KFUPM Campus
Smart and Sustainable Master Plan

Overall Master Plan Framework – Sustainability
Dhahran, KSA

KFUPM Contract No. 22402684 | 03 July, 2024

Sustainability Focus Areas Emphasis

Water
Collect, Manage, Treat and Provide Clean Water, Prioritize Efficiency and Reuse

Energy & Carbon
Reduce Carbon Emissions, Increase Energy Efficiency and Clean Renewable Energy Sources

Landscape & Irrigation
Maximize Reclaimed/Recycled Water Use, Optimize Irrigation and Native Planting Materials, Promote Ecosystem Health

Waste
Reduce or Eliminate Waste, Increase Landfill Diversion, Recycling and Composting, Optimize Disposal Methods, Waste to Energy

Health & Well-being
Integrate Health and Well-being into Urban Design, Architecture and Infrastructure

Resiliency
Respond to Climate, Protect and Adapt, Promote Ecosystem Health

Sustainable Design Benefits

Water Conservation & Reuse Benefits

Clean water for drinking and cooking, healthy landscapes and more comfortable outdoor spaces for students, faculty, visitors, reduced water loss and consumption, reduced utility costs

Existing Conditions: Campus water supply shifting away from wells and solely to local utility. Consumption is not metered. Loss due to leaks is unknown. Equipment and fixtures are inefficient and in disrepair.

Master Plan Recommendations: Building fixtures, central utility equipment and irrigation systems are efficient, metered and well-maintained. Water is collected, treated and reused.

Sustainable Design Benefits

Energy Conservation & Carbon Emissions Reduction

Focusing on operational cost savings and reducing the university's carbon footprint can assist the university in prioritizing renovation work and how new buildings should be designed

Existing Conditions: Most buildings on campus do not have adequate systems in place to provide efficient operations which can lead to higher costs and inefficient use of resources

Master Plan Recommendations: Reduce carbon emissions, increase energy efficiency and clean, renewable energy sources. Include updates to existing building envelopes to passively save energy.

Sustainable Design Benefits

Design for Health & Well-being

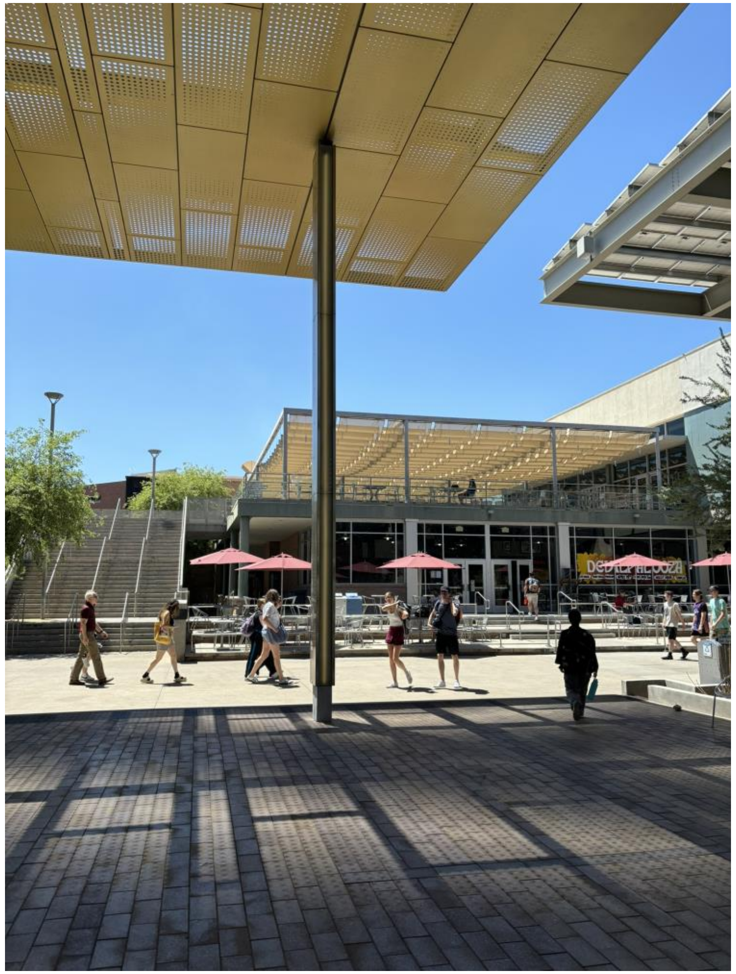
Accessible and varied spaces and amenities, both indoors and outdoors, that cater to student and staff needs will increase academic success and overall comfort and well-being for those on campus

Existing Conditions: There are opportunities on campus for visual and physical access to green space and activity spaces, along with good daylight access within some buildings, but access is not evenly dispersed through campus.

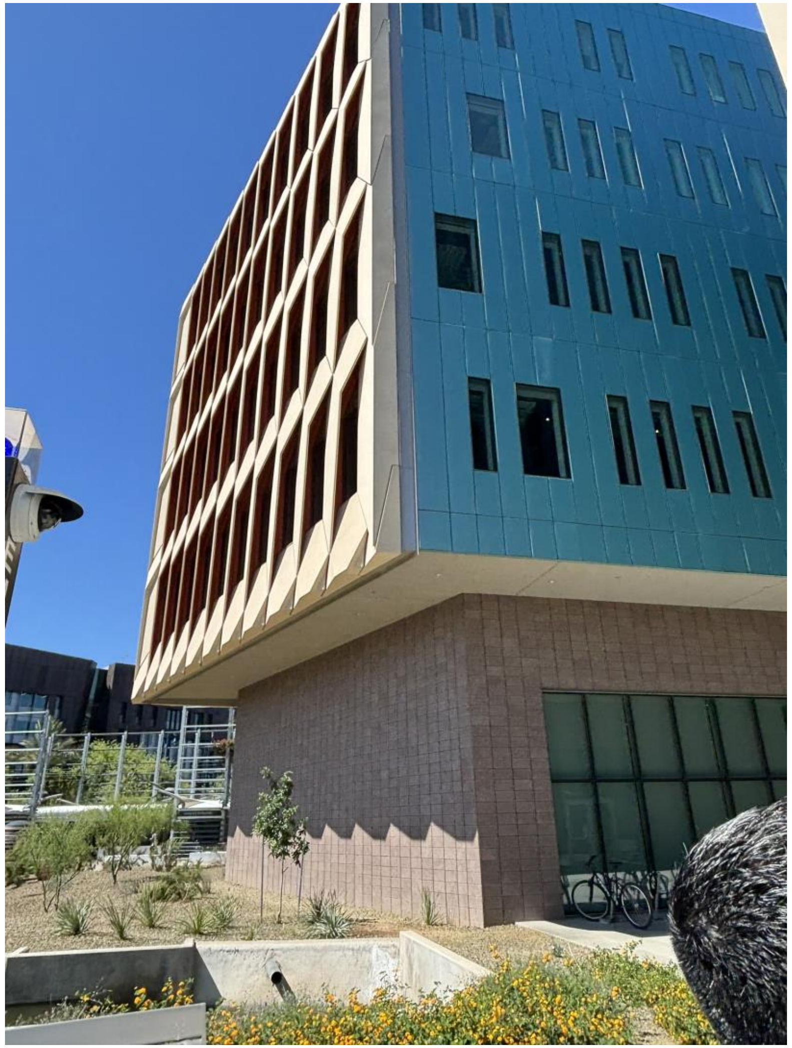
Master Plan Recommendations: Campus improvements could include more accessible and integrated green space and varied spaces both indoors and outdoors that foster well-being and address individual user needs.

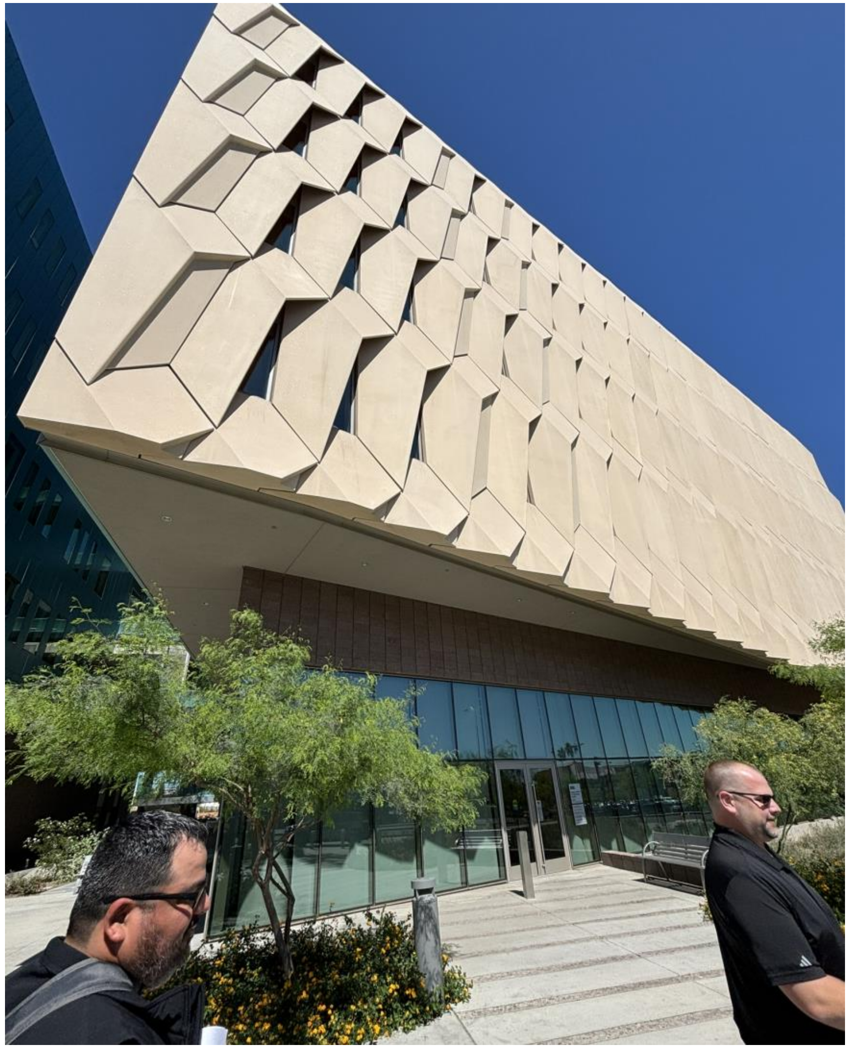
Benchmarking

Benchmarked Best Practices Climate-adaptive Design



Benchmarked Best Practices Climate-adaptive Design





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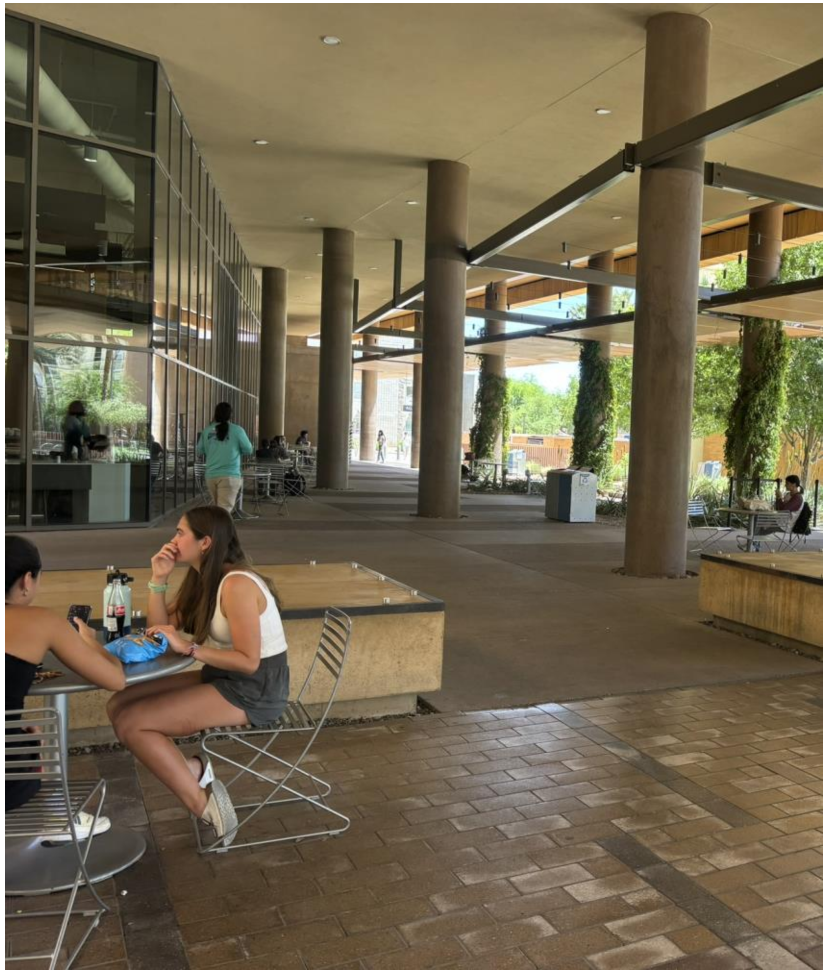

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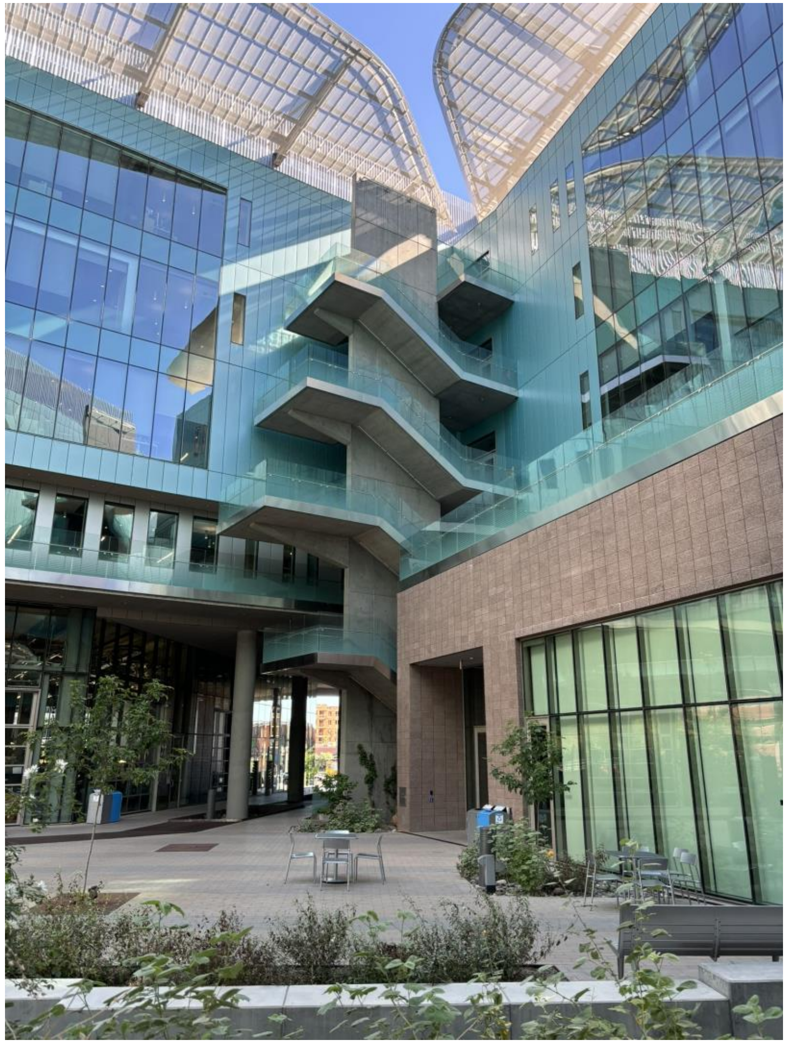
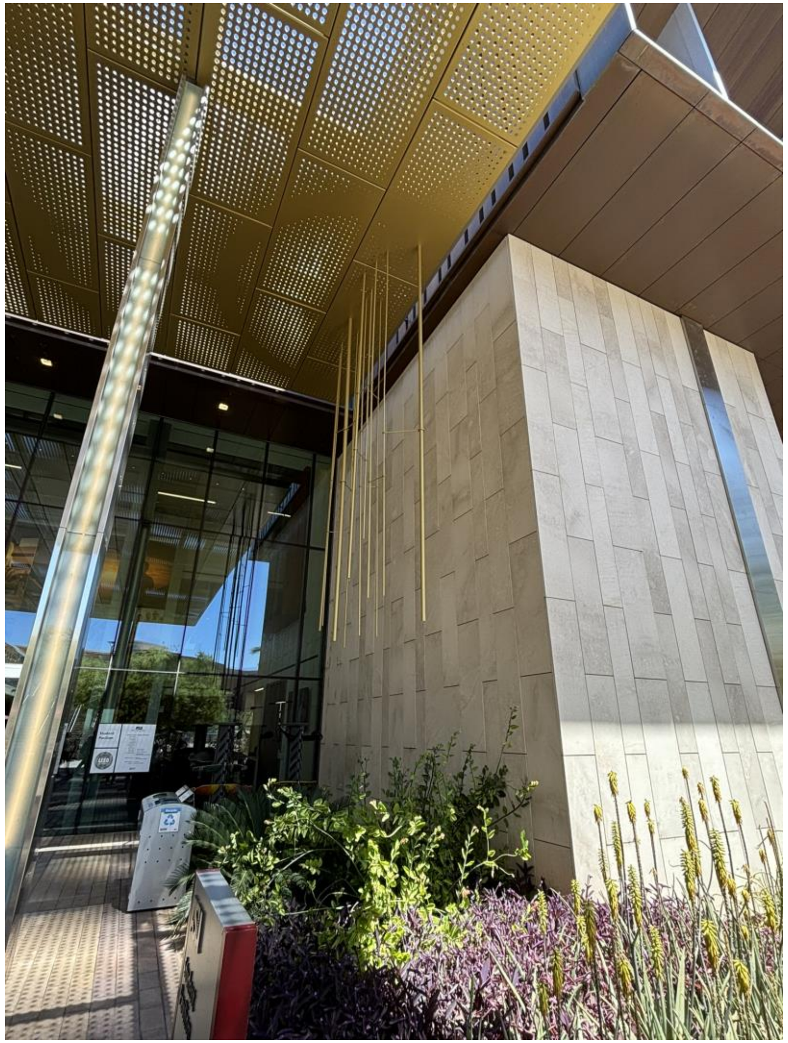
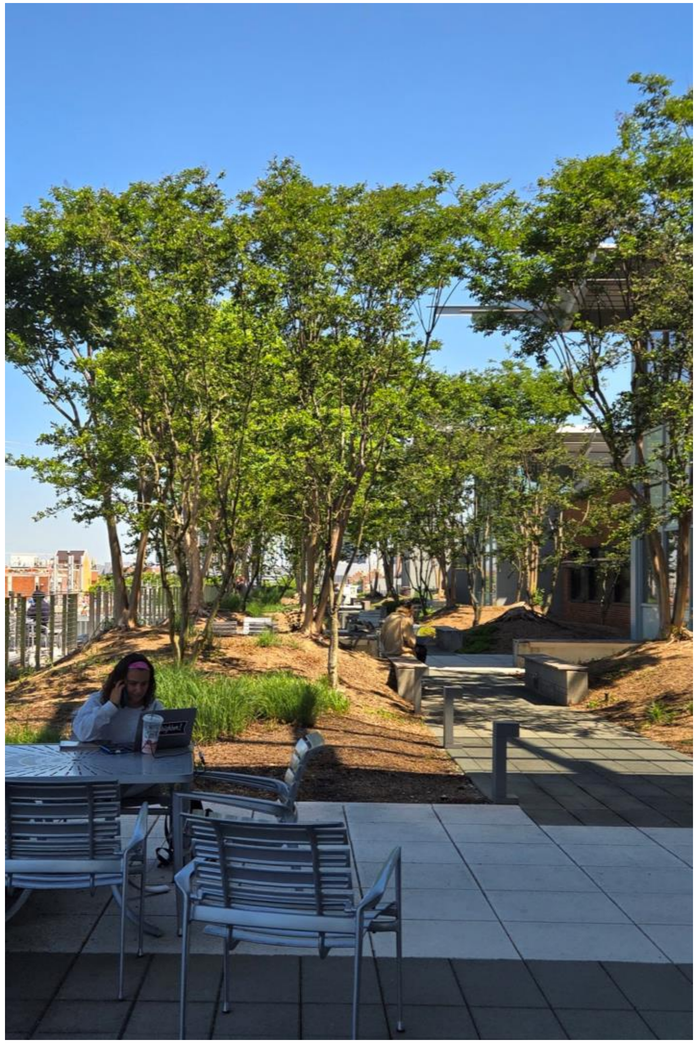


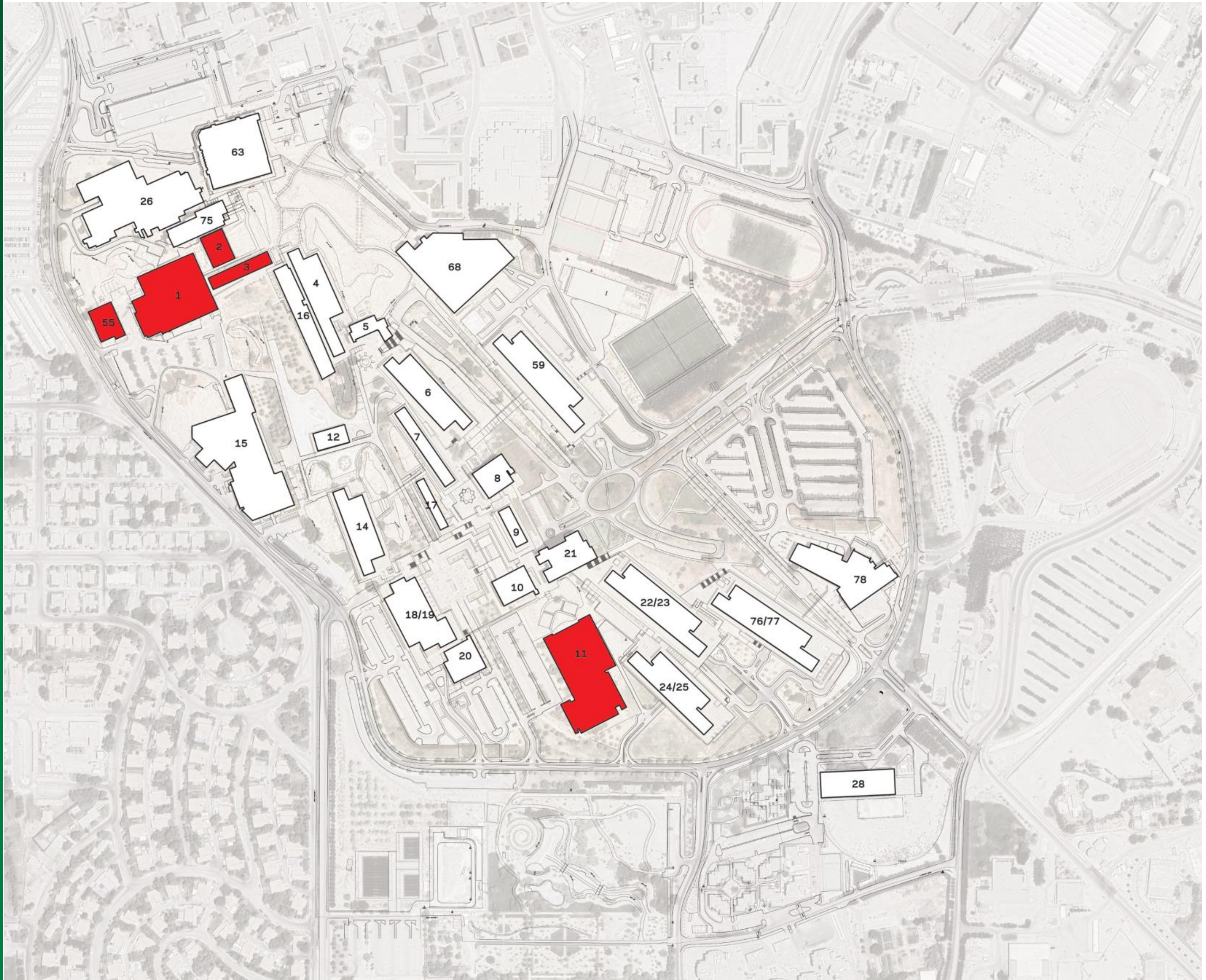
Benchmarked Best Practices Climate-adaptive Design





Building Energy

Buildings to be Demolished



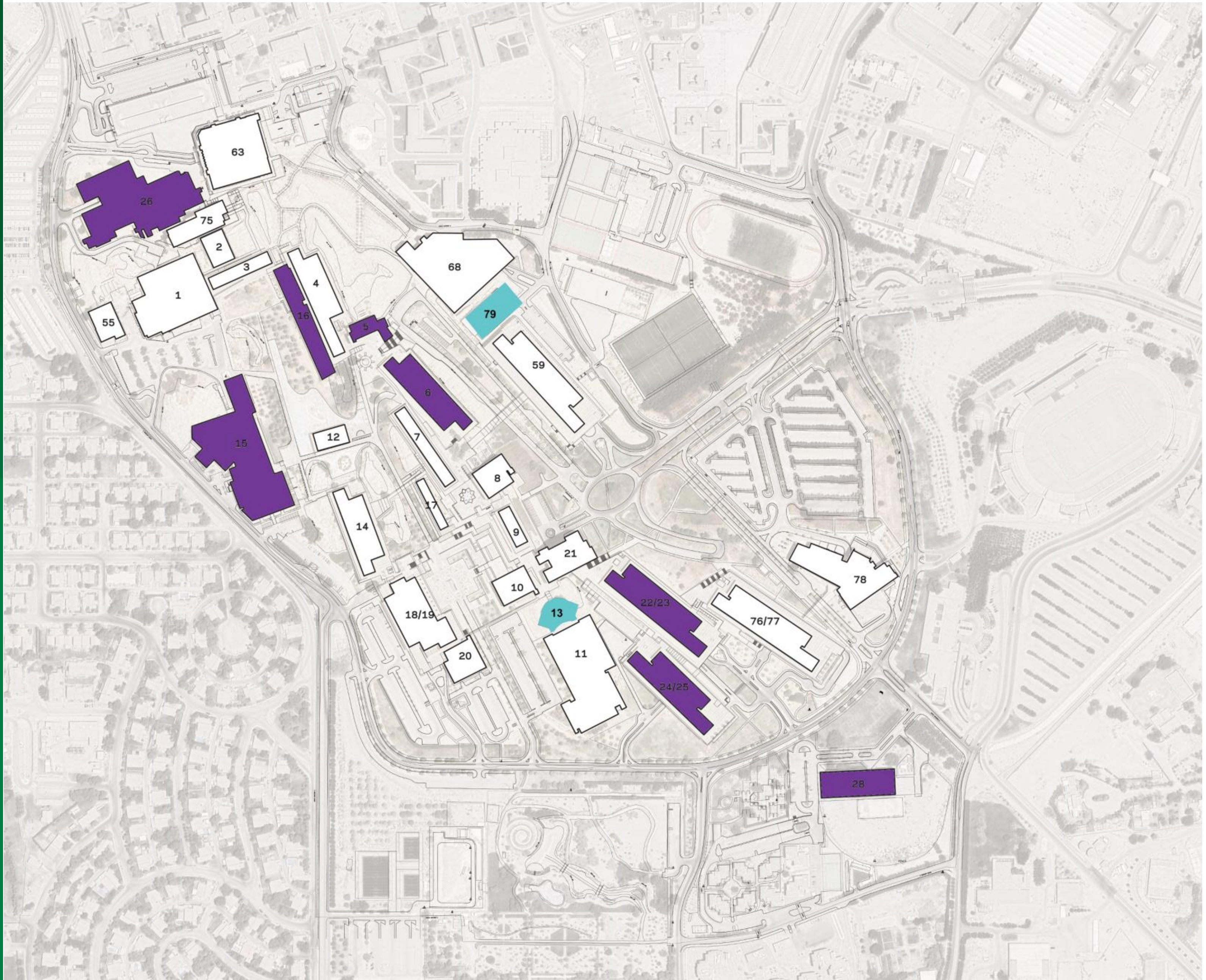
Total 5 Buildings

Buildings 1, 2, 3 are not named
Building 11 – Gymnasium
Building 55 – Research Laboratory

Sustainability Opportunities:
Construction Waste Management

- Reduce Disposal Rate
- Cognizant Collection of Material Streams
- Increase Recycling Opportunities
- Safe Disposal of Hazardous Waste
- Analyze Reuse Possibilities

Buildings Not Assessed



Total 10
Under Redesign:

Building 5, 6, 16 are not named
Building 15 – Research Institute
Building 22/23 – Class Room & Car Parking
Building 24/25 – KFUPM Business School & Car Parking
Building 26 – Heavy Equipment Laboratory Building
Building 28 – Energy Research Laboratory

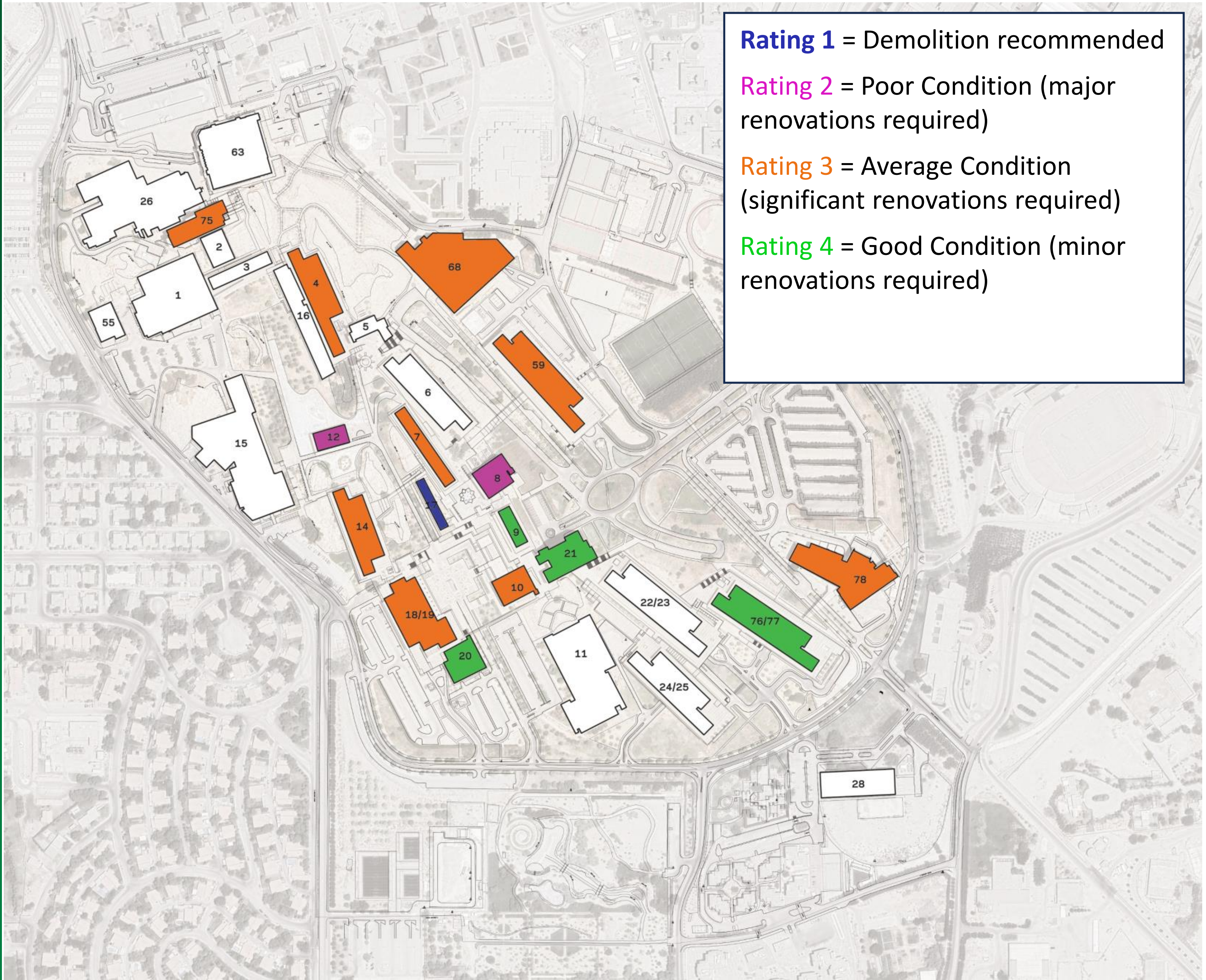
Total 2
Per KFUPM not to be assessed

Building 13 – Amphitheater
Building 79 – College of General Studies

Sustainability Opportunities:

- Performance Analysis Recommended Interventions in Subsequent Slides

Buildings Assessed to be Renovated



Rating 1 | Total 1

Building 17 – College of General Studies

Rating 2 | Total 2

Building 8 – Central Library
Building 12 – Al Saddique Mosque

Rating 3 | Total 8

Building 4, 7 are not named
Building 10 – Prince Nayef Bin Abdul Aziz International Center For Culture & Science
Building 14 – Information & Technology Center
Building 18/ 19 – Car Parking / College of Design & Built Environment
Building 75 – College of Engineering and Physics
Building 78 – College of Petroleum Eng. & Geo-Sciences

Rating 4 | Total 5

Building 9 – Faculty & Student Center
Building 20 – Conference Center
Building 21 – Administration Building
Building 76/77 – Class Room, College of Petroleum Eng. & Geo-Sciences / Car Parking

Sustainability Opportunities:

Performance Analysis Recommended Interventions in Subsequent Slides

Buildings Assessed to be Renovated

Building Example Rated at 3

KFUPM Building 58, Preparatory Year Class Room

MAJOR INTERVENTIONS – Rating 2 or 3

SITE

- Renewable Energy
- Socially Activated Spaces
- Universal Design

BUILDING

- Full Cycle Water Reuse
- Deep Energy Efficiency Retrofit
- Advanced Indoor Air Quality Measures
- On-going Maintenance Procedures
- Benchmarking + Retro Commissioning
- Intensive Acoustical Enhancements
- Effective Waste Management

Buildings Assessed to be Renovated

Building Example Rated at 4

KFUPM Building 76, Class Room, College of Petroleum Eng. & Geo-Sciences

MINOR INTERVENTIONS – Rating 4

BUILDING

- Renewable Energy
- Water Conservation Measures
- Light Energy Efficiency Retrofit
- Indoor Air Quality Improvements
- On-going Maintenance Procedures
- Benchmarking + Retro Commissioning
- Light Acoustical Upgrades
- Effective Waste Management

Focus on Building Energy: Performance Analysis with Box Model

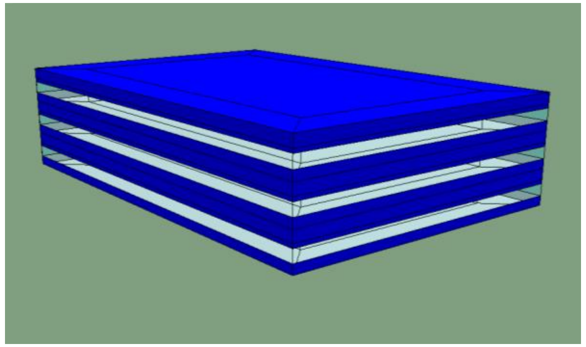
Box models offer insight and guidance to inform future building renovation interventions:

- Estimate energy use intensity, based on existing conditions
- Quantify impact of Energy Conservation Measures
- Develop replicable strategies for use across campus
- Inform future decisions for new construction or existing building renovations
- Establish estimated campus renewable energy demand to size generation capacity

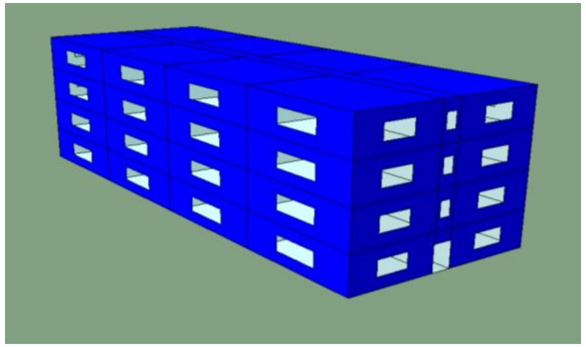
Focus on Building Energy: Performance Analysis with Box Model

Quantify energy performance opportunities and potential interventions using box models of ASHRAE Standard 140 building geometry and existing envelope and building systems performance:

- Academic Building



- Housing Building



Energy Efficiency Intervention Summary

Academic Building = 53% overall energy use intensity reduction

Individual Intervention Reductions:

- Envelope = 3.7%
  - **Roof – Insulation above deck (U-0.22)**
  - **Fenestration – Double pane (U-2.84, SHGC-0.22, VT-0.25)**
- Internal Loads: Lighting = 11.6%
  - **Lighting Power Density – 7.5 W/sqm**
- Internal Loads: Equipment = 15%
  - **Equipment – 16.0 W/sqm**
- Domestic Water Heating = 0.3%
  - **Peak demand – 3.8 l/hr**
- HVAC 1 = 29.8%
  - **Variable volume AHU with CHW cooling coil and electric re-heat**
- HVAC 2 = 7.7%
  - **Total energy recovery wheel**
- HVAC 3 = 8.4%
  - **High part load efficiency water cooled chiller with variable speed open cooling tower**

Energy Efficiency Intervention Summary

Academic Building = 53% energy use intensity reduction

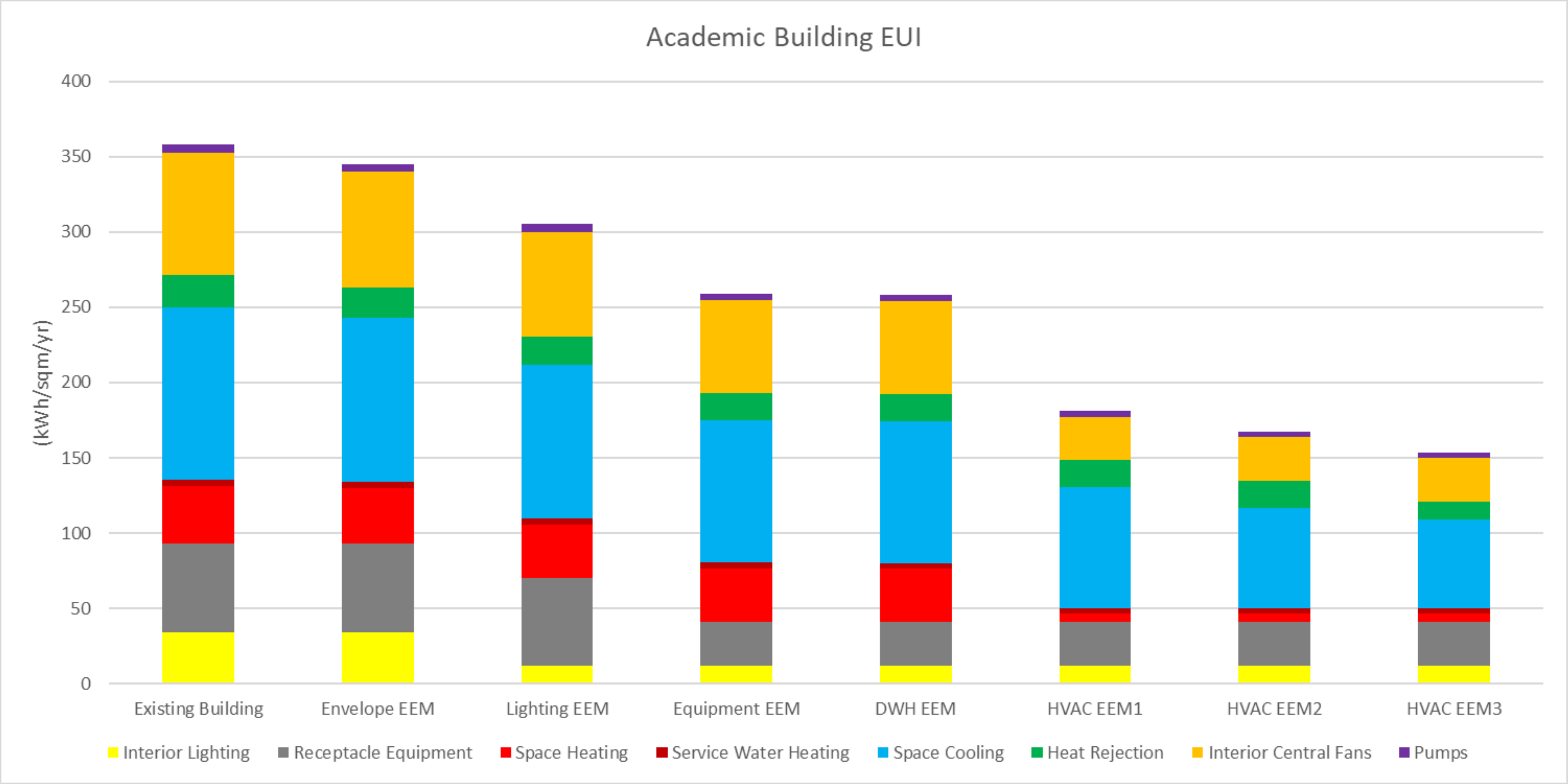


Chart indicates cumulative effect of adding each intervention to the previous ones

Energy Efficiency Intervention Summary

Residential Building = 66% energy use intensity reduction

Individual Intervention Reductions:

- Envelope = 3.2%
  - **Roof – Insulation above deck (U-0.22)**
  - **Fenestration – Double pane (U-2.84, SHGC-0.22, VT-0.25)**
- Internal Loads: Lighting = 11.3%
  - **Lighting Power Density – 5.6 W/sqm**
- Internal Loads: Equipment = 13.5%
  - **Equipment – 10.7 W/sqm**
- Domestic Water Heating = 0.4%
  - **Peak demand – 37.9 l/hr**
- HVAC 1 = 54%
  - **Variable volume AHU with CHW cooling coil and electric re-heat**
- HVAC 2 = 2%
  - **Total energy recovery wheel**
- HVAC 3 = 7.4%
  - **High part load efficiency water cooled chiller with variable speed open cooling tower**

Energy Efficiency Intervention Summary

Residential Building = 66% energy use intensity reduction

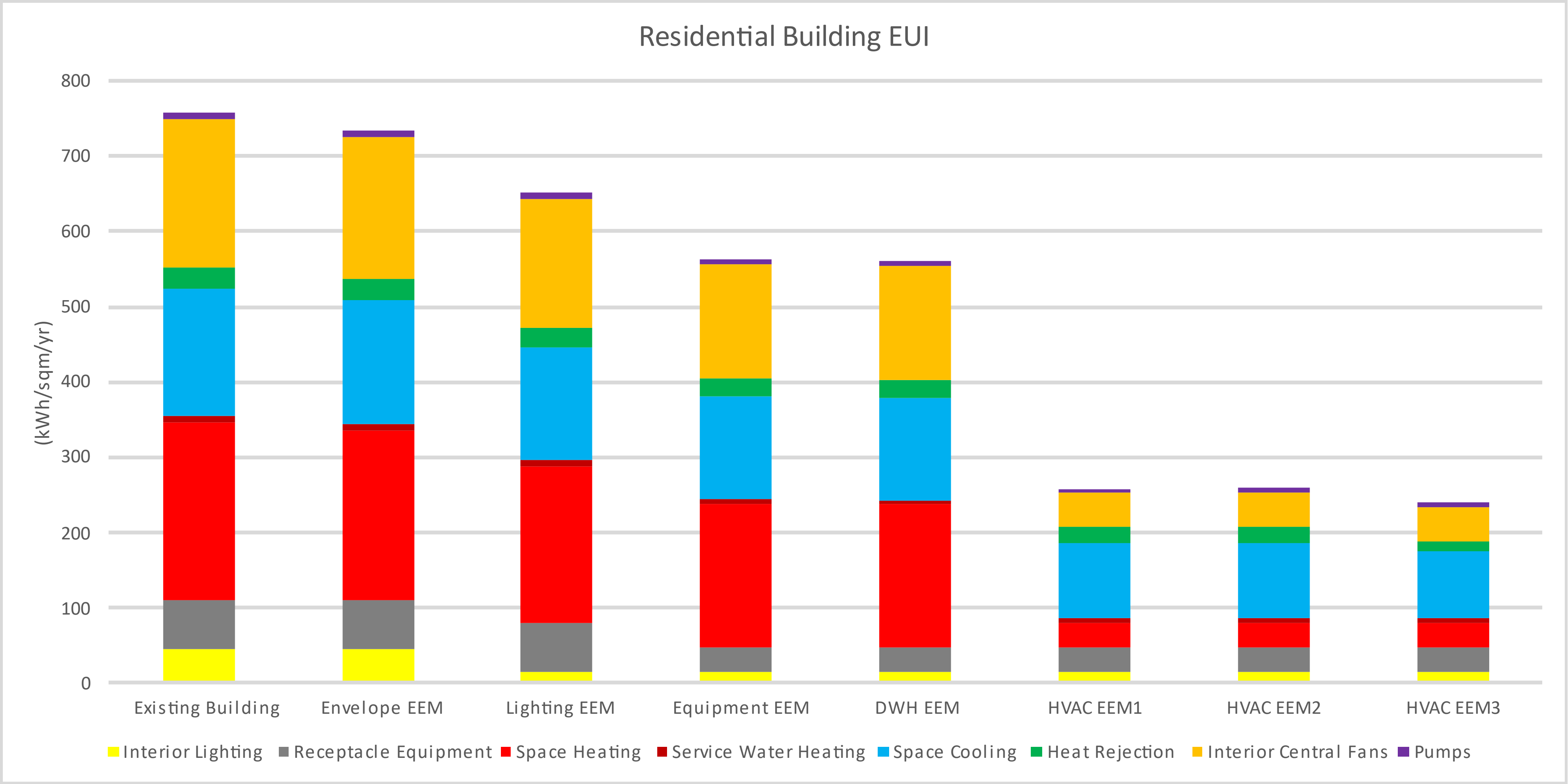


Chart indicates cumulative effect of adding each intervention to the previous ones

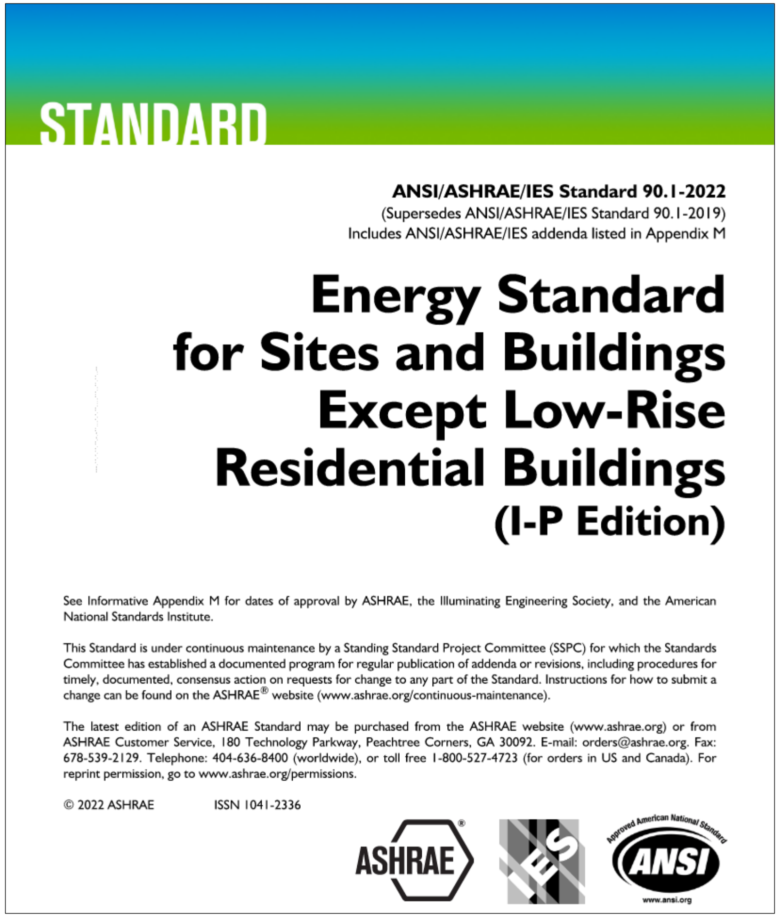
Energy Efficiency Interventions

Existing Building Assumptions:

Based upon Buildings Assessment Report and Codes Typical for the Time Built

- Envelope
  - Roof – Insulation above deck (U-0.43)
  - Walls – Uninsulated concrete (U-3.29)
  - Floors – Uninsulated concrete (U-1.83)
  - Slab on Grade – Uninsulated concrete (F-1.26)
  - Fenestration – Single pane (U-6.93, SHGC-0.40, VT-0.44)
- Internal Loads and Gains
  - Lighting Power Density – 16.0 W/sqm (Academic) / 16.0 W/sqm (Housing)
  - Equipment – 26.7 W/sqm (Academic) / 21.4 w/sqm (Housing)
- Domestic Water Heating
  - Peak demand – 7.6 l/hr (Academic) / 75.7 l/hr (Housing)
- HVAC
  - Constant volume AHU with CHW cooling coil and electric re-heat
  - Water cooled chiller with constant speed open cooling tower

Energy Efficiency Interventions



STANDARD

ANSI/ASHRAE/IES Standard 90.1-2022
(Supersedes ANSI/ASHRAE/IES Standard 90.1-2019)
Includes ANSI/ASHRAE/IES addenda listed in Appendix M

Energy Standard for Sites and Buildings Except Low-Rise Residential Buildings (I-P Edition)

See Informative Appendix M for dates of approval by ASHRAE, the Illuminating Engineering Society, and the American National Standards Institute.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. Instructions for how to submit a change can be found on the ASHRAE® website (www.ashrae.org/continuous-maintenance).

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Energy Efficiency Intervention Details

- Envelope
  - **Roof – Insulation above deck (U-0.22)**
  - Walls – Uninsulated concrete (U-3.29)
  - Floors – Uninsulated concrete (U-1.83)
  - Slab on Grade – Uninsulated concrete (F-1.26)
  - **Fenestration – Double pane (U-2.84, SHGC-0.22, VT-0.25)**

- Internal Loads
  - **LPD – 7.5 W/sqm (Academic) / 5.6 W/sqm (Housing)**
  - **Equipment – 16.0 W/sqm (Academic) / 10.7 w/sqm (Housing)**

- Domestic Water Heating
  - **Peak demand – 3.8 l/hr (Academic) / 37.9 l/hr (Housing)**

- HVAC
  - **Variable volume AHU with CHW cooling coil and electric re-heat**
  - **Total energy recovery wheel**
  - **High part load efficiency water cooled chiller with variable speed open cooling tower**

Envelope Energy Efficiency Interventions

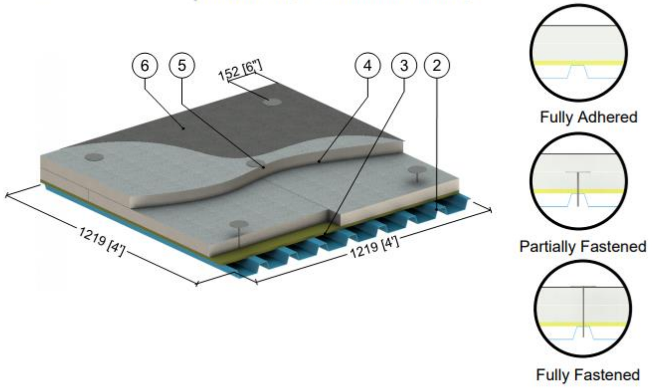
Results for implementing individual interventions:

- Academic Building = 3.7% reduction
- Residential Building = 3.2% reduction

Increased roof insulation

Appendix A: Catalogue Material Data Sheets BUILDING ENVELOPE THERMAL BRIDGING GUIDE v1.6

Detail 10.1.9 **Exterior Insulated Low Sloped Roof (3.4 fasteners/m², 0.3 fasteners/ft²)– Clear Roof Assembly**



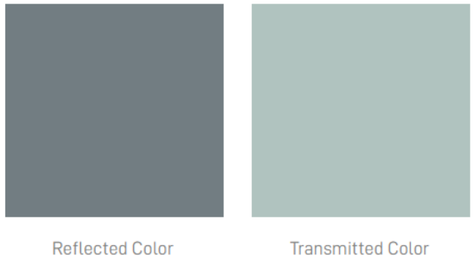
ID	Component	Thickness Inches (mm)	Conductivity Btu·in / ft²·hr·°F (W/m K)	Nominal Resistance hr·ft²·°F/Btu (m²K/W)	Density lb/ft³ (kg/m³)	Specific Heat Btu/lb·°F (J/kg K)
1	Interior Films[1]	-	-	R-1.1 (0.19 RSI)	-	-
2	Steel Deck	1/16" (1.6)	430 (62)	-	489 (7830)	0.12 (500)
3	Sheathing	1/2" (13)	1.1 (0.16)	R-0.5 (0.08 RSI)	50 (800)	0.26 (1090)
4	2 Layer Polyisocyanurate Insulation	Varies	Varies	R-22.8 to R-39.9 (4.02 to 7.03 RSI)	1.8 (28)	0.29 (1220)
5	#10 or #14 Steel Fasteners	3/16" (4.8) Ø, 1/4" (6.1) Ø	430 (62)	-	489 (7830)	0.12 (500)
6	Asphalt Cover Board and Roof Membrane	1/2" (12)	3 (0.43)	R-0.2 (0.03 RSI)	100 (1600)	100 (1500)
7	Exterior Film[1]	-	-	R-0.2 (0.03 RSI)	-	-

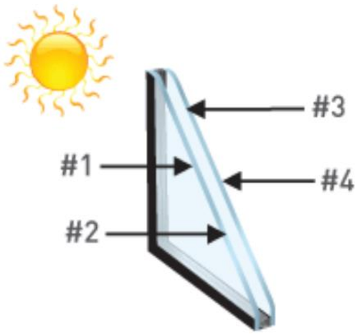
[1] Value selected from table 1, p. 26.1 of 2009 ASHRAE Handbook – Fundamentals depending on surface orientation

High performance IGU with low-E coating

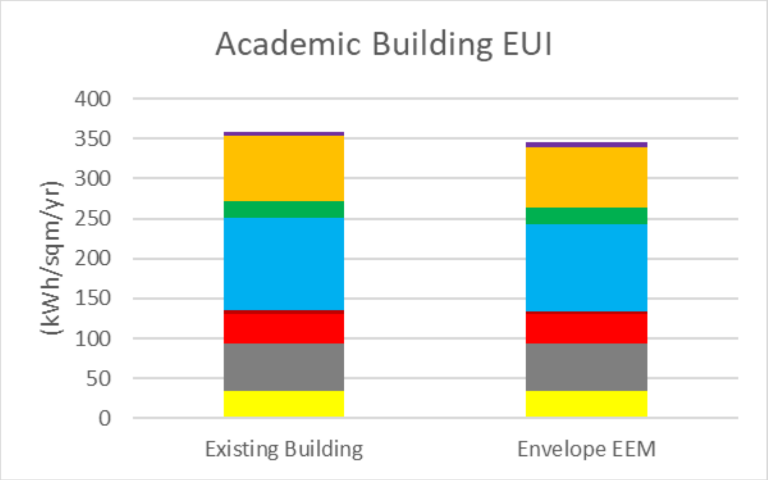
1" (25mm) Insulating VNE13-53

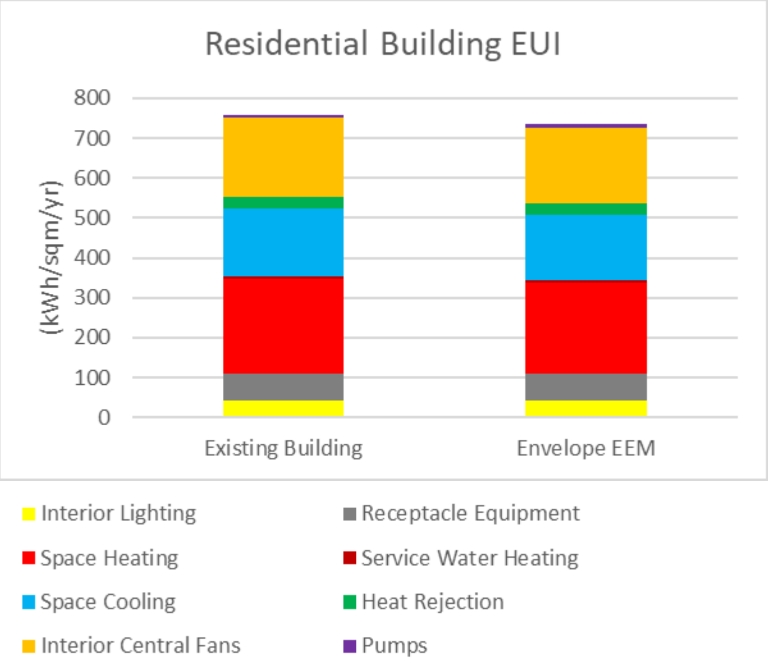
1/4" (6mm) Starphire® VNE-53 #2
1/2" (13.2mm) space - argon filled
1/4" (6mm) Starphire®





Cumulative Results with All Interventions



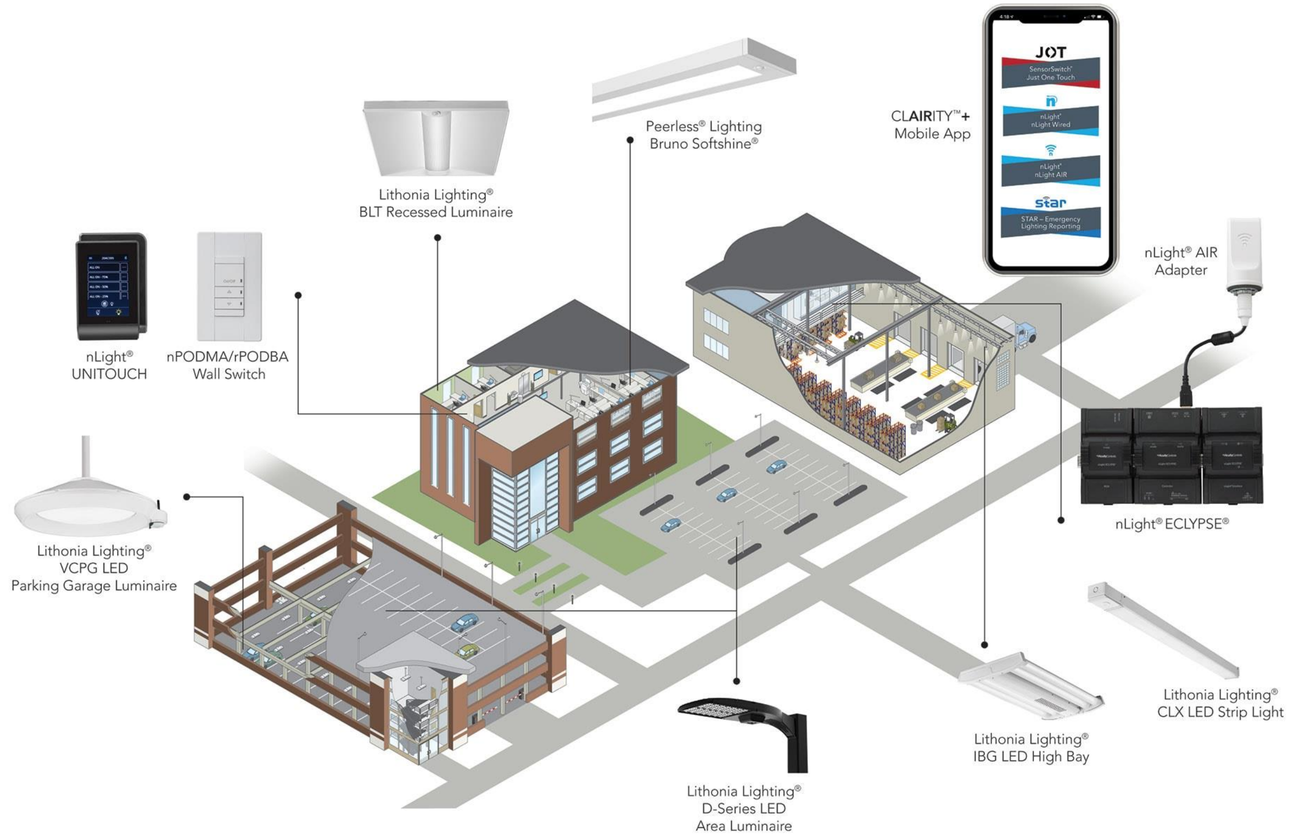


Lighting Energy Efficiency Interventions

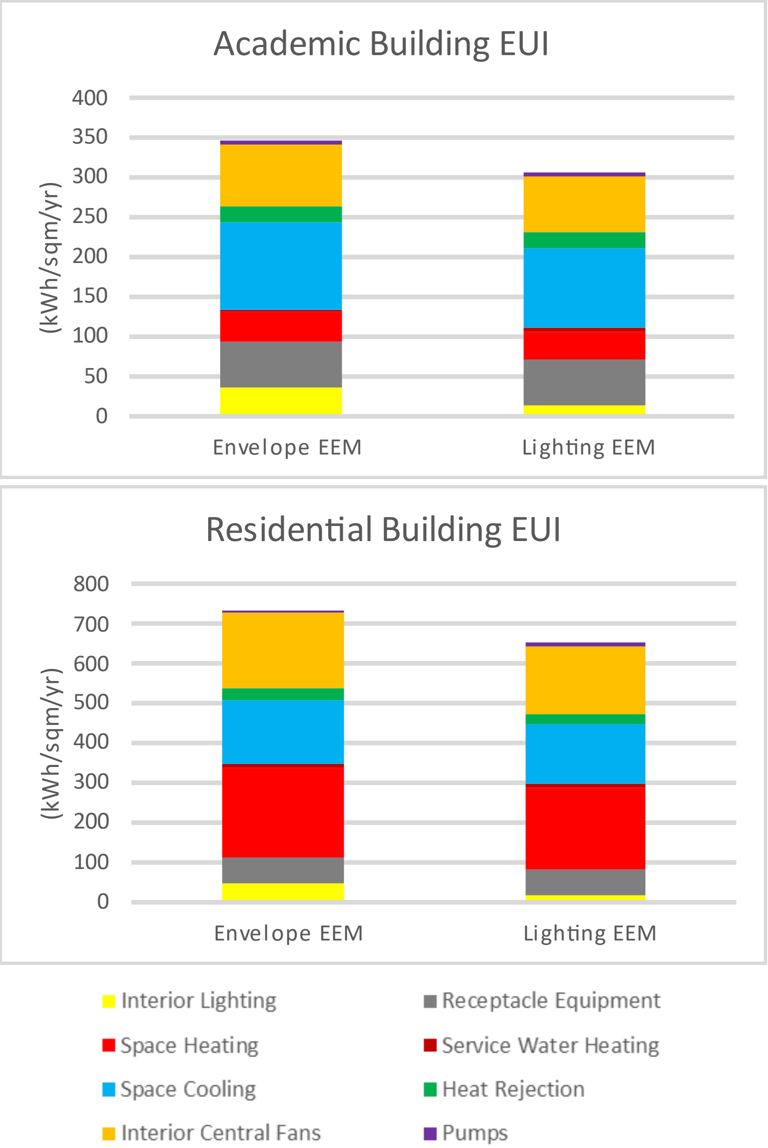
Results for implementing individual interventions:

- Academic Building = 11.6% reduction
- Residential Building = 11.3% reduction

High lumen per watt LED lighting fixtures and Advanced lighting control system



Cumulative Results with All Interventions



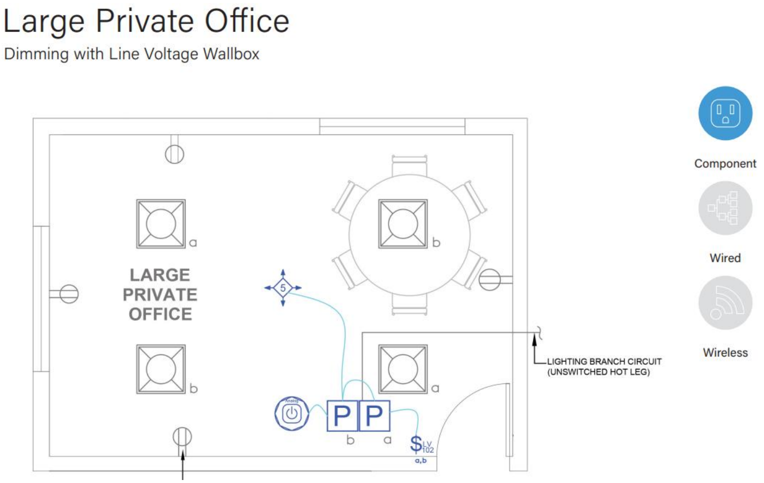
Equipment Energy Efficiency Interventions

Results for implementing individual interventions:

- Academic Building = 15% reduction
- Residential Building = 13.5% reduction

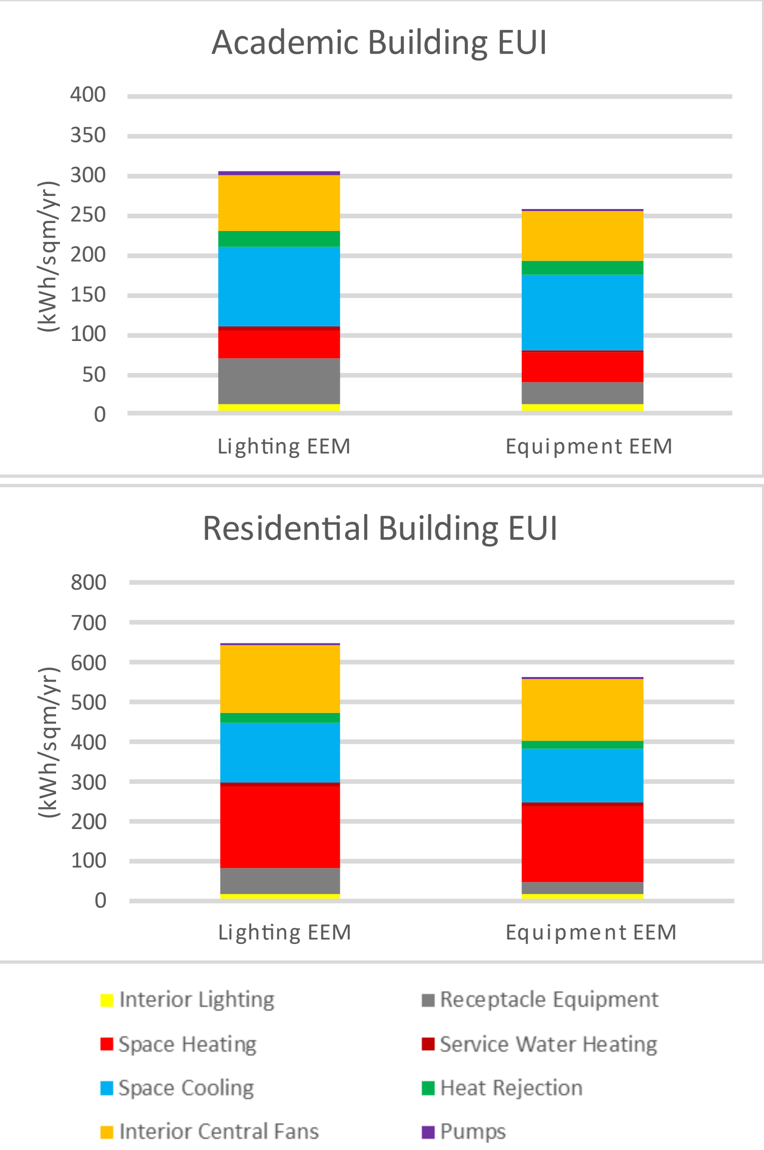
Energy star rated equipment

High efficiency cooking equipment



Plug load smart controls

Cumulative Results with All Interventions

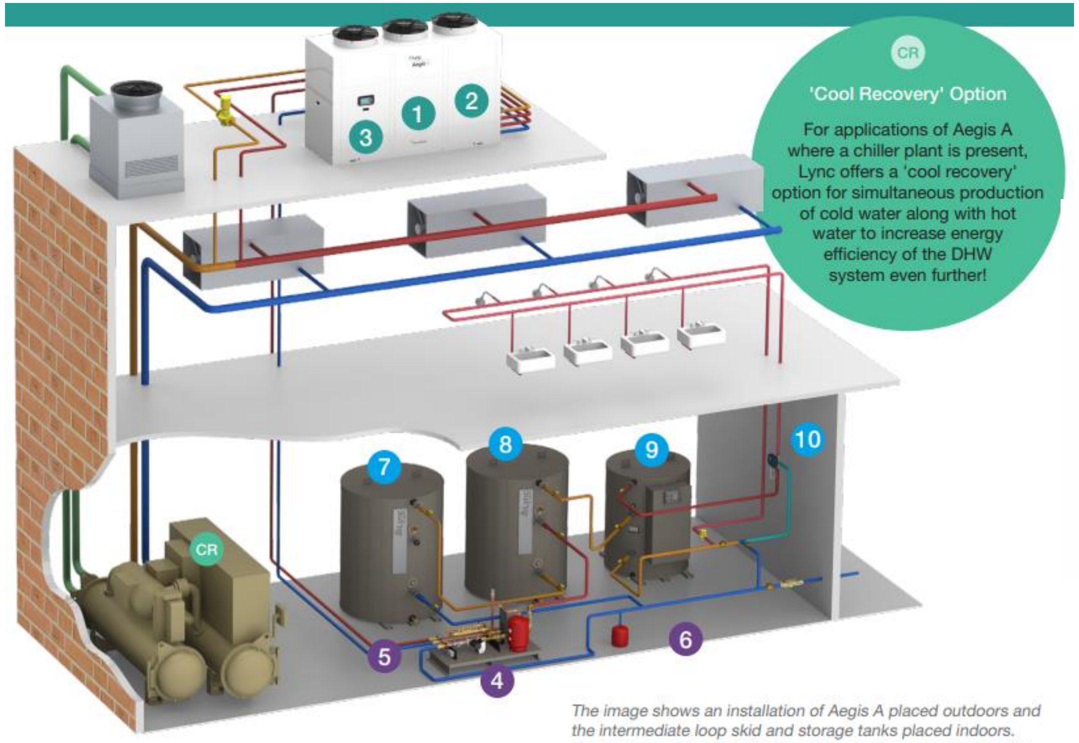


Domestic Water Heating Energy Efficiency Interventions

Results for implementing individual interventions:

- Academic Building = 0.3% reduction
- Residential Building = 0.4% reduction

Low flow plumbing fixtures and Heat pump water heaters

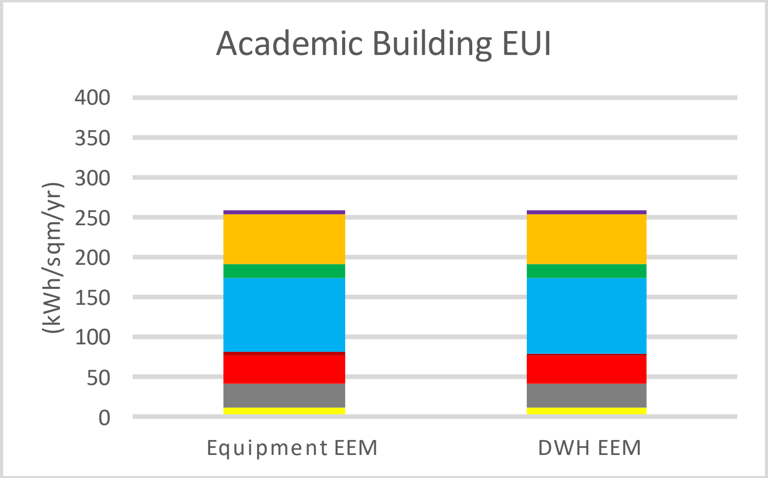


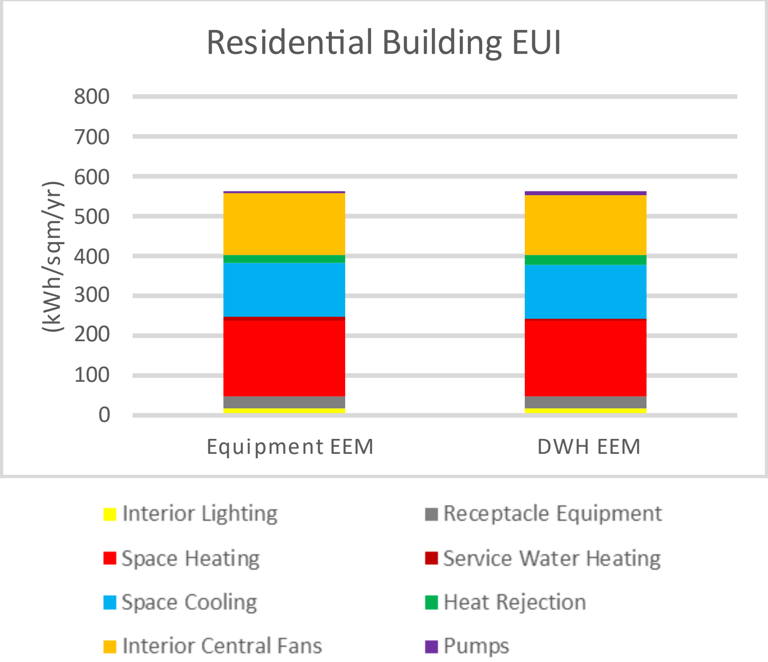
The image shows an installation of Aegis A placed outdoors and the intermediate loop skid and storage tanks placed indoors. The system can be installed in various ways appropriate to site conditions and selected Aegis heat pumps.

WaterSense • Meets EPA Criteria •

Certified by IAPMO R&T

Cumulative Results with All Interventions



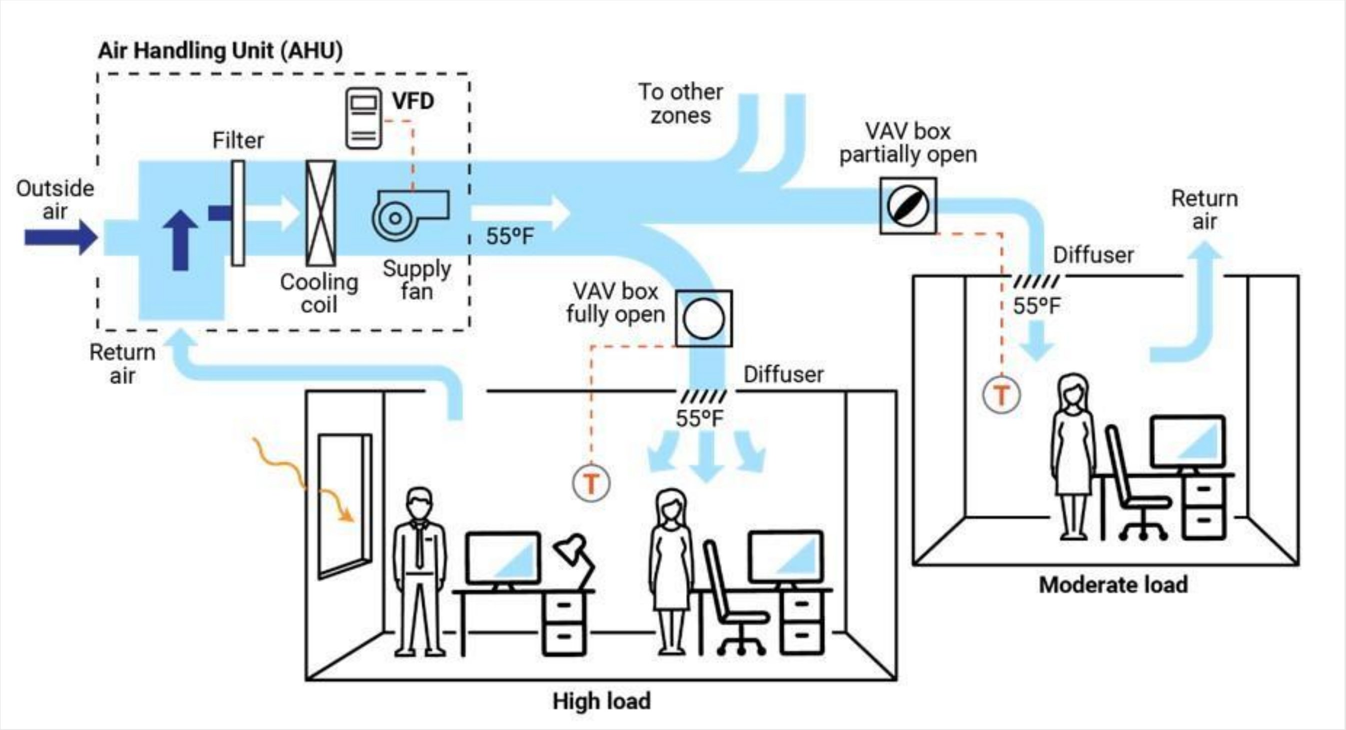


HVAC Energy Efficiency Intervention 1

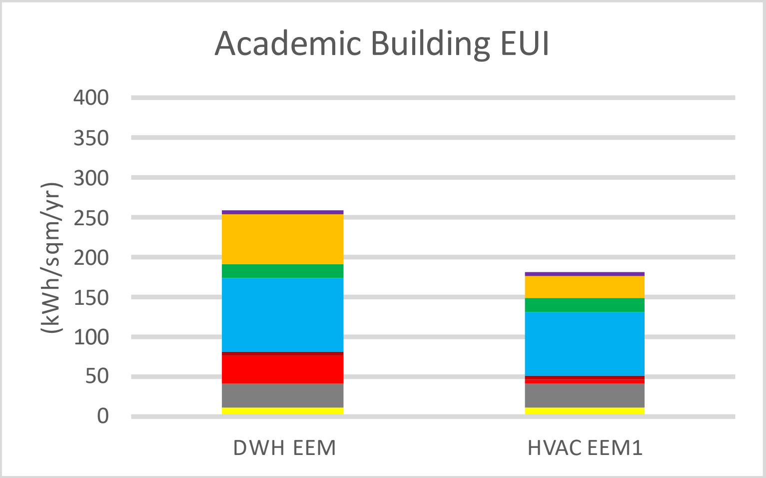
Results for implementing individual interventions:

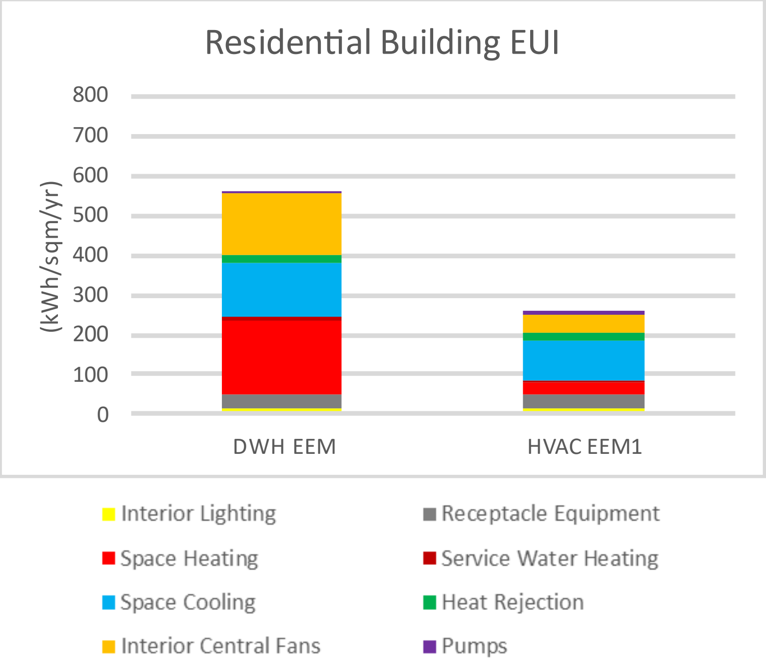
- Academic Building = 29.8% reduction
- Residential Building = 54% reduction

Variable Air Volume Air handling units



Cumulative Results with All Interventions





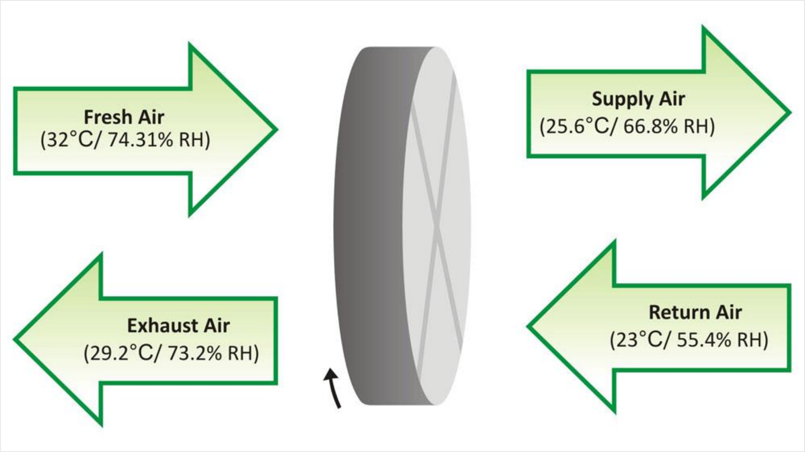
HVAC Energy Efficiency Intervention 2

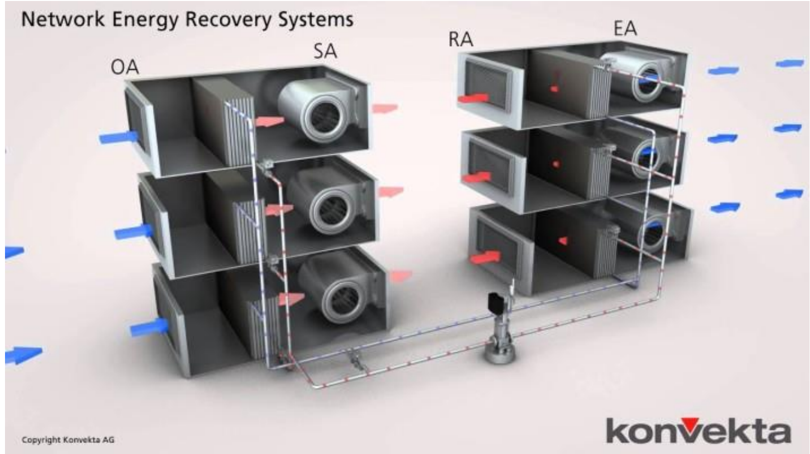
Results for implementing individual interventions:

- Academic Building = 7.7% reduction
- Residential Building = 2% reduction

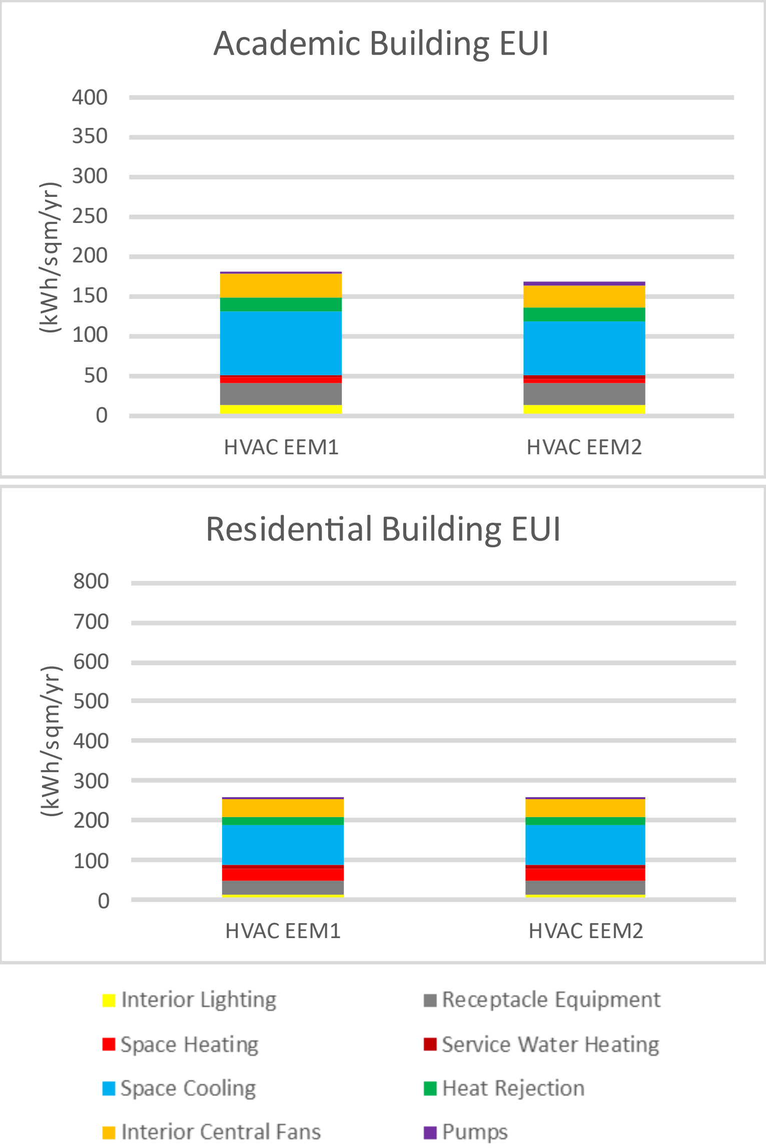
Energy Recovery System Options:

- Total energy recovery wheels
- Run around coil energy recovery





Cumulative Results with All Interventions



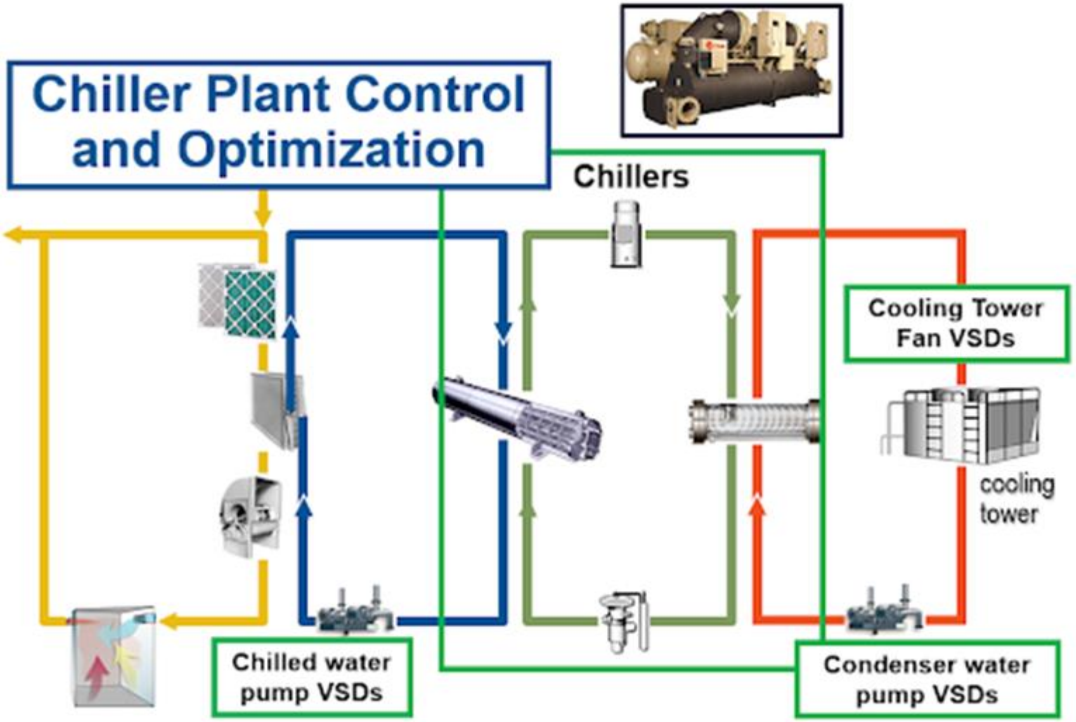
HVAC Energy Efficiency Intervention 3

Results for implementing individual interventions:

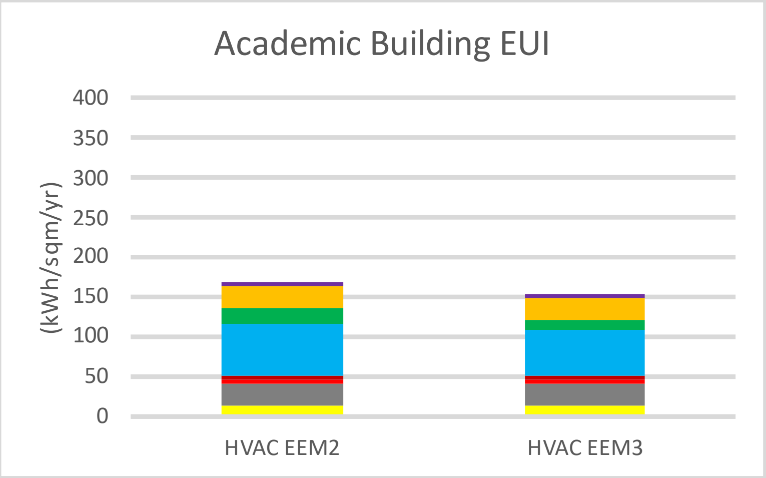
- Academic Building = 8.4% reduction
- Residential Building = 7.4% reduction

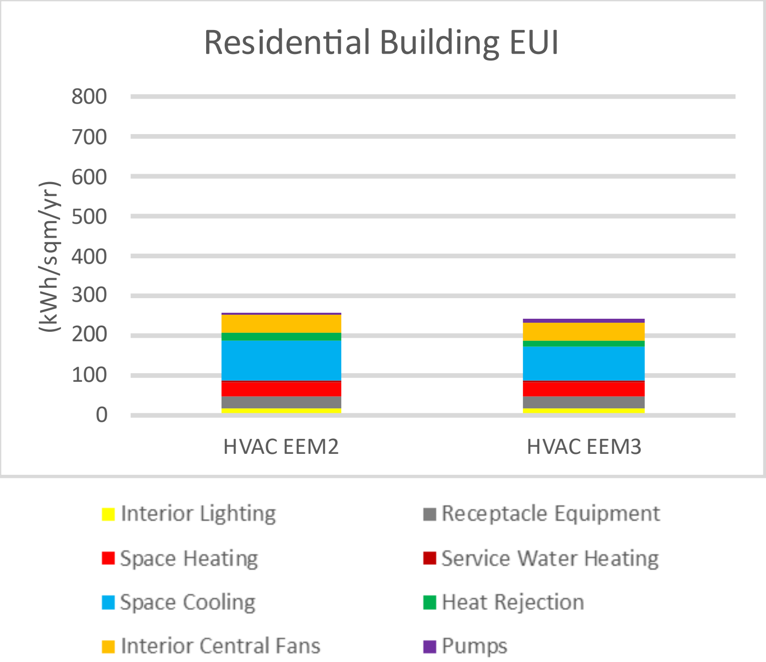
Chiller Plant Improvements:

- High performance chillers
- Variable speed pumping and cooling tower fans
- Chiller optimization controls



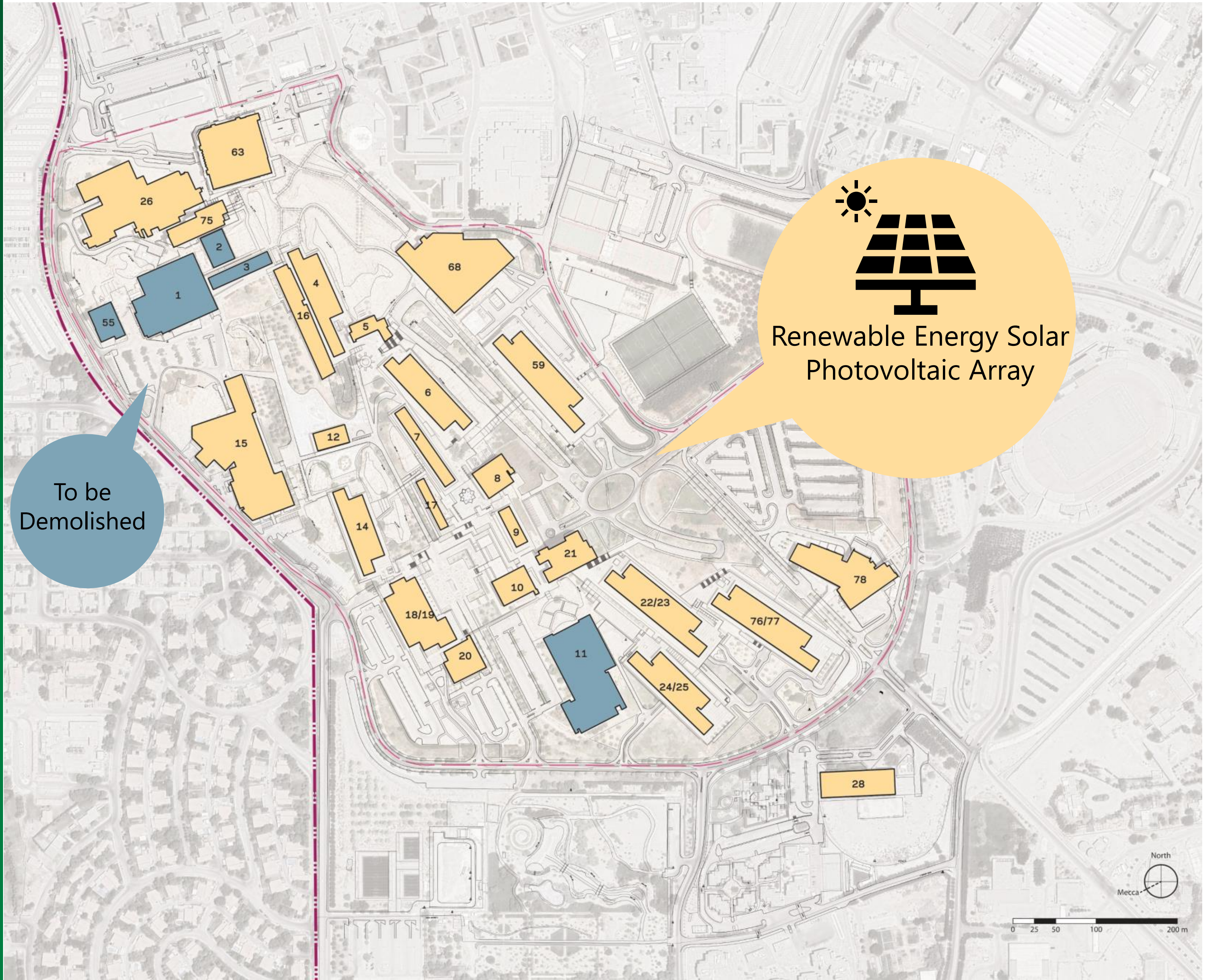
Cumulative Results with All Interventions





Site Energy

Renewable Energy Prospective



Sustainability Targets:

50% of Existing Buildings Roof Area

- Approx. 34,500 SM
- PV Potential Generation = 10,610,000 kWh/Year

100% of New Buildings Roof Area

- Approx. 31,800 SM
- PV Potential Generation = 9,800,000 kWh/Year

85% of Surface Parking Lots with Canopies

- Approx. 14,500 SM
- PV Potential Generation = 4,470,000 kWh/Year

** Consider existing roof infrastructure and roof conditions to support solar photovoltaic panel array*

Health & Well-being

Sustainability Criteria for Locating New Buildings

Scheme 3

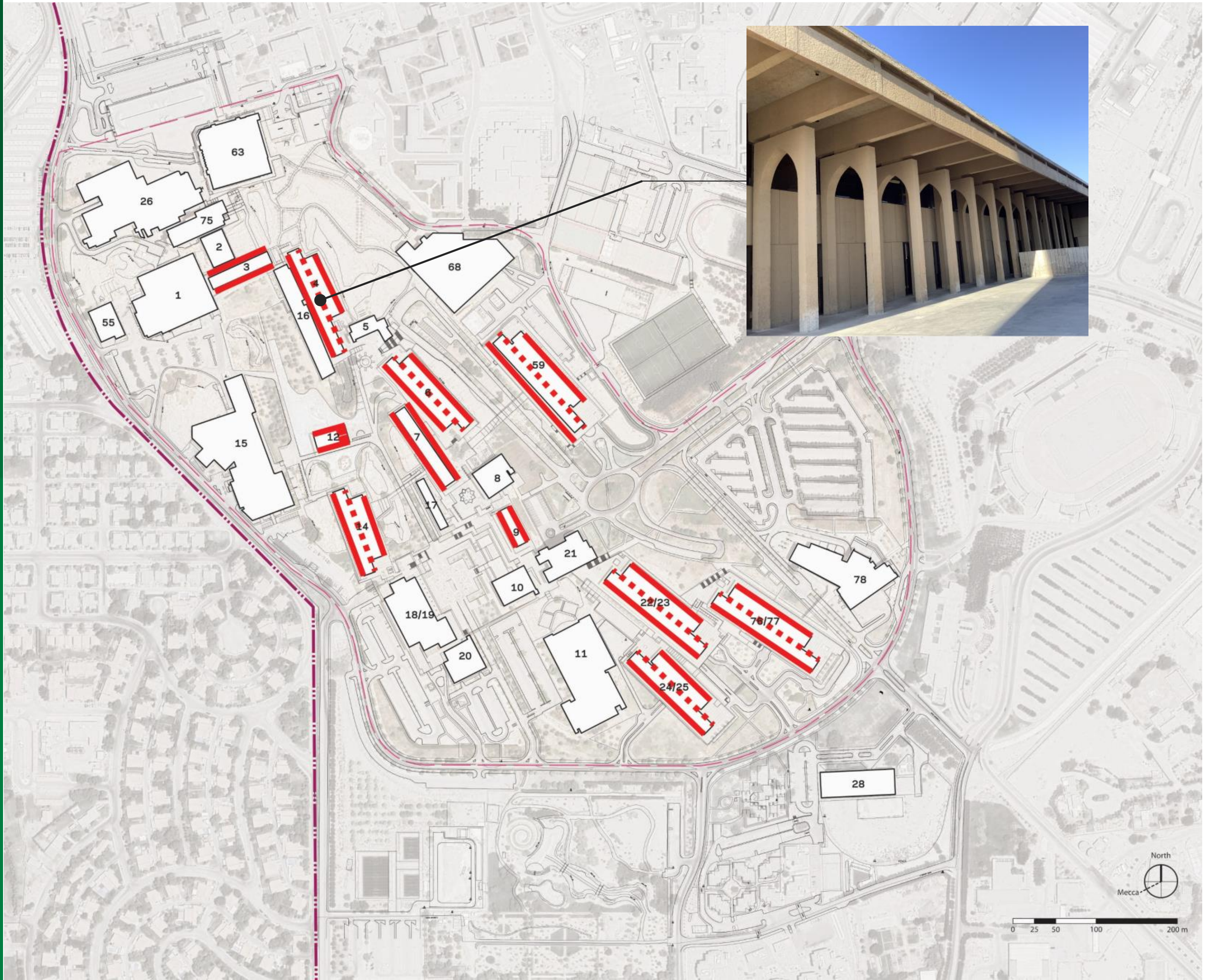
Scheme 2

Scheme 1

Co-locate buildings and services around spaces that provide the most gathering/engagement characteristics and with highest student circulation.

1. Densification – cluster buildings together
2. Walkability - ease of shaded pedestrian connections
3. Passive solar orientation – optimize building massing
4. Significant natural feature protection – avoid environmentally sensitive sites
5. Utility reliability – locate near reliable, upgraded utility plants
6. Site disturbance – align buildings with topography on previously developed sites
7. Expansion opportunities – locate for future growth

Pedestrian Comfort & Walkability




Canopied Spaces and Walkways


Comfortable and Connected


Right-size Pedestrian Pathways

Pedestrian Comfort & Walkability

Sustainability Targets:

Increase Shaded Pathways by:

Conservative – 50%

Moderate – 75%

Ambitious – 100%

**compared to WELL v2 rating system*

Promote Access to Hydration by locating exterior water filling stations at all community nodes and within proximity to transit.

Distances no greater than:

Conservative – 400 meters apart

Moderate – 300 meters apart

Ambitious – 200 meters apart

**400m is considered a reasonable walking distance*

Maximize Micromobility

Shaded Outdoor Areas

Durable Bicycle Storage

Complimentary E-Scooters

Maximize Micromobility

Sustainability Targets:

Shaded Bicycle Parking / Storage within 200 meters of building entry:

Conservative – 5%

Moderate – 10%

Ambitious – 25%

**% of Academic Core Population*

Integrate pathways with:

- Primary circulation avenues
- Effective shading opportunities such as linear canopies
- Artistic installations or nature-based patterns for enhanced engagement

Outdoor Open Space


Comfortable Outdoor Learning Spaces


Sheltered Gathering Spaces


Connected Green Spaces

Outdoor Open Space

Sustainability Targets:

Total Campus Open Space = 1,287,491 SM

Increase Vegetated Open Space by:

Conservative – 15% (193,123 SM)

Moderate – 30% (386,247 SM)

Ambitious – 50% (643,745 SM)

Increase Outdoor Shade by:

Conservative – 15% (193,123 SM)

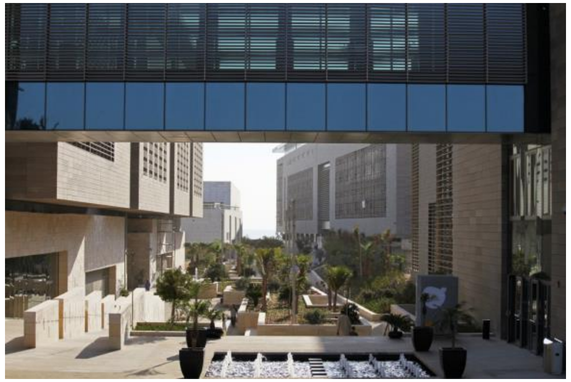
Moderate – 30% (386,247 SM)

Ambitious – 40% (514,996 SM)

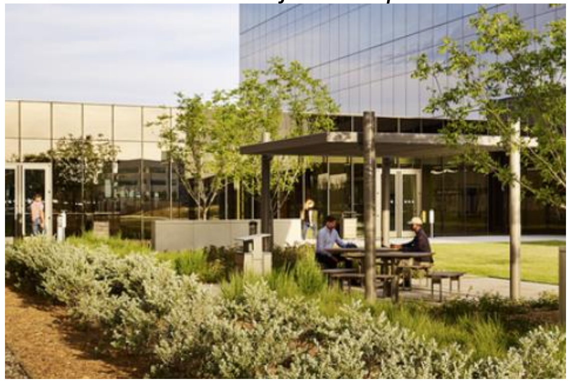
Outdoor space characteristics:

- Buildings integrated with green spaces
- Buildings with shaded outdoor spaces integrated with green spaces and pathways
- Shaded large gathering spaces
- Shaded/canopied main pedestrian pathway
- Intermittent canopies throughout

Outdoor Circulation & Social Spaces



Successful Use of Adjacent Spaces



Socially Activated Spaces

Embody Universal Design Principles

Outdoor Circulation & Social Spaces

Sustainability Targets:

All major academic buildings connected by accessible pathways.

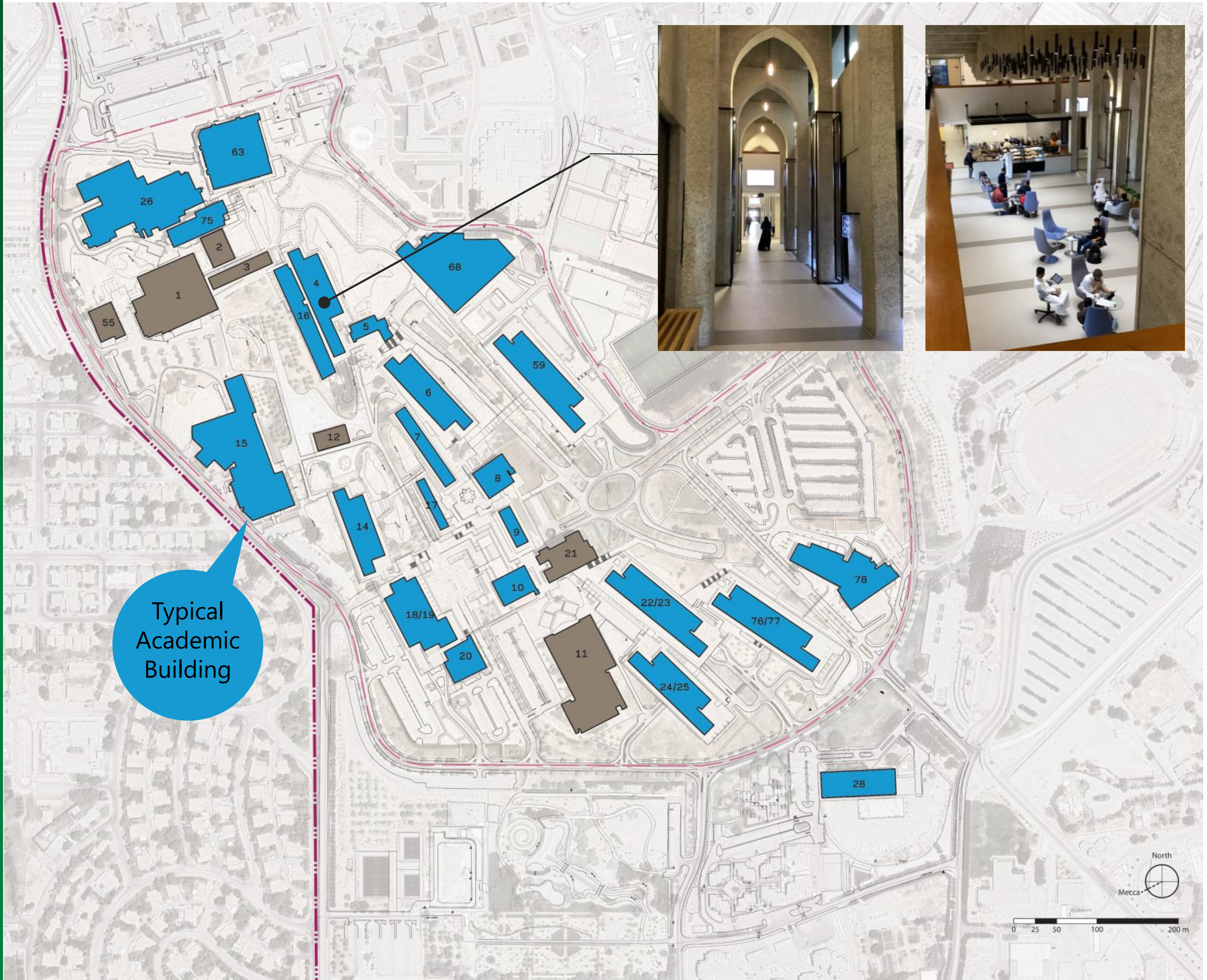
Reduce Heat Islands by:

- All new paving materials and roofs to have high solar reflectance index (SRI), recommended at SRI 82 and greater.
- Solar canopies over all surface parking

Apply Universal Design Strategies:

- Flexibility and Equitable in Use
- Size and Space for Approach and Use
- Simple and Intuitive
- Low Physical Effort

Indoor Designated Social Spaces



Areas of Recreation & Respite

Student Study & Collaboration Spaces

Interior Acoustical Considerations

Indoor Designated Social Spaces

Sustainability Targets:

Cultivate Socially Activated Spaces:

- Designated and Adaptable
- Daylight and Views to nature
- Visually balanced
- Connection to outdoors via terraces or courtyards
- Incorporate interior vegetation via green walls and plantings
- Nature based patterns and textures

Acoustical Enhancements:

- Sound mapping of acoustical zones
- Sound isolation at walls and doors
- Acoustical furnishings in open areas of learning and conferencing

Water

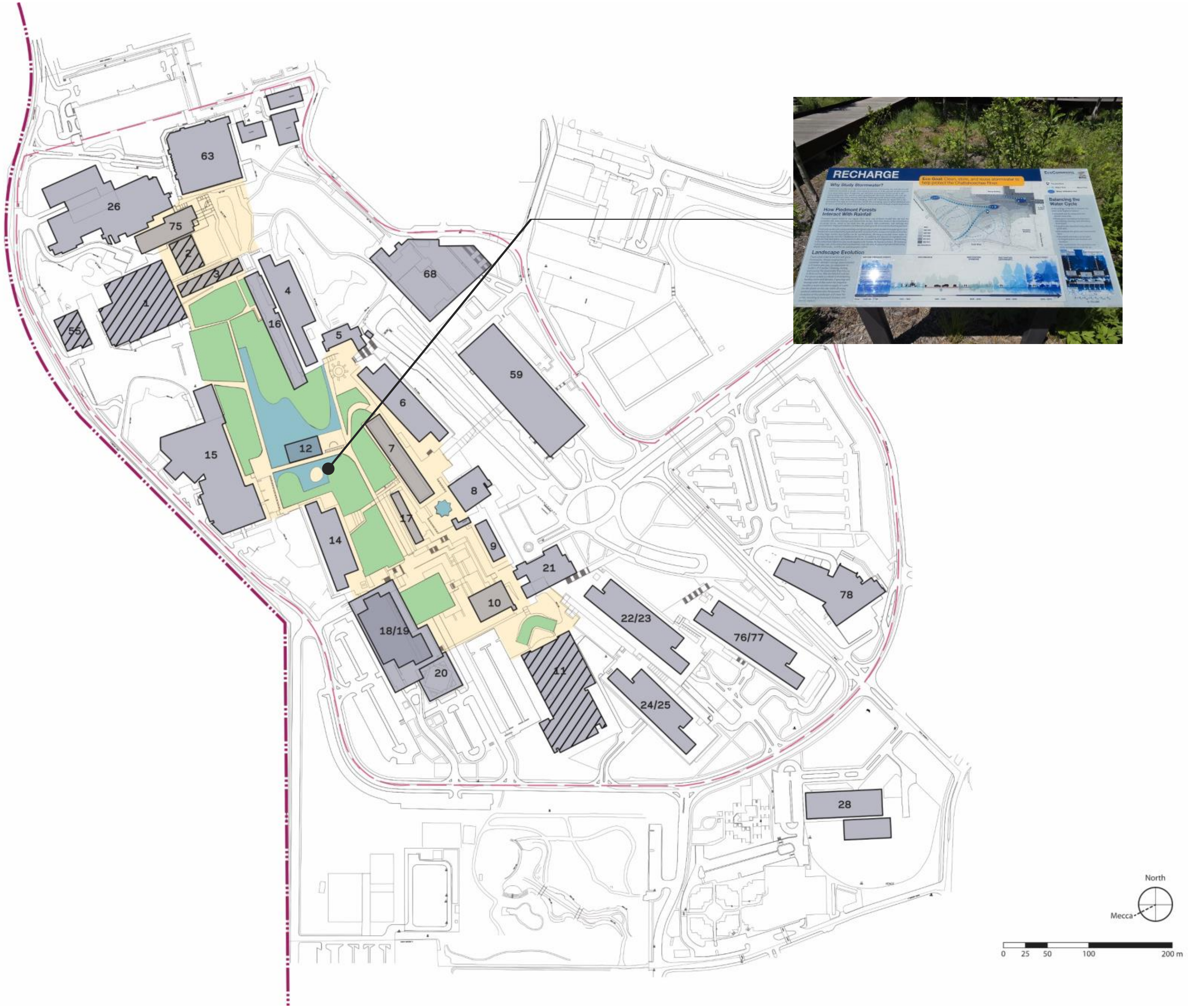
Whole Campus Water Cycle

Membrane Bioreactor

Biological Wastewater Treatment

Non-Potable Water Uses

Whole Campus Water Cycle



Sustainability Targets:

Conservative – 40% water use reduction through repairing leaks, regularly maintaining systems and upgrading fixtures

Moderate – 60% water use reduction through installing meters and monitoring equipment

Ambitious – 80% reduction/no water is wasted, all stormwater, greywater and effluent water is reclaimed, increased pocket parks and green spaces, upgraded treatment system

Whole Campus Opportunities:

Redesign of water network excluding wells

Increase bioswales at south end of campus to reduce localized flood risk

Increase volume of reclaimed stormwater in existing ponds, new green spaces and pocket parks throughout campus for irrigation

Landscape and Irrigation

Drought Tolerant

Drip Irrigation

Turf Alternatives

Landscape and Irrigation

Sustainability Targets:

Reduce Landscape Water Use Demand:

Conservative – 50%

Moderate – 75%

Ambitious – 100%

**compared to LEEDv4.1 baseline*

Reclaimed Water use for Irrigation:

Conservative – 30%

Moderate – 50%

Ambitious – 100%

Native and Drought tolerant landscaping areas and Xeriscape:

Conservative – 40%

Moderate – 60%

Ambitious – 100%

Install water use meters. Landscape irrigation budget. Remove all Astroturf for increased permeability and heat island mitigation

Thank You