the source can be found here - https://www.wbdg.org/ffc/federal-facility-criteria
- Energy Policy Act of 2005

Preferred Design & Analysis Tools

Daylight Visualization tools for design studies : Cove tool, Sefaira, DIVA, radiance, Ladybug, AGi32, Daysim

Design guidance:

- Whole Building Design guide (WBDG)- https://www.wbdg.org/
- GSA Sustainable Facilities Tool (SFTool)- https://sftool.gov/
- AIA 2030 Palette - http://2030palette.org/
- AIA COTE Tool kit: https://network.aia.org/blogs/michael-w-lassel-aia-leed-ap1/2019/08/29/aia-cote-toolkit



Tubular Daylit Workstations

CASE STUDY

DPR Construction Regional Office

Phoenix, AZ

The 16000 sft Office space has over 82 Solatubes strategically installed throughout the facility to bring daylight into all the spaces. Through some analysis and lighting studies, the appropriate height, location and size of the Solatube units was determined which helped for an even distribution of daylight throughout the space. It reduced the load on artificial lighting which helped in downsizing the Photo-voltaic system. Beyond just reducing energy, it connects employees to the daily cycle of the sun, entraining their circadian rhythms, relieving stress and improving productivity.

Other References:

- ASU Student Pavilion, Tempe,AZ
- Mesa Rim Climbing Gym, San Diego, CA
- AIA Top ten:http://www.aiatopten.org/

Energy

HVAC

Facility	Tempe Building Category	Future Master Plan Recommendations	HVAC CURRENT Primary System(s) Summary	HVAC MODERNIZATION Primary System(s) Summary Option 1
525 Office Building	Municipal Complex	Modernization (TBD)	Mixed OA/RA FCUs (CHW from District CHW Plant) with Electric Duct Heaters	Replacement of fan coil units as needed per maintenance assessment
Apache Police Department - Administration	Police/Courts	Modernization (2037)	VAV AHU (CHW from Apache Central Plant, HW from Apache Central Plant)	Replacement of VAV AHU components as needed per maintenance assessment. Verify Advanced VAV controls are functional, including economizer operation.
City Hall - Garden Level East Offices	Municipal Complex	Modernization (TBD)	Mixed OA/RA FCUs (CHW from District CHW Plant, HW from local boiler)	Replacement of boiler with high efficiency condensing boiler
City Hall - Garden Level West Offices	Municipal Complex	Modernization (TBD)	Mixed OA/RA FCUs (CHW from District CHW Plant, HW from local boiler)	Replacement of boiler with high efficiency condensing boiler
Diablo Stadium - Main Stadium	Sports Facility	Master Plan Implementation (TBD)	Multiple Split/Packaged DX/Heat Pumps	
Diablo Stadium - Maintenance Building	Sports Facility	Replacement (2034)	Packaged DX/Gas Heat RTU & Gas Unit Heater for Service Bay	
Escalante Building	Community Services	Modernization (2029)	Multiple Split/Packaged DX/Heat Pumps	Replacement of DX/Heat Pumps with current availability high efficiency units

HVAC MODERNIZATION Primary System(s) Summary Option 2	HVAC MAJOR RENOVATION AND/OR REPLACEMENT Primary System(s) Summary ASHRAE 90.1-2016 Baseline	HVAC MAJOR RENOVATION AND/OR REPLACEMENT Primary System(s) Summary High Performance Option 1: Advanced VAV w/ Reheat or Evaporative Cooling Unit	HVAC MAJOR RENOVATION AND/OR REPLACEMENT Primary System(s) Summary High Performance Option 2: Active Chilled Beams	HVAC MAJOR RENOVATION AND/OR REPLACEMENT Primary System(s) Summary High Performance Option 3: Displacement Ventilation
	Packaged VAV with Parallel Fan-Powered Boxes. Packaged VAV via DX cooling, Electric Resistance Heating. PFP box re-heat via Electric Resistance. Economizer required.	VAV with HW Reheat. CHW/HW via Air-Cooled Heat Pump Chiller modules that can produce CHW/HW simultaneously. Economizer required. Separate single-zone units with Demand Control Ventilation serving variable occupancy zones.	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/Medium-temp CHW loops for DOAS dehumidification and Active Chilled Beam dew point control OR add DX/Heat Pump DOAS and select Chiller modules for medium-temp CHW. 2 or 4 pipe Active Chilled Beams in occupied zones.	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/Medium-temp CHW loops for elevated Supply Air delivery temperature OR add DX/Heat Pump DOAS and select Chiller modules for medium-temp CHW. Displacement Ventilation diffusers/diffuser columns in all spaces.
Replacement of AHU with DOAS unit. Removal of VAV boxes and replacement with 2-pipe Active Chilled Beams. Limitation: Required CHW Loop delta T and existing medium/low pressure duct sizes.	Packaged VAV with Parallel Fan-Powered Boxes. Packaged VAV via DX cooling, Electric Resistance Heating. PFP box re-heat via Electric Resistance. Economizer required.	VAV with HW Reheat. CHW/HW via Air-Cooled Heat Pump Chiller modules that can produce CHW/HW simultaneously. Economizer required. Separate single-zone units with Demand Control Ventilation serving variable occupancy zones.	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/Medium-temp CHW loops for DOAS dehumidification and Active Chilled Beam dew point control OR add DX/Heat Pump DOAS and select Chiller modules for medium-temp CHW. 2 or 4 pipe Active Chilled Beams in occupied zones.	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/Medium-temp CHW loops for elevated Supply Air delivery temperature OR add DX/Heat Pump DOAS and select Chiller modules for medium-temp CHW. Displacement Ventilation diffusers/diffuser columns in all spaces.
	Packaged VAV with Parallel Fan-Powered Boxes. Packaged VAV via DX cooling, Electric Resistance Heating. PFP box re-heat via Electric Resistance. Economizer required.	VAV with HW Reheat. CHW/HW via Air-Cooled Heat Pump Chiller modules that can produce CHW/HW simultaneously. Economizer required. Separate single-zone units with Demand Control Ventilation serving variable occupancy zones.	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/Medium-temp CHW loops for DOAS dehumidification and Active Chilled Beam dew point control OR add DX/Heat Pump DOAS and select Chiller modules for medium-temp CHW. 2 or 4 pipe Active Chilled Beams in occupied zones.	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/Medium-temp CHW loops for elevated Supply Air delivery temperature OR add DX/Heat Pump DOAS and select Chiller modules for medium-temp CHW. Displacement Ventilation diffusers/diffuser columns in all spaces.
	Packaged VAV with Parallel Fan-Powered Boxes. Packaged VAV via DX cooling, Electric Resistance Heating. PFP box re-heat via Electric Resistance. Economizer required.	VAV with HW Reheat. CHW/HW via Air-Cooled Heat Pump Chiller modules that can produce CHW/HW simultaneously. Economizer required. Separate single-zone units with Demand Control Ventilation serving variable occupancy zones.	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/Medium-temp CHW loops for DOAS dehumidification and Active Chilled Beam dew point control OR add DX/Heat Pump DOAS and select Chiller modules for medium-temp CHW. 2 or 4 pipe Active Chilled Beams in occupied zones.	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/Medium-temp CHW loops for elevated Supply Air delivery temperature OR add DX/Heat Pump DOAS and select Chiller modules for medium-temp CHW. Displacement Ventilation diffusers/diffuser columns in all spaces.
	Packaged CV RTU Heat Pump w/ Economizer	Packaged Direct/Indirect Evaporative Cooling Unit w/ integrated Heat Pump Cooling/Heating secondary system. 100% Outside Air operation as option.	NA	NA
	Packaged VAV with Parallel Fan-Powered Boxes. Packaged VAV via DX cooling, Electric Resistance Heating. PFP box re-heat via Electric Resistance. Economizer required.	VAV with HW Reheat. CHW/HW via Air-Cooled Heat Pump Chiller modules that can produce CHW/HW simultaneously. Economizer required. Separate single-zone units with Demand Control Ventilation serving variable occupancy zones.	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/Medium-temp CHW loops for DOAS dehumidification and Active Chilled Beam dew point control OR add DX/Heat Pump DOAS and select Chiller modules for medium-temp CHW. 2 or 4 pipe Active Chilled Beams in occupied zones.	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/Medium-temp CHW loops for elevated Supply Air delivery temperature OR add DX/Heat Pump DOAS and select Chiller modules for medium-temp CHW. Displacement Ventilation diffusers/diffuser columns in all spaces.

Facility	Tempe Building Category	Future Master Plan Recommendations	HVAC CURRENT Primary System(s) Summary	HVAC MODERNIZATION Primary System(s) Summary Option 1
Fire Station 3	Fire	Modernization or Replacement (2027)	Split DX/Gas Furnace Heat & Evaporative Cooler/Gas Unit Heater for Truck Bay	Replacement of DX units with current availability high efficiency units
Hardy Substation - South Police Department	Police/Courts	Modernization (2033)	Multiple Split DX/Heat Pumps & Evaporative Cooler w/ Gas Heat for Shooting Range	Replacement of DX/Heat Pumps with current availability high efficiency units
Kiwanis Park - Maintenance Building	Service Yard	Replacement (2031)	Multiple Split DX/Heat Pumps & Evaporative Coolers	
Kiwanis Park - Recreation Center	Sports Facility	Modernization (2030)	Multiple Packaged DX/Gas Heat RTU/MAU	Replacement of DX MAU/RTUs with current availability high efficiency units
Kiwanis Police Department - Equine Facility	Police/Courts	Replacement (2028)	Evaporative Cooler	
Kiwanis Vehicle Maintenance South	Service Yard	Replacement (2031)	Evaporative Coolers & Gas Infrared for Service Bay	
Library Complex - Edna Vihel Community Center	Community Services	Demolition (2024)	Multiple Packaged Heat Pumps	
Library Complex - Historical Museum	Community Services	Modernization (2032)	CV AHU (CHW from library chiller) w/ multiple electric duct heaters	Replacement of CV AHU components as needed per maintenance assessment

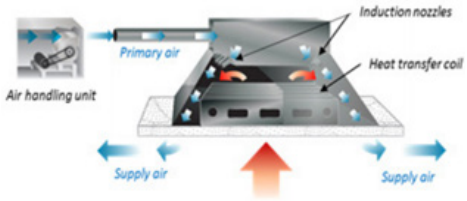
HVAC MODERNIZATION Primary System(s) Summary Option 2	HVAC MAJOR RENOVATION AND/OR REPLACEMENT Primary System(s) Summary ASHRAE 90.1-2016 Baseline	HVAC MAJOR RENOVATION AND/OR REPLACEMENT Primary System(s) Summary High Performance Option 1: Advanced VAV w/ Reheat or Evaporative Cooling Unit	HVAC MAJOR RENOVATION AND/OR REPLACEMENT Primary System(s) Summary High Performance Option 2: Active Chilled Beams	HVAC MAJOR RENOVATION AND/OR REPLACEMENT Primary System(s) Summary High Performance Option 3: Displacement Ventilation
	Packaged CV RTU Heat Pump w/ Economizer	Packaged Direct/Indirect Evaporative Cooling Unit w/ integrated Heat Pump Cooling/ Heating secondary system. 100% Outside Air operation as option.	NA	NA
	Packaged VAV with Parallel Fan-Powered Boxes. Packaged VAV via DX cooling, Electric Resistance Heating. PFP box re-heat via Electric Resistance. Economizer required.	VAV with HW Reheat. CHW/ HW via Air-Cooled Heat Pump Chiller modules that can produce CHW/HW simultaneously. Economizer required. Separate single-zone units with Demand Control Ventilation serving variable occupancy zones.	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/ Medium-temp CHW loops for DOAS dehumidification and Active Chilled Beam dew point control OR add DX/ Heat Pump DOAS and select Chiller modules for medium-temp CHW. 2 or 4 pipe Active Chilled Beams in occupied zones.	NA
	Packaged CV RTU Heat Pump w/ Economizer	Packaged Direct/Indirect Evaporative Cooling Unit w/ integrated Heat Pump Cooling/ Heating secondary system. 100% Outside Air operation as option.	NA	NA
	Packaged CV RTU Heat Pump w/ Economizer	VAV with HW Reheat. CHW/ HW via Air-Cooled Heat Pump Chiller modules that can produce CHW/HW simultaneously. Economizer required. Separate single-zone units with Demand Control Ventilation serving variable occupancy zones.	Pool/Gym Zones: VAV recommended Office Zones: Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/Medium-temp CHW loops for DOAS dehumidification and Active Chilled Beam dew point control OR add DX/ Heat Pump DOAS and select Chiller modules for medium-temp CHW. 2 or 4 pipe Active Chilled Beams in occupied zones.	NA
	Packaged CV RTU Heat Pump w/ Economizer	Packaged Direct/Indirect Evaporative Cooling Unit w/ integrated Heat Pump Cooling/ Heating secondary system. 100% Outside Air operation as option.	NA	NA
	Packaged CV RTU Heat Pump w/ Economizer	Packaged Direct/Indirect Evaporative Cooling Unit w/ integrated Heat Pump Cooling/ Heating secondary system. 100% Outside Air operation as option.	NA	NA
Replacement of AHUs with DOAS units. Addition of 2/4-pipe Active Chilled Beams. Limitation: Air-Cooled Heat Pump added to Library plant, significant hydronic piping added in occupied zones.	Packaged VAV with Parallel Fan-Powered Boxes. Packaged VAV via DX cooling, Electric Resistance Heating. PFP box re-heat via Electric Resistance. Economizer required.	VAV with HW Reheat. CHW/ HW via Air-Cooled Heat Pump Chiller modules that can produce CHW/HW simultaneously. Economizer required. Separate single-zone units with Demand Control Ventilation serving variable occupancy zones.	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/ Medium-temp CHW loops for DOAS dehumidification and Active Chilled Beam dew point control OR add DX/ Heat Pump DOAS and select Chiller modules for medium-temp CHW. 2 or 4 pipe Active Chilled Beams in occupied zones.	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/ Medium-temp CHW loops for elevated Supply Air delivery temperature OR add DX/Heat Pump DOAS and select Chiller modules for medium-temp CHW. Displacement Ventilation diffusers/diffuser columns in all spaces.

Facility	Tempe Building Category	Future Master Plan Recommendations	HVAC CURRENT Primary System(s) Summary	HVAC MODERNIZATION Primary System(s) Summary Option 1
Library Complex - Library	Community Services	Modernization (2038)	VAV AHU (CHW from local chiller) & VAV w/ Electric Re-Heat	Replacement of chiller with current availability high efficiency chiller OR replacement of chiller with air-cooled heat pump chiller modules that can produce CHW and HW simultaneously and thus allow removal of VAV electric re-heat. Limitation: VAV box replacements with HW reheat and significant hydronic piping added in occupied zones.
Library Complex - Pyle Adult Center	Community Services	Modernization (2028)	Multiple Packaged DX/Gas Heat Units	Replacement of DX RTUs with current availability high efficiency units
Main Police Department - Building 1	Police/Courts	Modernization (2027)	VAV AHU (CHW from local chiller, HW from local boiler) & VAV w/ HW Re-Heat	Replacement of chiller with current availability high efficiency chiller & replacement of boiler with high efficiency condensing boiler OR replacement of chiller/boiler with air-cooled heat pump chiller modules that can produce CHW and HW simultaneously.
Main Police Department - Courts Building	Police/Courts	Modernization (2027)	VAV AHU (CHW from local District CHW Plant chiller) & VAV w/ Electric Re-Heat	Replacement of VAV AHU components as needed per maintenance assessment
North Tempe Multi-Generational Facility	Community Services	Modernization (2035)	Multiple Packaged DX/Heat Pumps and Multiple Packaged DX/Gas Heat Units	Replacement of DX/Heat Pumps with current availability high efficiency units
Orchid House Office Space	Non-Owned	Modernization (2038)	Multiple Packaged Heat Pumps	Replacement of DX/Heat Pumps with current availability high efficiency units

HVAC MODERNIZATION Primary System(s) Summary Option 2	HVAC MAJOR RENOVATION AND/OR REPLACEMENT Primary System(s) Summary ASHRAE 90.1-2016 Baseline	HVAC MAJOR RENOVATION AND/OR REPLACEMENT Primary System(s) Summary High Performance Option 1: Advanced VAV w/ Reheat or Evaporative Cooling Unit	HVAC MAJOR RENOVATION AND/OR REPLACEMENT Primary System(s) Summary High Performance Option 2: Active Chilled Beams	HVAC MAJOR RENOVATION AND/OR REPLACEMENT Primary System(s) Summary High Performance Option 3: Displacement Ventilation
Replacement of AHUs with DOAS units. Addition of 2/4-pipe Active Chilled Beams. Limitation: Air-Cooled Heat Pump added to Library plant, significant hydronic piping added in occupied zones.	Packaged VAV with Parallel Fan-Powered Boxes. Packaged VAV via DX cooling, Electric Resistance Heating. PFP box re-heat via Electric Resistance. Economizer required.	VAV with HW Reheat. CHW/HW via Air-Cooled Heat Pump Chiller modules that can produce CHW/HW simultaneously. Economizer required. Separate single-zone units with Demand Control Ventilation serving variable occupancy zones.	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/Medium-temp CHW loops for DOAS dehumidification and Active Chilled Beam dew point control OR add DX/Heat Pump DOAS and select Chiller modules for medium-temp CHW. 2 or 4 pipe Active Chilled Beams in occupied zones.	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/Medium-temp CHW loops for elevated Supply Air delivery temperature OR add DX/Heat Pump DOAS and select Chiller modules for medium-temp CHW. Displacement Ventilation diffusers/diffuser columns in all spaces.
	Packaged VAV with Parallel Fan-Powered Boxes. Packaged VAV via DX cooling, Electric Resistance Heating. PFP box re-heat via Electric Resistance. Economizer required.	VAV with HW Reheat. CHW/HW via Air-Cooled Heat Pump Chiller modules that can produce CHW/HW simultaneously. Economizer required. Separate single-zone units with Demand Control Ventilation serving variable occupancy zones.	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/Medium-temp CHW loops for DOAS dehumidification and Active Chilled Beam dew point control OR add DX/Heat Pump DOAS and select Chiller modules for medium-temp CHW. 2 or 4 pipe Active Chilled Beams in occupied zones.	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/Medium-temp CHW loops for elevated Supply Air delivery temperature OR add DX/Heat Pump DOAS and select Chiller modules for medium-temp CHW. Displacement Ventilation diffusers/diffuser columns in all spaces.
Replacement of AHU with DOAS unit. Removal of VAV boxes and replacement with 2-pipe Active Chilled Beams. Limitation: Required CHW Loop delta T and existing medium/low pressure duct sizes.	Packaged VAV with Parallel Fan-Powered Boxes. Packaged VAV via DX cooling, Electric Resistance Heating. PFP box re-heat via Electric Resistance. Economizer required.	VAV with HW Reheat. CHW/HW via Air-Cooled Heat Pump Chiller modules that can produce CHW/HW simultaneously. Economizer required. Separate single-zone units with Demand Control Ventilation serving variable occupancy zones.	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/Medium-temp CHW loops for DOAS dehumidification and Active Chilled Beam dew point control OR add DX/Heat Pump DOAS and select Chiller modules for medium-temp CHW. 2 or 4 pipe Active Chilled Beams in occupied zones.	NA
	Packaged VAV with Parallel Fan-Powered Boxes. Packaged VAV via DX cooling, Electric Resistance Heating. PFP box re-heat via Electric Resistance. Economizer required.	VAV with HW Reheat. CHW/HW via Air-Cooled Heat Pump Chiller modules that can produce CHW/HW simultaneously. Economizer required. Separate single-zone units with Demand Control Ventilation serving variable occupancy zones.	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/Medium-temp CHW loops for DOAS dehumidification and Active Chilled Beam dew point control OR add DX/Heat Pump DOAS and select Chiller modules for medium-temp CHW. 2 or 4 pipe Active Chilled Beams in occupied zones.	NA
	Packaged VAV with Parallel Fan-Powered Boxes. Packaged VAV via DX cooling, Electric Resistance Heating. PFP box re-heat via Electric Resistance. Economizer required.	VAV with HW Reheat. CHW/HW via Air-Cooled Heat Pump Chiller modules that can produce CHW/HW simultaneously. Economizer required. Separate single-zone units with Demand Control Ventilation serving variable occupancy zones.	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/Medium-temp CHW loops for DOAS dehumidification and Active Chilled Beam dew point control OR add DX/Heat Pump DOAS and select Chiller modules for medium-temp CHW. 2 or 4 pipe Active Chilled Beams in occupied zones.	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/Medium-temp CHW loops for elevated Supply Air delivery temperature OR add DX/Heat Pump DOAS and select Chiller modules for medium-temp CHW. Displacement Ventilation diffusers/diffuser columns in all spaces.
	Packaged VAV with Parallel Fan-Powered Boxes. Packaged VAV via DX cooling, Electric Resistance Heating. PFP box re-heat via Electric Resistance. Economizer required.	VAV with HW Reheat. CHW/HW via Air-Cooled Heat Pump Chiller modules that can produce CHW/HW simultaneously. Economizer required. Separate single-zone units with Demand Control Ventilation serving variable occupancy zones	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/Medium-temp CHW loops for DOAS dehumidification and Active Chilled Beam dew point control OR add DX/Heat Pump DOAS and select Chiller modules for medium-temp CHW. 2 or 4 pipe Active Chilled Beams in occupied zones.	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/Medium-temp CHW loops for elevated Supply Air delivery temperature OR add DX/Heat Pump DOAS and select Chiller modules for medium-temp CHW. Displacement Ventilation diffusers/diffuser columns in all spaces.

Facility	Tempe Building Category	Future Master Plan Recommendations	HVAC CURRENT Primary System(s) Summary	HVAC MODERNIZATION Primary System(s) Summary Option 1
Rolling Hills - Maintenance Building	Golf Courses	Replacement (2033)	Evaporative Coolers & Electric Unit Heaters	
Tempe Center For The Arts	Community Services	Modernization (2036)	Multiple CV AHUs (CHW from local chiller, HW from local boiler)	Replacement of chiller with current availability high efficiency chiller & replacement of boiler with high efficiency condensing boiler OR replacement of chiller/boiler with air-cooled heat pump chiller modules that can produce CHW and HW simultaneously.
Traffic Operations Center Covered Storage	Service Yard	Replacement (2023)	NA	
Traffic Operations Center Office	Service Yard	Replacement (2023)	Multiple Packaged Heat Pumps	
Traffic Operations Center Warehouse	Service Yard	Replacement (2023)	Multiple Evaporative Coolers & Gas Unit Heaters	
West Side Multi-Generational Building	Community Services	Modernization (2031)	Multiple Split/Packaged Heat Pumps & Multiple Packaged DX/Gas Heat Units	Replacement of DX/Heat Pumps with current availability high efficiency units

HVAC MODERNIZATION Primary System(s) Summary Option 2	HVAC MAJOR RENOVATION AND/OR REPLACEMENT Primary System(s) Summary ASHRAE 90.1-2016 Baseline	HVAC MAJOR RENOVATION AND/OR REPLACEMENT Primary System(s) Summary High Performance Option 1: Advanced VAV w/ Reheat or Evaporative Cooling Unit	HVAC MAJOR RENOVATION AND/OR REPLACEMENT Primary System(s) Summary High Performance Option 2: Active Chilled Beams	HVAC MAJOR RENOVATION AND/OR REPLACEMENT Primary System(s) Summary High Performance Option 3: Displacement Ventilation
	Packaged CV RTU Heat Pump w/ Economizer	Packaged Direct/Indirect Evaporative Cooling Unit w/ integrated Heat Pump Cooling/ Heating secondary system. 100% Outside Air operation as option.	NA	NA
Option 1 + Replacement of AHUs with DOAS units. Addition of 4-pipe Active Chilled Beams. Limitation: Required CHW Loop temperatures/delta T and the need for extensive low-pressure ductwork installed. AHU to remain for large occupancy spaces/systems.	Packaged CV RTU Heat Pump w/ Economizer	VAV with HW Reheat. CHW/ HW via Air-Cooled Heat Pump Chiller modules that can produce CHW/HW simultaneously. Economizer required. Separate single-zone units with Demand Control Ventilation serving variable occupancy zones.	Performing Arts Theater: VAV recommended Non Large Occupancy Zones: Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/ Medium-temp CHW loops for DOAS dehumidification and Active Chilled Beam dew point control OR add DX/ Heat Pump DOAS and select Chiller modules for medium-temp CHW. 2 or 4 pipe Active Chilled Beams in occupied zones.	NA
	Packaged CV RTU Heat Pump w/ Economizer	NA	NA	NA
	Packaged CV RTU Heat Pump w/ Economizer	Packaged Direct/Indirect Evaporative Cooling Unit w/ integrated Heat Pump Cooling/ Heating secondary system. 100% Outside Air operation as option.	NA	NA
	Packaged CV RTU Heat Pump w/ Economizer	Packaged Direct/Indirect Evaporative Cooling Unit w/ integrated Heat Pump Cooling/ Heating secondary system. 100% Outside Air operation as option.	NA	NA
	Packaged VAV with Parallel Fan-Powered Boxes. Packaged VAV via DX cooling, Electric Resistance Heating. PFP box re-heat via Electric Resistance. Economizer required.	VAV with HW Reheat. CHW/ HW via Air-Cooled Heat Pump Chiller modules that can produce CHW/HW simultaneously. Economizer required. Separate single-zone units with Demand Control Ventilation serving variable occupancy zones.	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/ Medium-temp CHW loops for DOAS dehumidification and Active Chilled Beam dew point control OR add DX/ Heat Pump DOAS and select Chiller modules for medium-temp CHW. 2 or 4 pipe Active Chilled Beams in occupied zones.	Air-Cooled Heat Pump Chiller modules with the ability to produce CHW/HW simultaneously. CHW delta T sized to allow Low-Temp/ Medium-temp CHW loops for elevated Supply Air delivery temperature OR add DX/Heat Pump DOAS and select Chiller modules for medium-temp CHW. Displacement Ventilation diffusers/diffuser columns in all spaces.



Active Chilled Beam operation (source: Titus-HVAC)

Active Chilled Beams for use with suspended ceiling grid systems (source: Titus-HVAC)

Active Chilled Beams

The use of water as a heat transfer medium offers considerable energy savings and potentially more efficient space usage. A water pipe can transport the same amount of cooling energy as an air duct two-hundred and fifty (250) times its cross-sectional area. This enables the employment of air-water systems in very tight ceiling spaces for retrofit applications. It also allows for closer slab spacing in new construction applications which can a) reduce the building structural cost, b) allow more floors to be added to a multi-story structure, c) result in greater floor to ceiling heights or d) any combination of these. In addition, the transport energy to deliver a similar amount of space cooling with air is more than six times that of doing so with water. In consideration of this, air-water systems are designed to maximize the sensible cooling provided by their integral water coils while reducing space primary airflows to those which are required for proper space ventilation and latent cooling (humidity control).

Strategy Description

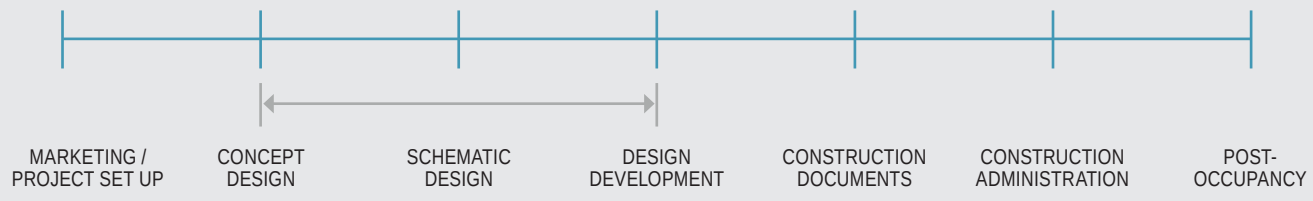
Active Chilled Beam utilize tempered chilled water supplied at or above the space dew point temperature to provide sensible cooling only. Active beams receive and transfer pretreated (ventilation) air from the air handling unit to the space. Using the ventilation air to pressurize a plenum with aerodynamically designed discharge nozzles, high velocity jets of air are created induction of room air over the water coil integral to the unit.

Building Typologies & Project Type

Applicable application to primary Tempe building typologies and project types.

	COMMUNITY SERVICES	FIRE STATIONS	HISTORIC BUILDINGS	OFFICE SPACES	POLICE / COURTS	SPORTS FACILITY	UTILITY	WATER MANAGEMENT
NEW CONSTRUCTION	X			X	X			
MAJOR RENOVATION	X			X	X			
MODERNIZATION	X			X	X			

Project Timeline Application & Implementation



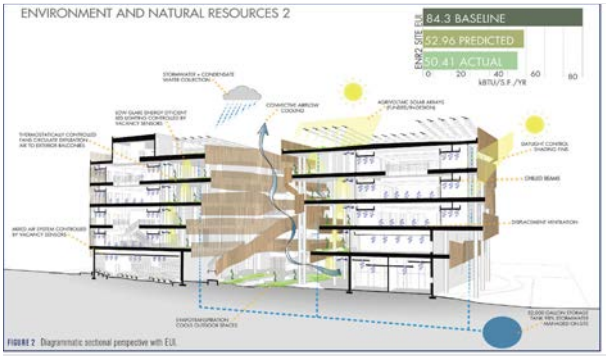
Active chilled beams may induce four (4) or more parts of room air for every one (1) part of primary air that is ducted to them. This induction ratio will depend upon the nozzles employed by the manufacturer and/or specified by the user. When supplied with conventional primary air temperatures (53 to 55°F) chilled water coils within active beams are usually capable of removing 60 to 80% of the space sensible heat gain, reducing the sensible cooling burden on the primary air accordingly. Because the temperature of water supplied to the chilled beams must be relatively warm (typically between 58°F and 60°F) to avoid unwanted condensation, the water chiller can be more efficient (higher COP) than if it was making colder water (typically between 40°F and 44°F) for central VAV air-handling units. Chilled Beams are designed to provide energy savings, excellent comfort and operate with minimal noise. When used with dedicated outdoor air systems (DOAS) and a dedicated Chilled Beam chiller, chilled beam systems can realize energy savings of 15-20%. An additional 20-25% savings can be realized from downsized ventilation systems due to the high efficiency of the water system for the sensible load.

Technical Links

- Understanding Chilled Beam Systems [Understanding Chilled Beam Systems (trane.com)]
- Chilled Beams: What They Are, Why Your Should Use Them [Chilled Beams: What They Are, Why You Should Use Them | 2013-05-20 | ACHRNEWS]

Holistic Design Implementation

Exploring Active Chilled Beams early in the design process is critical due to the impact on cooling/ventilation infrastructure when Chilled Beams are chosen as the comfort delivery system. Reductions in ductwork and terminal unit size may allow reduction in new construction slab to slab spacing resulting in reduced building structural costs. In addition, reduced central equipment capacities afford smaller mechanical room footprints that can result in 5 to 15% additional usable floor space.



Sectional Perspective of Environment and Natural Resources Building 2, U of A, Tucson, AZ

CASE STUDY

Environment and Natural Resources Building 2

University of Arizona

Tuscon, AZ

Chilled beams are used in the perimeter offices of the building. In conjunction with the other strategies used in this building like UFAD, vacancy sensors and thermostat controlled fans, this building surveyed at 72% satisfaction for Thermal Comfort and 91% for Indoor Air Quality.

Other References:

- ASU Student Pavilion, Tempe,AZ
- Beus center for Law and society, Phoenix, AZ
- Biodesign Institute C, ASU, Tempe
- AIA Top ten:http://www.aiatopten.org/
- New Buildings Institute - https://newbuildings.org/case-studies/

Operations and Maintenance

- A chilled beam does not typically contain a condensate drainage system. Because air from the occupied space passes over the cold surface of the coils, the indoor dew point must be maintained below the surface temperature of the chilled beam coil to prevent moisture from condensing on the coil and dripping into the space. Bottom line: chilled beams are for sensible cooling only, not dehumidification.
- Active chilled beams are available in either two-pipe or four-pipe configurations. Four-pipe systems can provide better zone-by-zone comfort control because some zones can receive chilled water for space cooling while others simultaneously receive hot water for space heating. But four-pipe systems also require twice as much piping and twice as many pipe connections, which further increases installed cost and increases the risk of water leaks.

Relevant Codes & Standards

- City of Tempe current codes - ASHRAE 90.1 2016 / IECC 2018.
- Latest and Advanced codes - IECC 2021, IGCC 2021, ASHRAE 90.1 2019/Zero code, ASHRAE Standard 189 2020
- WBDG Federal Facility Criteria is the source for the full text of all federal construction documents including Department of Defense Unified Facilities Guide Specifications (UFGS), Unified Facilities Criteria (UFC) and Federal Publications and Standards. Link to the source can be found here - https://www.wbdg.org/ffc/federal-facility-criteria
- Energy Policy Act of 2005

Associations and Organizations

- AHRI Active Chilled Beams Certification Program [Active Chilled Beams (ahrinet.org)]

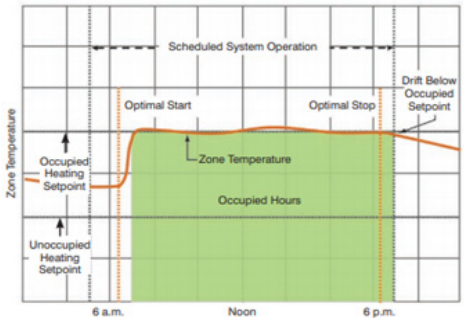
Preferred Design & Analysis Tools

Comfort Delivery Analysis:

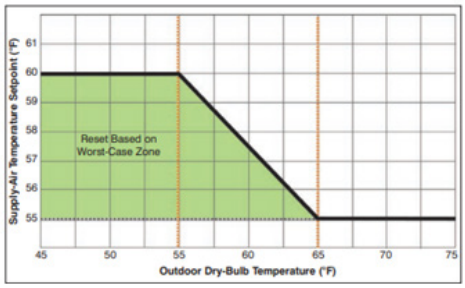
- Load Calculation/Sizing: Trane Trace, Carrier HAP, IES VE
- Energy Simulation: Cove tool, EnergyPlus, Sefaira, IES VE, eQuest

Design Guidance:

- Whole Building Design guide (WBDG)- https://www.wbdg.org/resources/windows-and-glazing
- AIA 2030 Palette - http://2030palette.org/
- AIA COTE Tool kit: https://network.aia.org/blogs/michael-w-lassel-aia-leed-ap1/2019/08/29/aia-cote-toolkit



Example of Optimal start/stop Control (source: ASHRAE Journal)



Example of Supply-Air-Temperature Reset Control (source: ASHRAE Journal)

Advanced VAV

Over the past several years, a series of Advanced Energy Design Guides, have been jointly developed by the U.S. Department of Energy, ASHRAE, the American Institute of Architects, the Illuminating Engineering Society, and the U.S. Green Building Council. These guides include climate specific recommendations that can be used to achieve 30% (or in some cases 50%) energy savings over conventional design. Most of these guides include several options for HVAC systems. In several of them, Advanced VAV systems are one of the options covered that can help the overall building achieve the stated energy-savings threshold. For example, in the recently published guide for small- and medium-sized office buildings, a high-performance rooftop Advanced VAV system is included as one of the options that can be used to achieve 50% energy savings.

Strategy Description

The first key ingredient to make a VAV system truly “advanced” is the use of optimized system control strategies. Control sequences such as optimal start/stop, fan-pressure optimization, supply-air-temperature reset, demand control ventilation, occupancy sensor mode determination, “colder” leaving air temperature setpoints, and expanded air-side economizer operation are all commonly used sequences, with some even required by state/local energy codes/ standards.

Building Typologies & Project Type

Applicable application to primary Tempe building typologies and project types.

	COMMUNITY SERVICES	FIRE STATIONS	HISTORIC BUILDINGS	OFFICE SPACES	POLICE / COURTS	SPORTS FACILITY	UTILITY	WATER MANAGEMENT
NEW CONSTRUCTION	X			X	X	X		
MAJOR RENOVATION	X			X	X	X		
MODERNIZATION	X			X	X	X		

Project Timeline Application & Implementation

Converting the basic VAV system into an Advanced VAV system relies on incorporating most, if not all, of these strategies in order to provide a truly optimized and high-performance comfort delivery system, with infrastructure and equipment typologies that offer flexibility and reliability. The impact of any of these Advanced VAV control strategies on overall operating costs depends on climate, building use, and utility cost structures. Therefore, whole-building energy simulation should be used to determine if a specific strategy makes sense for a given application.

Technical Links

- SMACNA High-Performance VAV Systems [https://www.smacna.org/docs/default-source/Market-Sector---HVAC/high-performance-vav-systems-article.pdf]
- California Energy Commission Advanced Variable Air Volume System Design Guide [https://newbuildings.org/sites/default/files/A-11_LG_VAV_Guide_3.6.2.pdf]
- Energy Design Resources Advanced Variable Air Volume System Design Guide [www.taylor-engineering.com/wp-content/uploads/2020/04/EDR_VAV_Guide.pdf (taylor-engineering.com)]
- ASHRAE Journal: VAV Reheat Versus Active Chilled Beams & DOAS [https://taylorengineers.com/wp-content/uploads/2020/05/ASHRAE_Journal_-_VAVR_vs_ACBDOAS.pdf]

Holistic Design Implementation

Exploring Advanced VAV systems early in the design process is critical as an alternative to the code minimum baseline of a standard VAV system, that might include some, but not all, of the Advanced VAV system strategies. With all the optimized control sequences implemented, the Advanced VAV system has the potential to offer operational performance similar to that of other hydronic-based decoupled ventilation comfort delivery systems.

ASU Health Services Building

CASE STUDY

ASU Health Services

Tempe, AZ

The 34,000-square-foot , two story structure, Arizona State University Health Services Building (ASU HSB) is an adaptive reuse project.

The campus's district natural gas co-generation system provides heating and cooling to the project through a variable air volume system.

Other References:

- ASU Student Pavilion, Tempe,AZ
- AIA Top ten:http://www.aiatopten.org/
- New Buildings Institute - https://newbuildings.org/case-studies/

Operations and Maintenance

- From a physical equipment standpoint, there are many similarities between a code minimum VAV system and an Advanced VAV system. The main differences lie with the sensors and control accessories associated with the optimized control sequences. In order to assure the fidelity of the savings associated with these sequences, the sensing points need to be maintained and calibrated on a regular basis.

Relevant Codes & Standards

- City of Tempe current codes - ASHRAE 90.1 2016 / IECC 2018.
- Latest and Advanced codes - IECC 2021, IGCC 2021, ASHRAE 90.1 2019/Zero code, ASHRAE Standard 189 2020
- WBDG Federal Facility Criteria is the source for the full text of all federal construction documents including Department of Defense Unified Facilities Guide Specifications (UFGS), Unified Facilities Criteria (UFC) and Federal Publications and Standards. Link to the source can be found here - https://www.wbdg.org/ffc/federal-facility-criteria
- Energy Policy Act of 2005

Preferred Design & Analysis Tools

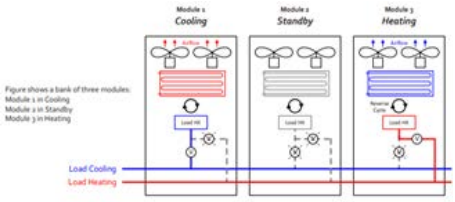
Comfort Delivery Analysis:

- Load Calculation/Sizing: Trane Trace, Carrier HAP, IES VE
- Energy Simulation: Cove tool, EnergyPlus, Sefaira, IES VE, eQuest

Design Guidance:

- Whole Building Design guide (WBDG)- https://www.wbdg.org/resources/windows-and-glazing
- AIA 2030 Palette - http://2030palette.org/
- AIA COTE Tool kit: https://network.aia.org/blogs/michael-w-lassel-aia-leed-ap1/2019/08/29/aia-cote-toolkit

Air-Cooled Heat Pump Chiller (source: Carrier)



Air-Cooled Heat Pump Chiller Single-Line Water Circuit (source: ClimaCool)

Air-Cooled Heat Pump Chiller

A heat pump chiller is a mechanical-compression cycle refrigeration system that can be reversed to either add heat to or remove hear from a hydronic medium needed for the heating and cooling modes of comfort delivery systems. In general, think of a heat pump as a heat transporter constantly moving heat from one place to another, to where it's needed or not needed, depending on the season. Even in air that seems too cold, heat energy is present. When it's cold outside, a heat pump extracts what outside heat is available and transfers it to the hydronic loop. When it's warm outside, it reverses directions and acts like an air conditioner, removing heat and releasing it to the atmosphere. The main benefit of a heat pump chiller is how they create heat. A heat pump chiller uses electricity to move heat from one place to another whereas a furnace burns fuel to create heat. Because of this, a heat pump will be more energy efficient and lessen the environmental impact from harmful emissions that contribute to climate change.

Strategy Description

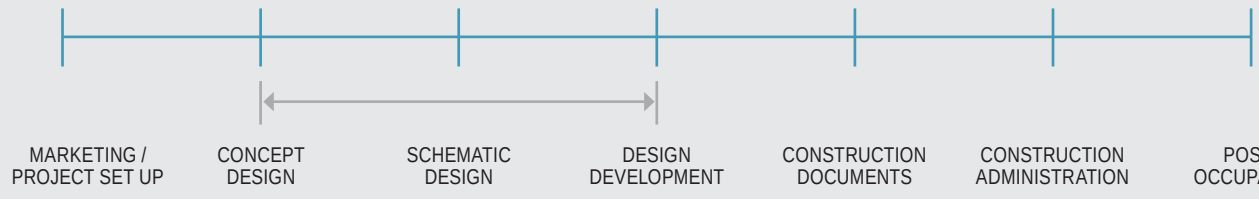
The use of modular heat pump chiller products has distinct advantages over a typical chiller/boiler system in that having multiple independent modules and refrigeration circuits will lessen the amount of down time during routine servicing and repairs.

Building Typologies & Project Type

Applicable application to primary Tempe building typologies and project types.

	COMMUNITY SERVICES	FIRE STATIONS	HISTORIC BUILDINGS	OFFICE SPACES	POLICE / COURTS	SPORTS FACILITY	UTILITY	WATER MANAGEMENT
NEW CONSTRUCTION	X			X	X			
MAJOR RENOVATION	X			X	X			
MODERNIZATION	X			X	X			

Project Timeline Application & Implementation



The modular chiller system can be designed with as many incremental steps of capacity as required as well as potential for system expansion to match nearly any project requirement. When selecting modular chiller sizes to meet the project full load tonnage, incremental capacity steps provided should be considered to provide a good balance between the building load profile and the available capacity steps of the chiller. Modular chillers provide compact footprints and quick installation, ideal for renovation and modernization projects. Commonly available heat pump chillers on the market presently offer high efficiency compressors, environmentally friendly refrigerant options, low noise compressor and condenser fans, and the option for integration into building automation systems.

Technical Links

- ClimaCool Modular Chiller System Application Guide [Modular Chiller Systems Application Guide (climacoolcorp.com)]

Holistic Design Implementation

Exploring the use of Air-Cooled Heat Pump Chiller should be explored early in the project design process in order to determine system parameters for an all-electric comfort high efficiency comfort delivery system. When used in combination with buildings that have (or will have) on-site electric generating renewable energy systems, an all-electric heating/cooling generation infrastructure allows the hurdles of grid power purchase agreements or net-metering configurations as the generated power can be utilized on site with the benefit of no site-generated CO2 from fossil-fuel based heating equipment.

- New Buildings Institute - https://newbuildings.org/case-studies/

Tubular Daylit Workstations

CASE STUDY

DPR Construction Regional Office

Phoenix, AZ

The 16000 sft Office space has over 82 Solatubes strategically installed throughout the facility to bring daylight into all the spaces. Through some analysis and lighting studies, the appropriate height, location and size of the Solatube units was determined which helped for an even distribution of daylight throughout the space. It reduced the load on artificial lighting which helped in downsizing the Photo-voltaic system. Beyond just reducing energy, it connects employees to the daily cycle of the sun, entraining their circadian rhythms, relieving stress and improving productivity.

Other References:

- ASU Student Pavilion, Tempe,AZ
- Mesa Rim Climbing Gym, San Diego, CA
- AIA Top ten:http://www.aiatopten.org/

Operations and Maintenance

- Standardized components bring easy replacement or repair.
- Use of redundant modular systems results in no interruption of system due to maintenance downtime.

Relevant Codes & Standards

- City of Tempe current codes - ASHRAE 90.1 2016 / IECC 2018.
- Latest and Advanced codes - IECC 2021, IGCC 2021, ASHRAE 90.1 2019/Zero code, ASHRAE Standard 189 2020
- WBDG Federal Facility Criteria is the source for the full text of all federal construction documents including Department of Defense Unified Facilities Guide Specifications (UFGS), Unified Facilities Criteria (UFC) and Federal Publications and Standards. Link to the source can be found here - https://www.wbdg.org/ffc/federal-facility-criteria
- Energy Policy Act of 2005

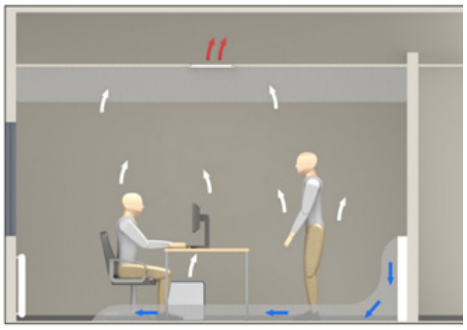
Preferred Design & Analysis Tools

Comfort Delivery Analysis:

- Load Calculation/Sizing: Trane Trace, Carrier HAP, IES VE
- Energy Simulation: Cove tool, EnergyPlus, Sefaira, IES VE, eQuest

Design Guidance:

- Whole Building Design guide (WBDG)- https://www.wbdg.org/resources/windows-and-glazing
- AIA 2030 Palette - http://2030palette.org/
- AIA COTE Tool kit: https://network.aia.org/blogs/michael-w-lassel-aia-leed-ap1/2019/08/29/aia-cote-toolkit



Stratified Room Air Distribution (source: Titus HVAC)

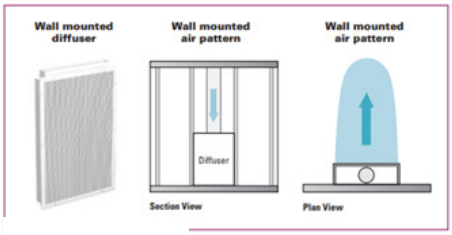
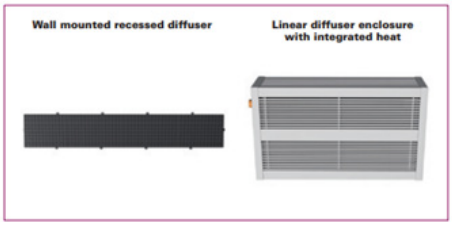


Figure 25: Wall mounted diffusers



Displacement Ventilation Diffuser Types (source: Price Industries)

Displacement Ventilation

Displacement Ventilation relies on delivering air directly at the floor level. The fundamental approach to displacement ventilation utilizes the natural buoyancy forces created by the convective flows from heat sources in the space. As supply air enters the room at floor level, the interaction between heat sources begins to warm and displace the air into the upper or stratified zone. Over time, the air in a displacement application becomes layered, with the warmest temperatures located near the ceiling. As a result of stratified conditioning of only the lower occupied space, energy is saved. Typically, the warmest layer contains the most contaminants, by placing the return location in or near the ceiling level we are able to maximize the removal of polluted air. This approach not only improves air quality in the occupied zone, it also helps us maintain thermal comfort.

Strategy Description

In fully mixed air distribution systems such as VAV systems, cool or warm supply air is delivered at relatively high velocity from ceiling-mounted diffusers. When ceiling diffusers are properly selected and positioned, this high velocity air doesn't result in occupant discomfort because it is delivered outside the occupied zone. The purpose of the high velocity supply is to create low velocity room air motion through entrainment.

Building Typologies & Project Type

Applicable application to primary Tempe building typologies and project types.

	COMMUNITY SERVICES	FIRE STATIONS	HISTORIC BUILDINGS	OFFICE SPACES	POLICE / COURTS	SPORTS FACILITY	UTILITY	WATER MANAGEMENT
NEW CONSTRUCTION	X			X	X			
MAJOR RENOVATION	X			X	X			
MODERNIZATION	X			X	X			

Project Timeline Application & Implementation

Ideally, this air motion will thoroughly mix the supply air with the room air resulting in uniform temperatures and contaminant levels throughout the occupied zone. Internal heat loads and contaminants are eventually picked up and carried away by the return air. In fully-stratified air distribution systems such as Displacement Ventilation, cool supply air is typically delivered at reduced velocity from low sidewall diffusers. The supply air is always cooler than the room air, so it quickly drops to the floor and moves slowly across the room. When this slow-moving air mass encounters a heat load, it rises and carries the heat and pollutants towards the ceiling. A layer of warm air forms above the occupied zone due to natural buoyancy. Internal heat loads and contaminants are carried away by the return air.

The main differences between these systems are:

VAV Systems | Mixed air distribution

• Suitable for both heating and cooling with a supply temperature range generally between 55 to 90°F

• Conditioned air is discharged into the unoccupied zone at relatively high velocities

• Minimal temperature variations throughout the space

• Uniform contaminant concentrations throughout the space

Displacement Ventilation Systems | Fully stratified air distribution

• Suitable for cooling only with a supply temperature generally ranging from 62 to 70°F

• Conditioned air is discharged directly to the occupied zone at low velocity

• Sensible heat gains that emanate away from the conditioned air layer escape due to natural buoyancy

• Heat and respiratory pollutants rise into the upper unoccupied zone

• Occupied zone CO_2 concentrations are significantly reduced

Technical Links

- Titus Displacement Ventilation Design Engineering Guidelines [https://www.titus-hvac.com/file/9915/displacement_guidelines2018.pdf]
- Price Displacement Ventilation Engineering Guide [https://www.priceindustries.com/content/uploads/assets/literature/engineering-guides/displacement-ventilation-engineering-guide.pdf]
- IWBI Displacement ventilation [Displacement ventilation | WELL Standard (wellcertified.com)]
- Krueger Displacement Ventilation [https://www.krueger-hvac.com/file/9265/Displacement_Engineering.pdf]

Environment and Natural Resources Building 2, U of A, Tucson, AZ

CASE STUDY

Environment and Natural Resources Building 2

University of Arizona

Tuscon, AZ

Low Static Pressure Underfloor Displacement Ventilation is served to all the central open offices and conference rooms of this building. In conjunction with the other strategies used in this building like chilled beams, vacancy sensors and thermostat controlled fans, this building surveyed at 72% satisfaction for Thermal Comfort and 91% for Indoor Air Quality.

Other References:

- Beus center for Law and society, Phoenix, AZ
- ASU - Student Pavilion — Tempe, AZ (Event Space)
- DMV — Fresno, CA
- AIA Top ten:http://www.aiatopten.org/
- New Buildings Institute - https://newbuildings.org/case-studies/

Holistic Design Implementation

Exploring Displacement Ventilation early in the design process is critical due to the impact on cooling/ventilation infrastructure and air-shafts/air-column locations when Displacement Ventilation is chosen as the comfort delivery system.

Operations and Maintenance

- Low side wall air distribution with the air supply temperature slightly cooler or warmer than the desired space temperature.
- Although displacement ventilation is well-suited for a wide variety of applications, the following spaces may be better served by mixed air systems:
    - Spaces with ceiling heights lower than 9 feet
    - Spaces furnished with cubicles or other partitions
    - Applications involving contaminants that are heavier and/or colder than room air in the occupied zone
- Displacement ventilation requires outlets that supply air at extremely low velocities, (typically 50-70 fpm). These outlets are commonly located low on a sidewall or at the base of a column. The low average face velocity results in rather large diffuser panels.
- Lower cooling energy and lower capacity demands will help maintain equal thermal conditions in the occupied zone.
- Higher temperature supply air can maximize the hours of economizer free cooling.
- Improved chiller COP due to higher EWT and higher supply air temperature.

Relevant Codes & Standards

- City of Tempe current codes - ASHRAE 90.1 2016 / IECC 2018.
- Latest and Advanced codes - IECC 2021, IGCC 2021, ASHRAE 90.1 2019/Zero code, ASHRAE Standard 189 2020
- WBDG Federal Facility Criteria is the source for the full text of all federal construction documents including Department of Defense Unified Facilities Guide Specifications (UFGS), Unified Facilities Criteria (UFC) and Federal Publications and Standards. Link to the source can be found here - https://www.wbdg.org/ffc/federal-facility-criteria
- Energy Policy Act of 2005

Preferred Design & Analysis Tools

Comfort Delivery Analysis:

- Load Calculation/Sizing: Trane Trace, Carrier HAP, IES VE
- Energy Simulation: Cove tool, EnergyPlus, Sefaira, IES VE, eQuest

Design Guidance:

- Whole Building Design guide (WBDG)- https://www.wbdg.org/resources/windows-and-glazing
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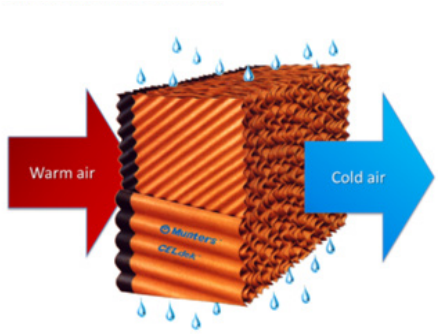
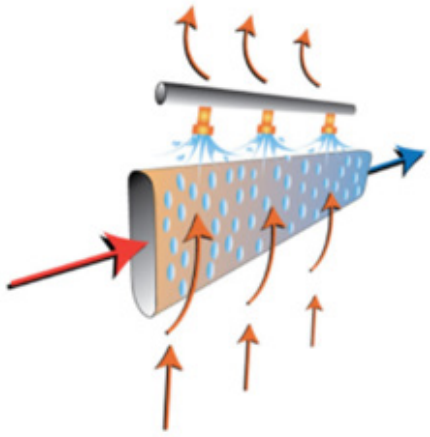


Direct Evaporative Cooling (source: Munters)



Indirect Evaporative Cooling (source: Munters)

Packaged Direct/Indirect Evaporative Cooling

Evaporative cooling is not a new concept for the City of Tempe. Evaporative cooling works by using the evaporation of water across an airstream to provide the cooling effect, reducing the air's dry-bulb temperature while increasing its humidity ratio. The effectiveness of evaporative cooling is largely dependent on the climate in which it is being considered. Hot, arid climates are the obvious choice for its use, whereas humid climates will limit its effectiveness. In favorably mild climates, evaporative-cooling technologies have the potential to replace vapor-compression cooling systems. However, for most suitable climates it will need to be supplemented with some form of mechanical cooling.

Strategy Description

Direct evaporative cooling (DEC) — the process of adding moisture directly to an airstream and allowing the latent heat of evaporation to cool the air — is typically achieved using a wetted medium installed in an air handling unit. This method is generally preferred to spraying water into the airstream.

Building Typologies & Project Type

Applicable application to primary Tempe building typologies and project types.

	COMMUNITY SERVICES	FIRE STATIONS	HISTORIC BUILDINGS	OFFICE SPACES	POLICE / COURTS	SPORTS FACILITY	UTILITY	WATER MANAGEMENT
NEW CONSTRUCTION	X	X		X	X	X	X	X
MAJOR RENOVATION	X	X		X	X	X	X	X
MODERNIZATION	X	X		X	X	X	X	X

Project Timeline Application & Implementation

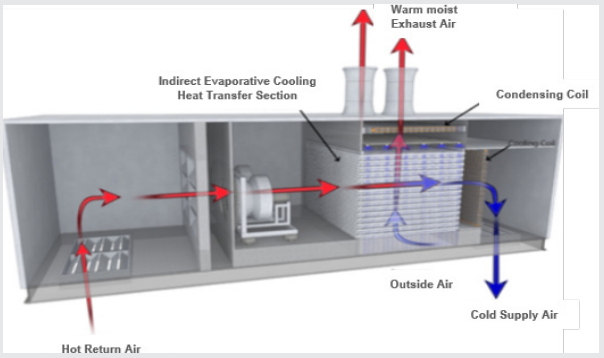
Indirect evaporative cooling (IEC) relies on a secondary airstream, in which the evaporative cooling process takes place and sensibly cools the primary airstream via a heat exchanger. The secondary airstream can be exhaust/return air from the building, or 'scavenger' air from outside. The advantage of indirect over direct evaporative cooling is that no moisture is added to the primary airstream. The disadvantage is that it is less efficient at cooling because of the added heat-exchange process between the primary and secondary airstreams. Indirect evaporative cooling is more suited to building types where humidity control is required — for example, a Sports Facility. Today's indirect evaporative coolers use only a fraction of the energy of typical HVAC systems such as Variable Air Volume (VAV) or Direct Expansion (DX) rooftop package units.

The basic packaged Indirect Evaporative Cooling unit consists of a primary and secondary air moving device, an evaporative heat exchanger, and a water collection and recirculation system that includes a wetting apparatus and pump. Packaged IEC units may be selected in various configurations of this arrangement with all components in a single-unit casing. Some packaged units are also available with supplemental direct expansion (DX) refrigeration or chilled water coil, a direct evaporative cooling section, and/or heating section.

Though water conservation is of great concern today, evaporative cooling can be appropriately applied to minimize excess water use. Water consumption calculations should be completed, and the added-water costs should be compared against energy savings for all evaporative cooling system designs.

Technical Links

- CIBSE Journal: Making the case for evaporative cooling [Making the case for evaporative cooling — CIBSE Journal]
- New Buildings Institute: Indirect Evaporative Cooling [IEC_ZNE_TAG2.pdf (newbuildings.org)]
- Consulting-Specifying Engineer: Indirect Cooling Technologies [Consulting - Specifying Engineer | Indirect cooling technologies (csemag.com)]
- Munters Evaporative Cooling [Direct & Indirect Evaporative Cooling Solutions | Munters]



IEC system used at ASU Student Pavilion
Climate Wizard (CW-80)-

CASE STUDY

Student Pavilion

Arizona State University

Tempe, AZ

The Student pavilion building uses mixed type of air conditioning. It uses displacement ventilation for event spaces on the first floor and active chilled beams on all the perimeter classroom spaces. Indirect Evaporative Cooling system is used as a pre-cooler to the AHUs serving the core office and study spaces.

Other References:

- University of Arizona - Architecture, Tuscon, AZ
- ASU- Bio design Institute C - Tempe, AZ
- AIA Top ten:http://www.aiatopten.org/
- New Buildings Institute - https://newbuildings.org/case-studies/

Operations and Maintenance

- Direct and/or Indirect Evaporation units offer significant potential in the right climate to save cooling energy. Energy savings are achieved either by eliminating the need for mechanical cooling, or by extending the range of economizer hours — to reduce chiller operating hours — and reducing the mechanical cooling load.
- Legionella, the bacteria responsible for Legionnaire's disease, markedly thrives in aquatic environments at temperatures of 77 to 108 F and at conditions containing scale and sediment, biofilms, and stagnation, all or some of which can be present in evaporative cooling systems. ASHRAE 12-2000 includes separate recommendations for direct and indirect evaporative coolers. An effective water treatment program might include scaling and corrosion inhibitors as well as oxidizing or nonoxidizing biocides approved by the local authority's environmental regulatory agency.

Relevant Codes & Standards

- City of Tempe current codes - ASHRAE 90.1 2016 / IECC 2018.
- Latest and Advanced codes - IECC 2021, IGCC 2021, ASHRAE 90.1 2019/Zero code, ASHRAE Standard 189 2020
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- Energy Policy Act of 2005

Preferred Design & Analysis Tools

Comfort Delivery Analysis:

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Design Guidance:

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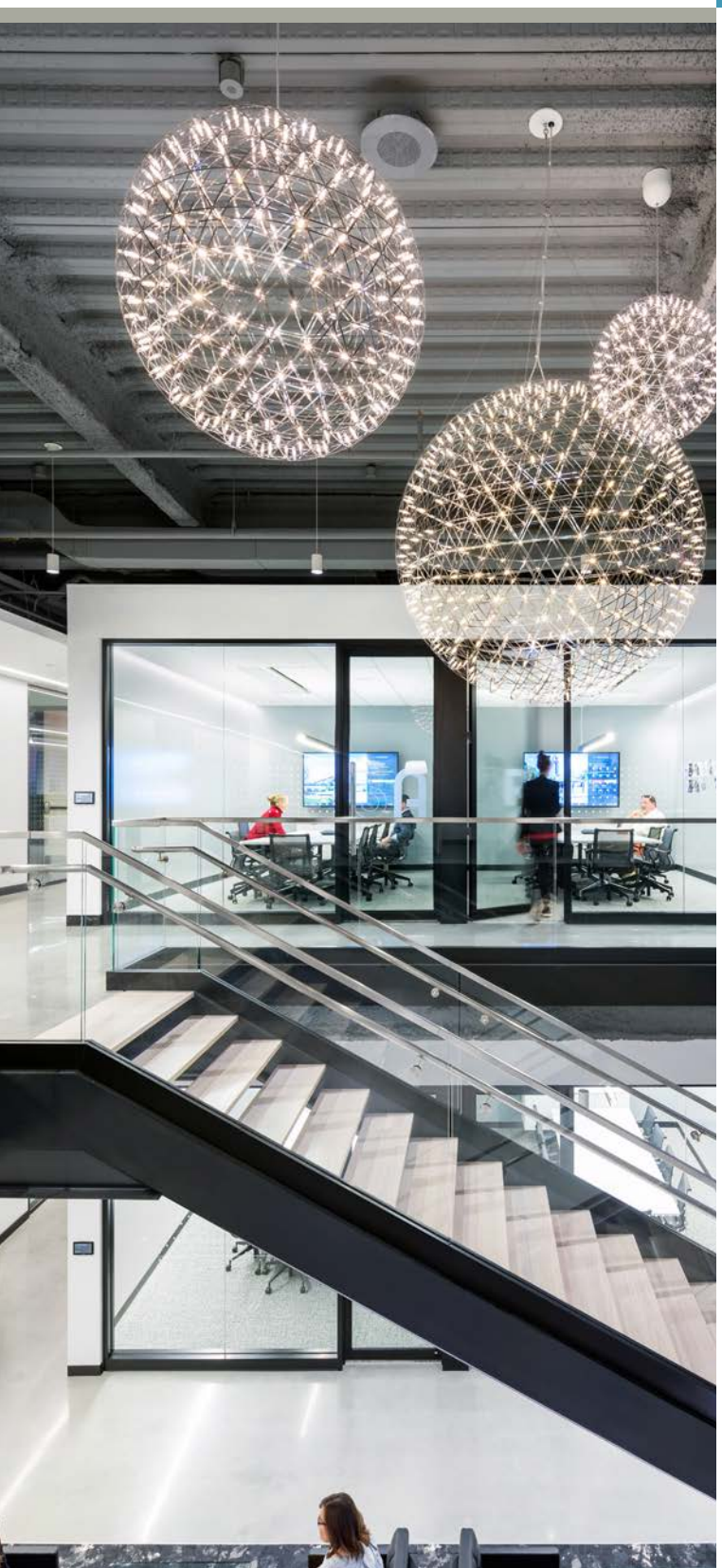
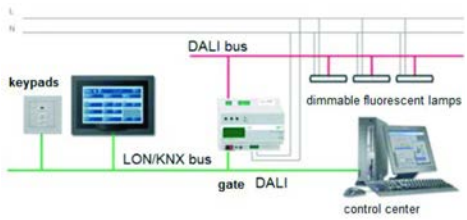
- AIA 2030 Palette - http://2030palette.org/
- AIA COTE Tool kit: https://network.aia.org/blogs/michael-w-lassel-aia-leed-ap1/2019/08/29/aia-cote-toolkit

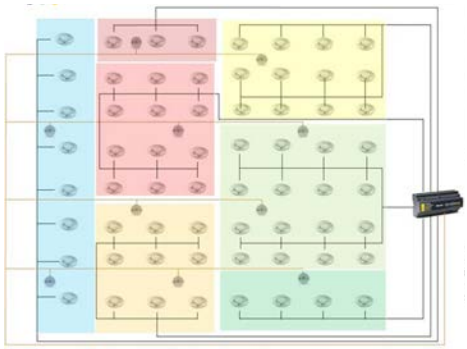
Energy



Lighting



Principle diagram of control system DALI


DALI connection to individual fixtures

Digital Addressable Lighting Interface (DALI)

Due to the recent strides in Internet-Of-Things technology and advancements in Building Management systems, much finer control over the various building systems has become very sought after. DALI is a standardized system for two way communication between the various light fixtures and the BMS. It provides a flexible way to control and configure the light fixtures, thereby providing opportunities to increased energy savings and comfort levels. It can also be used to gather useful insights into the usage of the lighting systems.

Strategy Description

DALI is a standard 2 way communication protocol. It provides definitions for the various addressing schemes for the lighting fixtures and standardizes the access mechanisms and control systems.

Technical Links

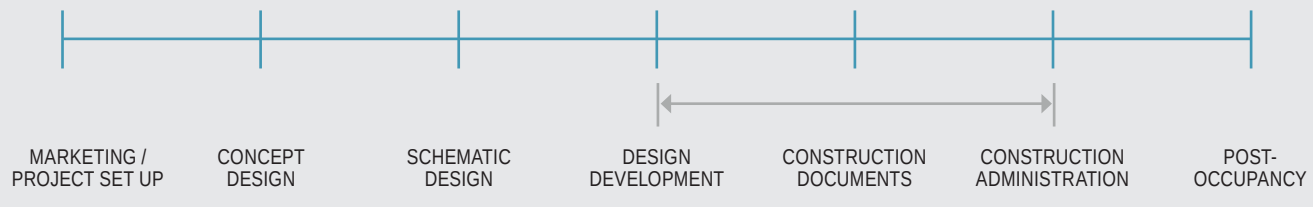
- Philips ActiLume DALI: https://www.lighting.philips.com/
- Lutron Dali : https://www.lutron.com/en-US

Building Typologies & Project Type

Applicable application to primary Tempe building typologies and project types.

	COMMUNITY SERVICES	FIRE STATIONS	HISTORIC BUILDINGS	OFFICE SPACES	POLICE / COURTS	SPORTS FACILITY	UTILITY	WATER MANAGEMENT
NEW CONSTRUCTION	X			X	X	X	X	X
MAJOR RENOVATION	X			X	X	X	X	X
MODERNIZATION								

Project Timeline Application & Implementation



Holistic Design Implementation

DALI compatible lighting fixtures need to be installed to take advantage of the various BMS optimizations that can be achieved. Hence the decision to implement this interface for the lighting systems needs to be taken during the design development phase of the project. DALI fixture specifications and modes can be used to factor-in to the energy savings for the lighting systems.

Operations and Maintenance

Depending on the grouping of the lighting fixtures, initial setup of the DALI system involves creating a database to associate light addresses with the physical locations of the lights and control devices to operate them. This database creation needs to be undertaken with care to avoid controlling devices that are not expected to be controlled. When the layout is altered, the database needs to be updated and maintained. In circumstances where anything more than turning ON/OFF of lights is not required, DALI systems may not be suitable.

Relevant Codes & Standards

City of Tempe current codes - ASHRAE 90.1 2016 / IECC 2018

Latest and Advanced codes - IECC 2021, IGCC 2021, ASHRAE 90.1 2019/Zero code, ASHRAE Standard 189 2020.

Federal Criteria

- WBDG Federal Facility Criteria for Lighting. Link to the source can be found here - https://www.wbdg.org/ffc/federal-facility-criteria
  - UFC 3-530-01 Interior and Exterior Lighting Systems and Controls
  - UFGS 26 51 00 Interior Lighting
- Energy Policy Act of 2005

Standards

- IES Lighting Handbook
- IES RP-1, American National Standard Practice for Office Lighting (ANSI Approved)

Other Resources:

- DALI Product Database : https://www.dali-alliance.org/products/
- The Lighting Controls Association (LCA), a council of the National Electrical Manufacturers Association (NEMA) : https://lightingcontrolsassociation.org/

ASU Student Pavilion- Study space

CASE STUDY

Student Pavilion

Arizona State University

Tempe, AZ

The Student Pavilions work spaces and open study space lighting is equipped with DALI system that is incorporated into Building automation systems via KNX Bus systems. It provides flexibility to operate the lighting fixtures according to the ambient conditions and occupancy of the study space.

Other Precedents:

Arup Office, Los Angeles, CA

Alvine Engineering Corporate HQ, Omaha, NE

Capital One Corporate HQ, McLean, VA

Principle of Circadian Lighting

Fixtures with varying Light Temperatures

Circadian Lighting

According to a 2018 report by National Safety Council, two-thirds of the US labor force experiences workplace fatigue. Bad lighting is associated with a range of ill-health effects both mental and physical like eye strain, headaches, fatigues and also stress and anxiety especially when the time spent at work increases. To counter this challenging issue, Circadian Lighting is gaining significance in workspaces and health care facilities.

Strategy Description

The concept of circadian lighting follows that of human circadian rhythm, which is a 24 hour internal clock. Currently there are 3 electric light approaches to implement a circadian lighting system, intensity tuning, color tuning and stimulus tuning. In the Intensity tuning method, the color temperature of the light is maintained constant, but the intensity is modulated according to the time of day and the opposite is done in color tuning method whereas in the stimulus tuning method, the wavelengths of light produced is tuned to mimic daylight spectrum.

Technical Links

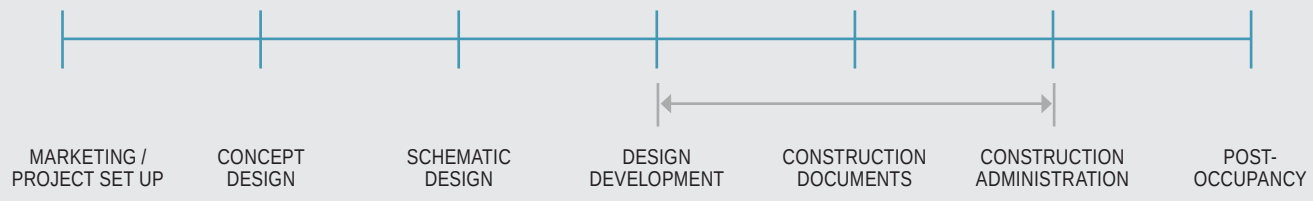
- enLux Circadian series: https://enluxled.com/
- Walalight Human centric Lighting: https://www.walalight.com/

Building Typologies & Project Type

Applicable application to primary Tempe building typologies and project types.

	COMMUNITY SERVICES	FIRE STATIONS	HISTORIC BUILDINGS	OFFICE SPACES	POLICE / COURTS	SPORTS FACILITY	UTILITY	WATER MANAGEMENT
NEW CONSTRUCTION	X			X	X	X		
MAJOR RENOVATION	X			X	X	X		
MODERNIZATION								

Project Timeline Application & Implementation



Holistic Design Implementation

Circadian Lighting systems need to be factored into the design of the building early on in the schematic phase of the design. This can be used effectively to meet the standard illuminance targets for the building that will be factored into the lighting calculations.

Operations and Maintenance

Since most of the products supporting the circadian lighting methodologies are relatively modern, post installation adjustments to the schedules, color temperatures or intensities of light are very easily programmable through a smart phone or web application.

Due to differences in human physiology, there might be some individuals who may face issues due to the circadian lighting systems. In such cases, careful tuning of the system intensity and method is needed to ensure the comfort of all the users of the space. This requires increased effort from the operations and maintenance teams of the building.

Relevant Codes & Standards

City of Tempe current codes - ASHRAE 90.1 2016 / IECC 2018

Latest and Advanced codes - IECC 2021, IGCC 2021, ASHRAE 90.1 2019/Zero code, ASHRAE Standard 189 2020.

Federal Criteria

- WBDG Federal Facility Criteria for Lighting. Link to the source can be found here - https://www.wbdg.org/ffc/federal-facility-criteria
  - UFC 3-530-01 Interior and Exterior Lighting Systems and Controls
  - UFGS 26 51 00 Interior Lighting
- Energy Policy Act of 2005

Standards

- IES Lighting Handbook
- WELL Building guide
- IES RP-1, American National Standard Practice for Office Lighting (ANSI Approved)
- IES RP-16, Nomenclature and Definitions for Illuminating Engineering (ANSI Approved)

Delos NY Headquarters lighting systems

CASE STUDY 1

Delos Living HQ

New York, NY

Delos living is a wellness real-estate company, who employed the circadian lighting technologies in their NY workspaces. The company used Ketra Circadian lighting systems that provide high degree of tunability and control which aligns with WELL lighting requirements.

CASE STUDY 2

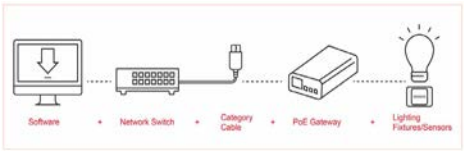
Arup Office

Los Angeles, CA

This 66,000-sq.ft. office employed human centric lighting system with Digital addressable lighting control enabling reduction of energy consumption while maintaining the workplace lighting quality for the employee wellbeing.

The architectural lighting for the project is built on an extensive network of lighting control protocols—digitally addressable, 0-10V, DMX and Bluetooth—enabling maximum flexibility.

Demonstration of PoE



Configuration of PoE System

Power over Ethernet

As the number of connected devices increases multi-fold in a smart building, connecting each device to the control system through wireless networks makes the network very congested and might incur additional costs to upgrade the networks. To avoid such scenarios, power over ethernet technology can be leveraged to power and connect the low voltage lighting fixtures using a single ethernet cable. This technology is already quiet instrumental in deploying networking devices across large distances where the wiring costs are significant. Furthermore, PoE systems provide a much reliable way to connect to the lighting fixtures due to the higher fidelity of the Ethernet cables over wireless technologies.

Strategy Description

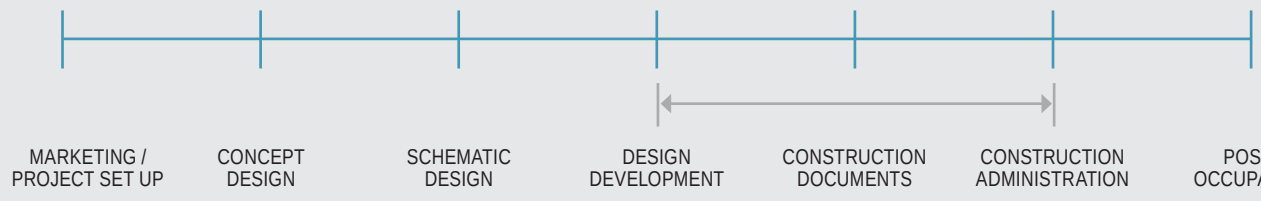
Power over Ethernet refers to the ability to use ethernet cable to power light fixtures and transmit data between the fixtures and control systems. In this technology, a single ethernet cable can be used to deliver power to the low voltage lighting fixtures which are in compliance with the PoE standards outlined in IEEE 802.3 at the same time connect them to the control software. When the ethernet cable is plugged into the fixture, it is automatically powered, assigned a unique IP address and automatically discovered by lighting control software. Since each fixture has a unique IP, the system can be reprogrammed as needed without the need for rewiring.

Technical Links

- Philips PoE: https://www.usa.lighting.philips.com/
- Cree lighting Smart cast Intelligence platform: https://www.creelighting.com/

	COMMUNITY SERVICES	FIRE STATIONS	HISTORIC BUILDINGS	OFFICE SPACES	POLICE / COURTS	SPORTS FACILITY	UTILITY	WATER MANAGEMENT
NEW CONSTRUCTION	X			X	X	X	X	X
MAJOR RENOVATION	X			X	X	X	X	X
MODERNIZATION								

Project Timeline Application & Implementation



Holistic Design Implementation

PoE systems need to be explored during the design development phase of the project. This technology can be used in applications where the cabling needs to be minimal. Since each of the lighting fixture is individually address unlike the DALI systems, the layout and interconnectivity of the fixtures need not be planned out ahead of time. The grouping and database of lighting can be done in software without any rewiring.

Relevant Codes & Standards

- City of Tempe current codes - ASHRAE 90.1 2016 / IECC 2018
- Latest and Advanced codes - IECC 2021, IGCC 2021, ASHRAE 90.1 2019/Zero code, ASHRAE Standard 189 2020.

Federal Criteria

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- Energy Policy Act of 2005

Standards

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- IES RP-16, Nomenclature and Definitions for Illuminating Engineering (ANSI Approved)

CompuCom Digital campus HQ

CASE STUDY

CompuCom Digital Campus

Charlotte HQ

Charlotte, SC

CompuCom's 151,000 sft. HQ in Charlotte SC implemented a power over ethernet interior lighting technology which saved the company $275,000 in electrical labor and wiring. The use of this technology also eliminated the need for batteries in sensors, alarms and emergency exit signs

Other Precedents:

Quest Corporate Campus, Roseville, CA features SmartCast® PoE based on the Cisco Digital Ceiling framework

04 Water

Sloan-JetRinse Technology

Sloan HYB -1000

HYBRID WATERLESS URINALS

Arizona has been at the forefront in installing waterless urinals and finding other ways to reduce water consumption. This is especially important for Maricopa County which is expected to have an extremely high intensity drought risk (US Drought Monitor, Jan2021). In 2004, AZ was the first state to recommend the installation of waterless urinals in all new state buildings. Hybrid waterless urinals are the wave of the future and should become more of a requirement than a recommendation.

Strategy Description

Unlike complete waterless Urinals, these Hybrid urinals make use of proprietary technologies like Jet-rinse by Sloan where the housing and drain line are injected with 1 Gallon of water every 72 hours to prevent struvite buildup and clogs. This keeps the urinal clean, hygienic, odor free and clog free.

Technical Links:

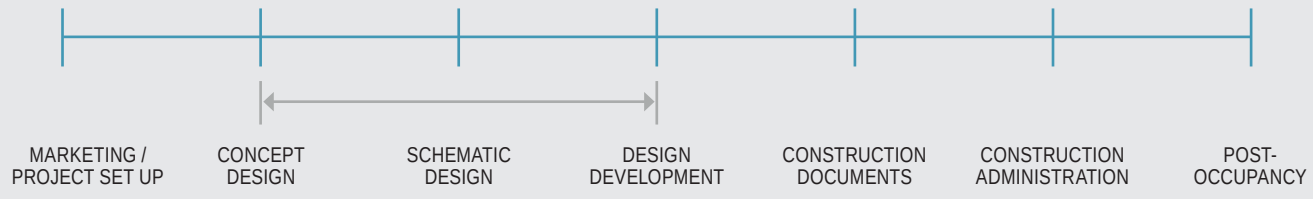
- Sloan Hybrid Urinal - https://www.sloan.com
- Kohler Waterless Urinal - https://www.us.kohler.com
- Waterless.Co - No flush Urinals - https://www.waterless.com

Building Typologies & Project Type

Applicable to primary Tempe building typologies and project types.

	COMMUNITY SERVICES	FIRE STATIONS	HISTORIC BUILDINGS	OFFICE SPACES	POLICE / COURTS	SPORTS FACILITY	UTILITY	WATER MANAGEMENT
NEW CONSTRUCTION	X			X	X	X	X	X
MAJOR RENOVATION	X			X	X	X	X	X
MODERNIZATION								

Project Timeline Application & Implementation



Holistic Design Implementation

It is crucial to perform a baseline water analysis in the early stages of design preferably after programming and zoning, it helps in understanding project's water end uses and outdoor water usage based on the occupancy. It also provides an opportunity to benchmark and set the water efficiency targets for the project. After which, the next step is to evaluate water reduction, water reuse/recycle strategies that help achieve the water conservation goals. Water sense labeled products/fixtures that best align with the project goals will be recommended once the final analysis is done.

Operations and Maintenance

- Water free urinals require regular maintenance to prevent struvite formation from causing drain line blockages-cartridge change & line flushing.
- Some hybrid urinals offer an automatic drain-rinsing feature that utilizes a controller and solenoid valve to inject water through housing and the lateral drain line.
- Battery is a long-lasting lithium and should provide approximately 8 years of operation.

Relevant Codes & Standards

- Codes and Standards: City of Tempe current codes - ASHRAE 90.1 2016 / IECC 2018, International Plumbing Code 2018, Uniform plumbing code 2018
- Latest and Advanced codes - IECC 2021, IGCC 2021, ASHRAE 90.1 2019/Zero code, ASHRAE Standard 189 2020.
- All toilets sold in the U.S. must comply with ASME A112.19.
- EPA Clean Water Act- https://www.epa.gov/laws-regulations/summary-clean-water-act

DPR Office, Phoenix AZ

Kohler Waterless Urinal

CASE STUDY

DPR Construction Regional Office

Phoenix, AZ

The 16533 s.ft office building has highly efficient fixtures which include waterless urinals, dual-flush water closets, 0.5 gpm, 10-second duration, automatic sensor lavatory faucets, and 1.5 gpm shower heads. The kitchen sink even utilizes a 0.5 gpm aerator and all of these features combine to reduce interior water use by 41% over LEED 2009 baselines.

Plumbing fixtures used: Water Tec (reverse osmosis system); Kohler (waterless urinals); Sloan (electronic faucets); Sloan Flushometer (dual-flush toilets); Rheem SolPak (solar water heating system)

Preferred design and Analysis tools

EPA Commercial and Institutional (CI) Facility Water Assessment Tools: are available at (https://www.epa.gov/watersense/tools-ci-facilities#CI%20Water%20Assessment%20Tools)

- Commercial, Industrial, and Institutional (CII) Water Assessment Tool - This Excel-based tool can be used to conduct a basic water conservation assessment for Connercial and Institutional buildings. The tool can be downloaded at https://www.brendlegroup.com/actions-insights/resources/
- Federal Energy Management Program (FEMP) Water Screening Tool: This Excel-based tool can be used by federal agencies to identify potential water saving and cost saving opportunities for a specific project/ site /water end uses. The tool can be downloaded at http://energy.gov/eere/femp/downloads/water-project-screening-tool
- GEMI Water Sustainability Tool (http://www.gemi.org/water/)
- EDF-GEMI Water Management Application (WaterMAPP) Tool: This Excel-based multi-tabbed spreadsheet has three primary components: the Water Scorecard - to assess water efficiency, Water Efficiency Calculator to estimate water and financial savings rom cooling tower or free-air cooling improvements and, Cycles of Concentration Estimator to estimates the recommended maximum cycles of concentration from cooling towers based on the water quality. The tool can be downloaded at http://gemi.org/EDFGEMIwaterMAPP/

EPA's Water Tracking Tools:

ENERGY STAR®'s Portfolio Manager - This is a free online resource for tracking utility data over time. It can be used to track both water and energy use. Link to the resource - http://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager

EPA Watersense Product Directory: https://lookforwatersense.epa.gov/products/

Design guidance:

- Whole Buillding Design guide Water Conservation - https://www.wbdg.org/resources/water-conservation
- GSA Sustainable Facilities Tool (SFTool)- https://sftool.gov/
- AIA 2030 Palette - http://2030palette.org/
- AIA COTE Tool kit: https://network.aia.org/blogs/michael-w-lassel-aia-leed-ap1/2019/08/29/aia-cote-toolkit

Other Resources :

Adaptation to Climate Change - Links:

- United States Drought monitor - The U.S.Drought monitor is a map database that shows Drought intensity and impact across the US. It is a joint collaboration by National Drought Mitigation Center (NDMC) at the University of Nebraska-Lincoln, The National Oceanic and Atmospheric Administration (NOAA), and the U.S. Department of Agriculture (USDA). https://droughtmonitor.unl.edu/CurrentMap/StateDroughtMonitor.aspx?AZ
- Climate Ready Water Utilities Toolbox - Tools from EPA that can be used to find water utility-specific information on funding opportunities, reports, tools and models, and workshops and seminars that can help a water utility become climate ready. http://www.epa.gov/safewater/watersecurity/climate/toolbox.html
- CREAT Climate Scenarios Projection Map: https://epa.maps.arcgis.com/apps/MapSeries/

Associations and Organizations:

- Alliance for Water Efficiency- It is a stakeholder-based non-profit organization dedicated to the efficient and sustainable use of water. Website: http://www.allianceforwaterefficiency.org/
- American Water Works Association (AWWA) -Its mission is to unite the water community to protect public health and to provide safe and sufficient water for all. Website: http://www.awwa.org/
- National Association of Clean Water Agencies (NACWA). NACWA provides policy leadership and technical expertise in protecting water quality. Website: http://www.nacwa.org/
- Water Innovations Alliance - it works to promote federal and state policies that support development, reduce barriers, and improve market conditions for the U.S. water technologies market. Website: http://www.waterinnovations.org/

Sloan- Automatic Flush Valve

Sloan Uppercut Dual Flush

Niagara Stealth Dual Flush toilet

DUAL FLUSH WATER CLOSETS

One of the highest water consumption in commercial space is for the toilets and urinals. Any amount of water savings that can be achieved by better technologies in this space can add up to a significant water savings on the whole. Dual Flush water closets are one such simple innovations that can have a large impact on the water consumption.

Strategy Description

Dual flush toilets have a different flushing mechanism that enables them to effectively conserve water over standard toilets. It has two flush mechanisms to dispense different amounts of water. This can be used varyingly for liquid waste or solid waste. This ultimately means using less water overall. Infrared Sensor based touch-less options are also available for this strategy which roughly activate the different flush mechanisms based on the time the user spends at the toilet.

Technical Links:

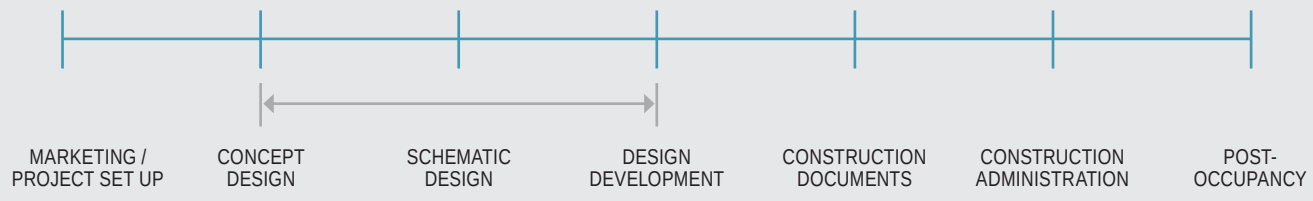
- Sloan Dual Flush Sensor based - https://www.sloan.com
- Niagara Stealth Dual Flush Technology - https://niagaracorp.com

Building Typologies & Project Type

Applicable to primary Tempe building typologies and project types.

	COMMUNITY SERVICES	FIRE STATIONS	HISTORIC BUILDINGS	OFFICE SPACES	POLICE / COURTS	SPORTS FACILITY	UTILITY	WATER MANAGEMENT
NEW CONSTRUCTION	X			X	X	X	X	X
MAJOR RENOVATION	X			X	X	X	X	X
MODERNIZATION								

Project Timeline Application & Implementation



Holistic Design Implementation

It is crucial to perform a baseline water analysis in the early stages of design preferably after programming and zoning, it helps in understanding project's water end uses and outdoor water usage based on the occupancy. It also provides an opportunity to benchmark and set the water efficiency targets for the project. After which, the next step is to evaluate water reduction, water reuse/recycle strategies that help achieve the water conservation goals. Water sense labeled products/fixtures that best align with the project goals will be recommended once the final analysis is done.

Operations and Maintenance

- The dual flush toilet uses a larger diameter trapway that doesn't clog as often as a conventional toilet, needs less water to flush efficiently and saves more water than a low flow toilet when flushing liquid waste.
- The major concern identified with this technology is that typically, dual flush toilets only retain a little water in the bowl, and flushing won't always get rid of all the waste. Even in full flush mode, there's some occasional streaking.

Relevant Codes & Standards

- City of Tempe current codes - ASHRAE 90.1 2016 / IECC 2018, International Plumbing Code 2018, Uniform plumbing code 2018
- Latest and Advanced codes - IECC 2021, IGCC 2021, ASHRAE 90.1 2019/Zero code, ASHRAE Standard 189 2020.

Preferred design and Analysis tools

- GEMI Water Sustainability Tool (http://www.gemi.org/water/)
- EPA Commercial and Institutional (CI) Facility Water Assessment Tools: are available at (https://www.epa.gov/watersense/tools-ci-facilities#CI%20Water%20Assessment%20Tools)
- EPA Watersense Product Directory: https://lookforwatersense.epa.gov/products/

DPR Office, Phoenix AZ

Kohler Waterless Urinal

CASE STUDY

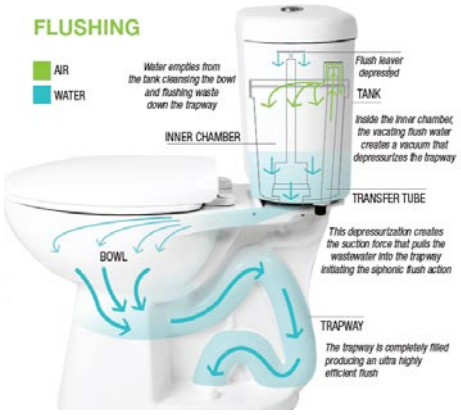
DPR Construction Regional Office

Phoenix, AZ

The 16533 s.ft office building has highly efficient fixtures which include waterless urinals, dual-flush water closets, 0.5 gpm, 10-second duration, automatic sensor lavatory faucets, and 1.5 gpm shower heads. The kitchen sink even utilizes a 0.5 gpm aerator and all of these features combine to reduce interior water use by 41% over LEED 2009 baselines.

Plumbing fixtures used: Water Tec (reverse osmosis system); Kohler (waterless urinals); Sloan (electronic faucets); Sloan Flushometer (dual-flush toilets); Rheem SolPak (solar water heating system)

Niagara UHET - Filling Mechanis



Niagara Stealth Dual Flush toilet

ULTRA HIGH EFFICIENCY TOILETS (UHET)

The Energy Policy Act of 1992 states that new toilets must not use more than 1.6 gallons per flush (gpf). With the growing demand for high efficient fixtures, High-efficiency toilets (HETs)/ Ultra High efficiency toilets (UHETs) that go beyond the standard and uses anywhere between 0.8 -1.28 gpf, 20% less water than mandated by the Act are being widely recommended.

Strategy Description

Ultra-High-Efficiency toilets (UHETs) are toilets that use less than 1 (gpf) gallons of water per flush. These toilets decrease their water consumption by employing features like Siphon Jet Flush Action by TOTO, that uses gravity based tornado technology and vaccum assist design by Niagara

Technical Links:

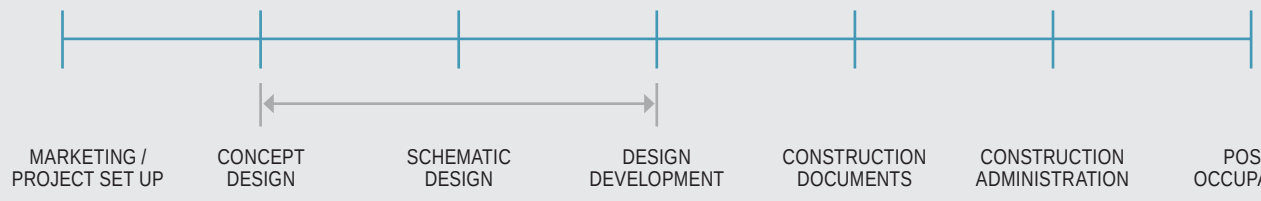
- Commercial UHET-1.0gpf - https://www.totousa.com
- Niagara Stealth UHET-0.65gpf - https://niagaracorp.com
- American Standard-H2O UHET- https://www.americanstandard-us.com

Building Typologies & Project Type

Applicable to primary Tempe building typologies and project types.

	COMMUNITY SERVICES	FIRE STATIONS	HISTORIC BUILDINGS	OFFICE SPACES	POLICE / COURTS	SPORTS FACILITY	UTILITY	WATER MANAGEMENT
NEW CONSTRUCTION	X			X	X	X	X	X
MAJOR RENOVATION	X			X	X	X	X	X
MODERNIZATION								

Project Timeline Application & Implementation



Holistic Design Implementation

It is crucial to perform a baseline water analysis in the early stages of design preferably after programming and zoning, it helps in understanding project's water end uses and outdoor water usage based on the occupancy. It also provides an opportunity to benchmark and set the water efficiency targets for the project. After which, the next step is to evaluate water reduction, water reuse/recycle strategies that help achieve the water conservation goals. Water sense labeled products/fixtures that best align with the project goals will be recommended once the final analysis is done.

Operations and Maintenance

- Common complaints about these toilets include noise and flushing or water pressure issues. They rely on a pressure-assisted system that makes a distinctive "whooshing" sound which tends to be louder than a regular toilet flush.
- If the water pressure is not sufficient for the smooth operation, they will not eliminate waste with a single flush or work as intended. Annual inspection of valves and worn parts is required.
- Calibrate automatic sensors to ensure they are working properly to limit double or "phantom" flushing.

Relevant Codes & Standards

- City of Tempe current codes - ASHRAE 90.1 2016 / IECC 2018, International Plumbing Code 2018, Uniform plumbing code 2018
- Latest and Advanced codes - IECC 2021, IGCC 2021, ASHRAE 90.1 2019/Zero code, ASHRAE Standard 189 2020.
- All toilets sold in the U.S. must comply with ASME A112.19.2

Preferred design and Analysis tools

- GEMI Water Sustainability Tool (http://www.gemi.org/water/)
- EPA Commercial and Institutional (CI) Facility Water Assessment Tools: are available at (https://www.epa.gov/watersense/tools-ci-facilities#CI%20Water%20Assessment%20Tools)
- EPA Watersense Product Directory: https://lookforwatersense.epa.gov/products/

Verona Place Apartments, UCI, Irvine, CA

Niagara Stealth UHET

CASE STUDY

HOUSING ON UCI CAMPUS

Irvine, CA

Verano Place Apartments, a mutli family housing on University of California Irvine campus has installed high efficient fixtures listed below including the Niagara UHET that uses 37% less water than the standard HET. One year after the installation, the project saved nearly 16 million gallons.

The fixtures installed were Niagara Conservation's EPA WaterSense® certified Ultra-High-Efficiency-Technology® Stealth 0.8 GPF toilets, 0.5 GPM kitchen and bathroom aerators and 1.5 GPM Earth® showerheads.

Faucet with and without Aerator

Neoprel Bubble and Needle aerators

ULTRA LOW FLOW AERATORS

Aerators play a vital role in shaping the user experience of the plumbing technology and efficiency. The use of Ultra Low Flow Aerators has the ability to save water without compromising on performance.

Strategy Description

Aerators work by mixing air into the water stream, thus breaking the large stream of water into a multitude of tiny streams. Ultra low flow aerators reduce the water flow to a greater extent of upto 0.35-0.5 gpm than the standard aerators that offer 1.5-2.2gpm from the faucet without reducing the pressure. Coupling the Ultra Low Flow Aerators with sensors can achieve even more water savings for applications like faucets and shower heads.

Technical Links:

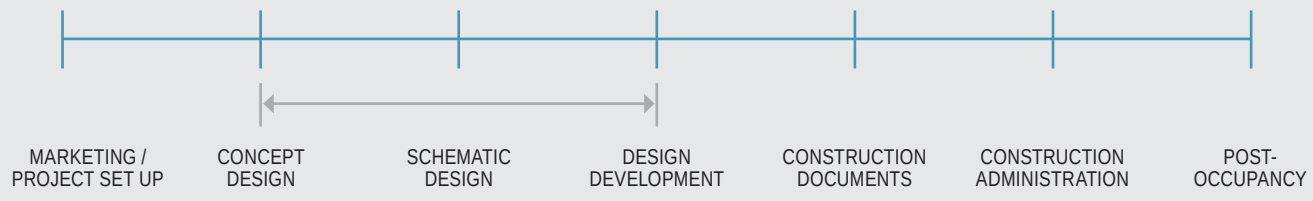
- Neoprel Mikado Aerator -0.35gpm- https://www.neoperl.net
- Niagara Dual thread Aerator-0.5 gpm - https://niagaracorp.com
- Sloan Aerator -0.35 gpm- https://sloanrepair.com

Building Typologies & Project Type

Applicable to primary Tempe building typologies and project types.

	COMMUNITY SERVICES	FIRE STATIONS	HISTORIC BUILDINGS	OFFICE SPACES	POLICE / COURTS	SPORTS FACILITY	UTILITY	WATER MANAGEMENT
NEW CONSTRUCTION	X			X	X	X	X	X
MAJOR RENOVATION	X			X	X	X	X	X
MODERNIZATION								

Project Timeline Application & Implementation



Holistic Design Implementation

It is crucial to perform a baseline water analysis in the early stages of design preferably after programing and zoning is completed, it helps to understand projects water end uses and outdoor water usage based on the occupancy. It also provides an opportunity to benchmark and set the water efficiency targets for the project. The next step is to evaluate water reduction, water reuse / recycle strategies that helps achieve the water conservation goals which takes place through out th erst of the deign process. Water sense labeled Products/fixtures that best aligns with the project goals will be recommended after the final analysis is done.

Operations and Maintenance

- The use of smaller water emitting openings may cause ultra low-flow faucets to clog with debris or mineral deposits more often than conventional faucets. More frequent cleaning will help reduce any debris or mineral build-ups
- It is important to note Tankless water heaters require a minimum flow rate in order to turn on and heat the water. When deciding which aerator to use, choose an aerator with the correct flow rate to allow your tankless water heater to activate properly.

Relevant Codes & Standards

- City of Tempe current codes - ASHRAE 90.1 2016 / IECC 2018, International Plumbing Code 2018, Uniform plumbing code 2018
- Latest and Advanced codes - IECC 2021, IGCC 2021, ASHRAE 90.1 2019/Zero code, ASHRAE Standard 189 2020.

Preferred design and Analysis tools

- GEMI Water Sustainability Tool (http://www.gemi.org/water/)
- EPA Commercial and Institutional (CI) Facility Water Assessment Tools: are available at (https://www.epa.gov/watersense/tools-ci-facilities#CI%20Water%20Assessment%20Tools)
- EPA Watersense Product Directory: https://lookforwatersense.epa.gov/products/

Verona Place Apartments, UCI, Irvine, CA

Niagara Dual Thread Aerator - Needle spray - 0.5 gpm

CASE STUDY

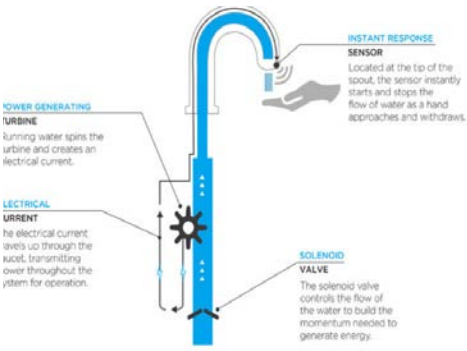
APARTMENTS ON UCI CAMPUS

Irvine, CA

Verano Place Apartments, a mutli family housing at University of California Irvine campus has installed high efficient fixtures listed below including the ultra low flow aerator with 0.5 gpm for all its faucets. One year after the installation, the project saves nearly 16 million gallons.

Plumbing fixtures used: The fixtures installed were Niagara Conservation's EPA WaterSense® certified Ultra-High-Efficiency-Technology® Stealth 0.8 GPF toilets, 0.5 GPM kitchen and bathroom aerators and 1.5 GPM Earth® showerheads.

EcoPower Hydro turbine



EcoPower Hydro turbine - Working Mechanism

Sloan Basys Faucet Line- Turbine and Solar Based

POWER HARVESTING ELECTRONIC FAUCETS

As the scale of the project becomes larger, the maintenance of plumbing fixtures steadily balloons to become a significant functional cost on the owner's part. To alleviate this cost, the use of power harvesting electronic faucets is encouraged. These faucets can be installed to continuously harvest the energy required for their sensors and operation from their surroundings.

Strategy Description

There are two main types of Power Harvesting Electronic Faucets currently available, they are Turbine Based and Solar based faucets. In a turbine based faucet, the energy from the flow of water through the faucet is recovered using a turbine to generate electricity, where as in the solar based faucet, the light from the surroundings is harvested using a photo voltaic panel. This harvested electricity is used to power the sensors inside the faucet.

Technical Links:

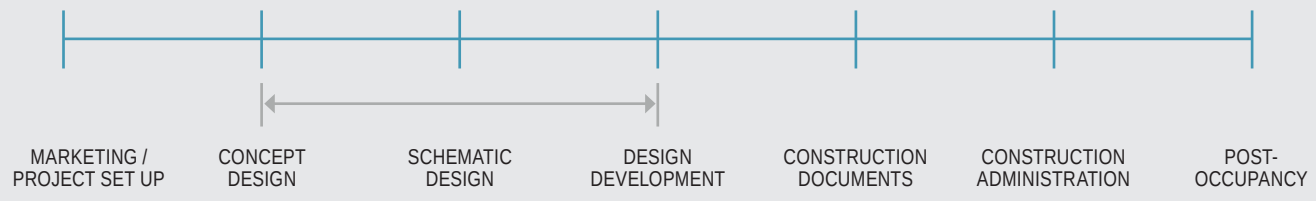
- Sloan Basys faucet Line- https://www.sloan.com
- TOTO Self sustaining Faucets -https://www.totousa.com

Building Typologies & Project Type

Applicable to primary Tempe building typologies and project types.

	COMMUNITY SERVICES	FIRE STATIONS	HISTORIC BUILDINGS	OFFICE SPACES	POLICE / COURTS	SPORTS FACILITY	UTILITY	WATER MANAGEMENT
NEW CONSTRUCTION	X			X	X	X	X	X
MAJOR RENOVATION	X			X	X	X	X	X
MODERNIZATION								

Project Timeline Application & Implementation



Holistic Design Implementation

It is crucial to perform a baseline water analysis in the early stages of design preferably after programing and zoning is completed, it helps to understand projects water end uses and outdoor water usage based on the occupancy. It also provides an opportunity to benchmark and set the water efficiency targets for the project. The next step is to evaluate water reduction, water reuse / recycle strategies that helps achieve the water conservation goals which takes place through out th erst of the deign process. Water sense labeled Products/fixtures that best aligns with the project goals will be recommended after the final analysis is done.

Operations and Maintenance

- Eco Power faucets are specifically designed to keep controls and components below deck and out of the way of both accidental and intended damage. And all components are easily and readily accessible when required. The faucet has an easy access screen to protect working components from debris and natural waterborne elements.

Relevant Codes & Standards

- City of Tempe current codes - ASHRAE 90.1 2016 / IECC 2018, International Plumbing Code 2018, Uniform plumbing code 2018
- Latest and Advanced codes - IECC 2021, IGCC 2021, ASHRAE 90.1 2019/Zero code, ASHRAE Standard 189 2020.

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Boston University Campus, MA

TOTO EcoPower sensor faucets

CASE STUDY

BOSTON UNIVERSITY

Boston, MA

As a part of the remodeling effort of bathrooms and kitchens on Campus at Boston University, Campus Planning and Operations have committed to reduce to university's water consumption. They installed Low-flow shower heads that use 1.6 gallons per minute (gpm) versus 3.5 gpm, and low-flow toilets that use 1.3 gallons of water per flush versus 3.5 gallons, self-sustaining TOTO EcoPower sensor faucets at several locations on campus. These faucets use water to power the motion sensor that turns the water on and off. With as few as 10 uses per day, the EcoPower system replenishes its charge.

Tools

FACADE DESIGN TOOL
Provides options to choose the design conditions of a window and rank and compare the performance data in terms of annual energy, peak demand, carbon, daylight illuminance, glare, and thermal comfort.

https://www.commercialwindows.org/fdt.php

WINDOW
A federally funded computer program developed by Lawrence Berkeley National Laboratory (LBNL), calculates U-values, SHGC, and Tvis of window systems constructed from glass and frames of known

https://windows.lbl.gov/software/window

eQuest®
Replacement to PowerDOE

http://doe2.com

- Product selection tool - https://www.vitrum.ca/performance-data/Helps to choose a specific or high performance glass by their performance parameters.