BUILDINGENERGY BOSTON

Resilience and Sustainable Design for Laboratories: Harvard Case Study

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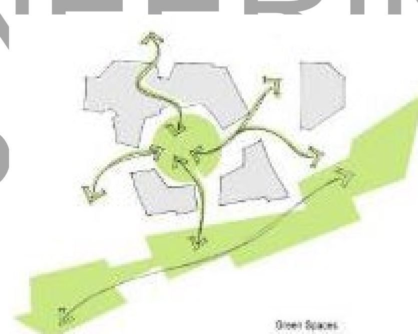
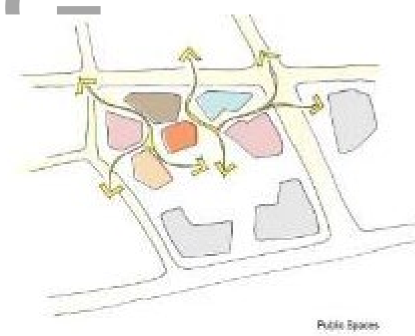
Curated by Megan Nedzinski (Vermont Integrated Architecture)

Northeast Sustainable Energy Association (NESEA) | March 19, 2024

HARVARD UNIVERSITY
SCIENCE & ENGINEERING COMP

PROJECT DURATION
2006-2009 / 2014-2020
AREA
535,000 SF
ROLE
Architect
CERTIFICATIONS
LEED Platinum
LBC Materials Petal



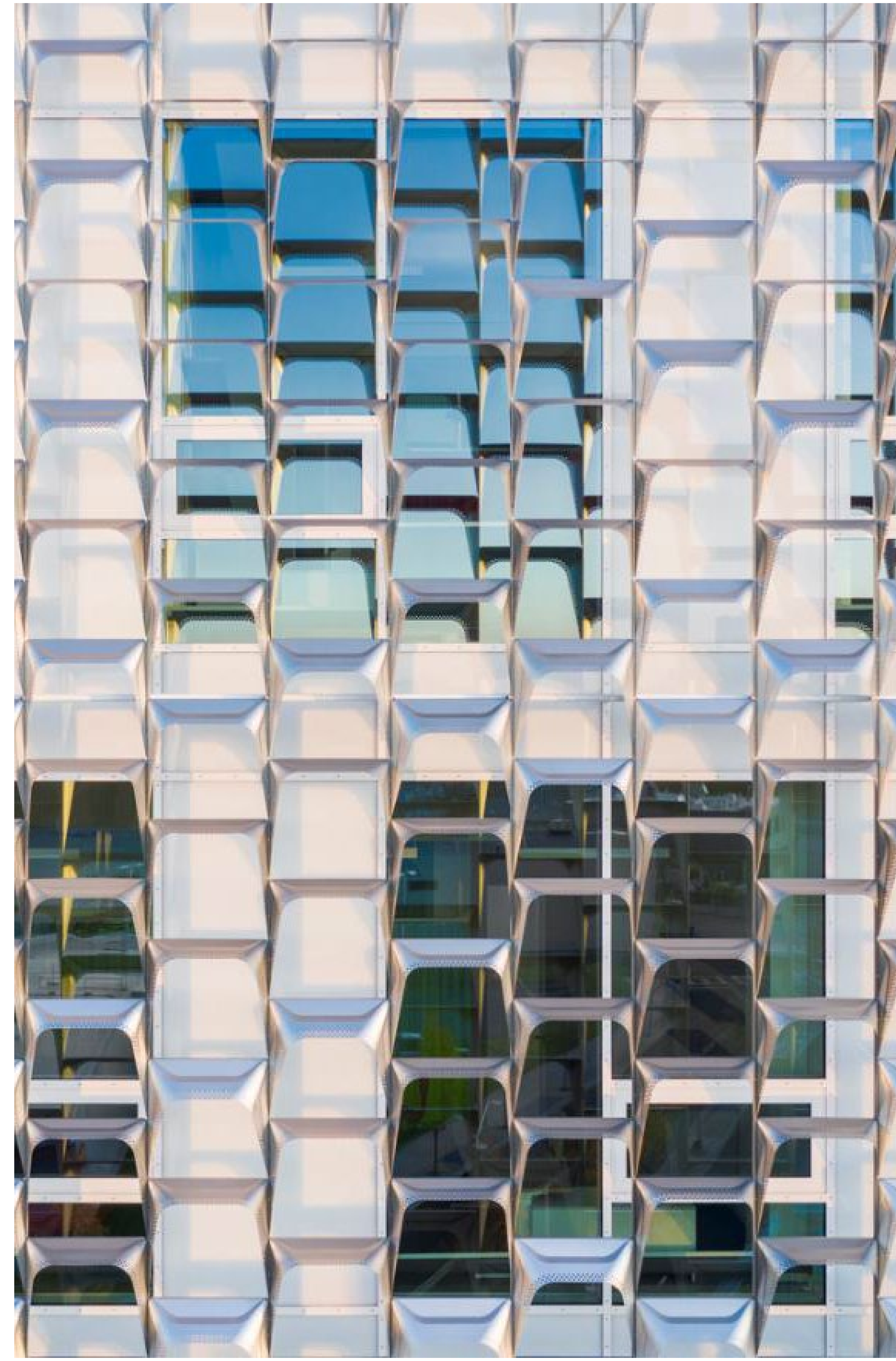


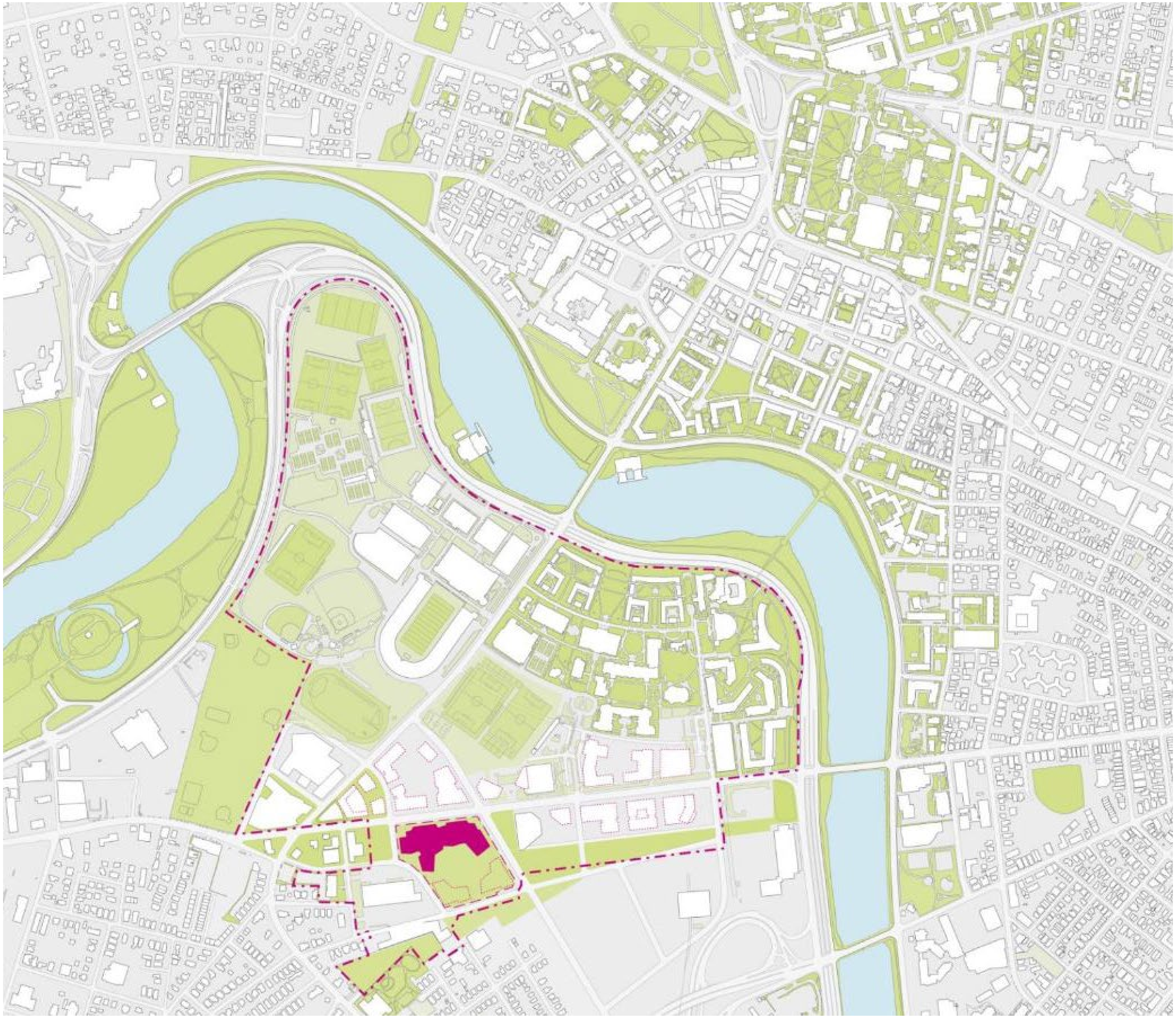
Case Study Topics:

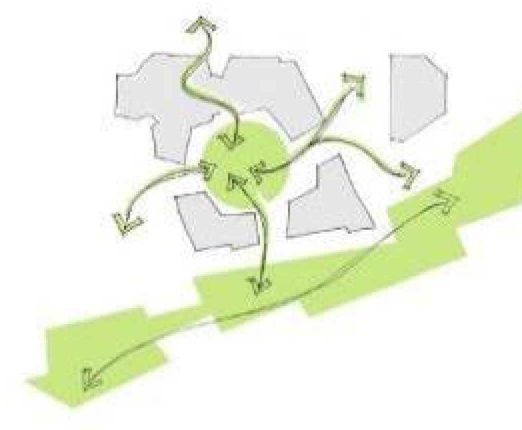
Resilience Planning

Water Story

Sustainability and Performance







Project History

- Began in early 2000's as a Biotechnology Research Center
- Design Completed & Construction began for a 4 Building Complex, roughly 1,000,000 SF
- Project halted after 400,000 SF below-grade Shell Constructed
- 2012 – Programming began for a New World-Class Facility to house the School of Engineering and Applied Science.

Project Charter

Providing Uncompromised, High Performance Research & Learning Spaces

Beyond State-of-the-Art Laboratory Efficiency

Optimize ventilation strategies

Establish long-term sustainable operation plans, including staffing

Healthiest Building at Harvard

Minimize material use and reduce chemicals of concern

Provide access to outdoors to bring daylight and nature into building

Unparalleled User Comfort and Controllability

Increase user control over natural ventilation and daylight

Provide holistic thermal comfort with minimal noise

"Wearing it On Your Sleeve"

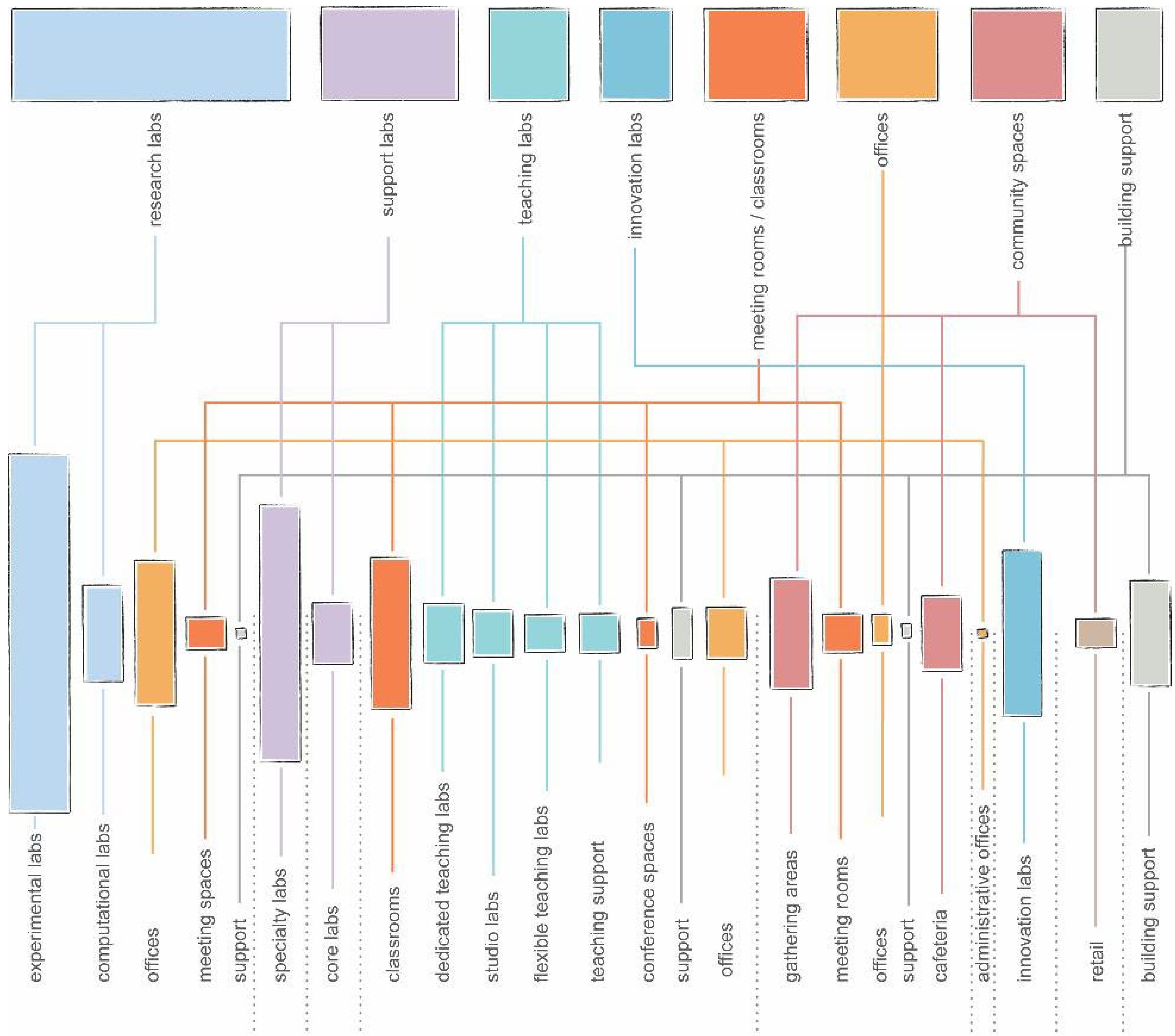
Interactive user experience

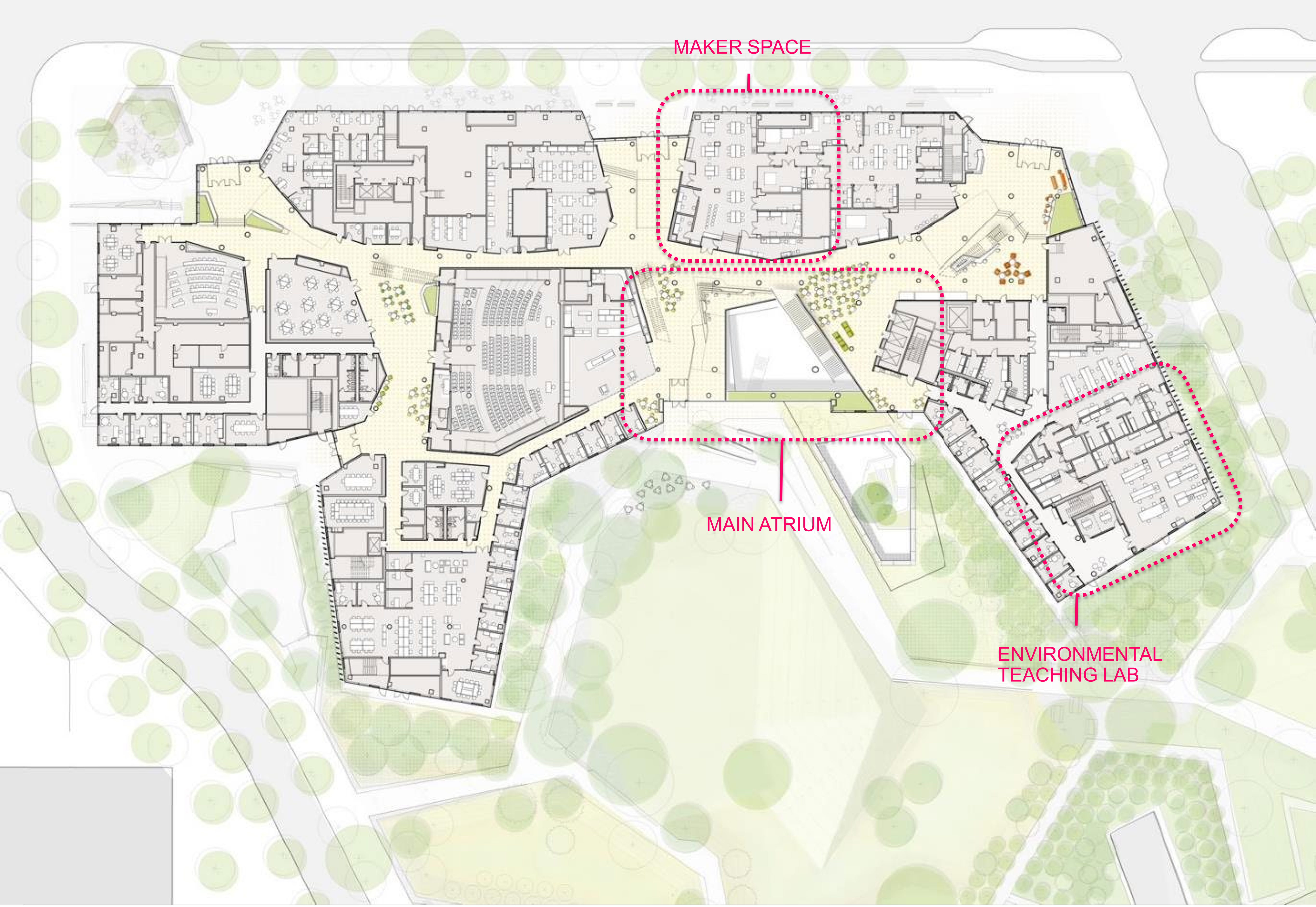
Sustainable living lab: extensive metering/feedback mechanisms

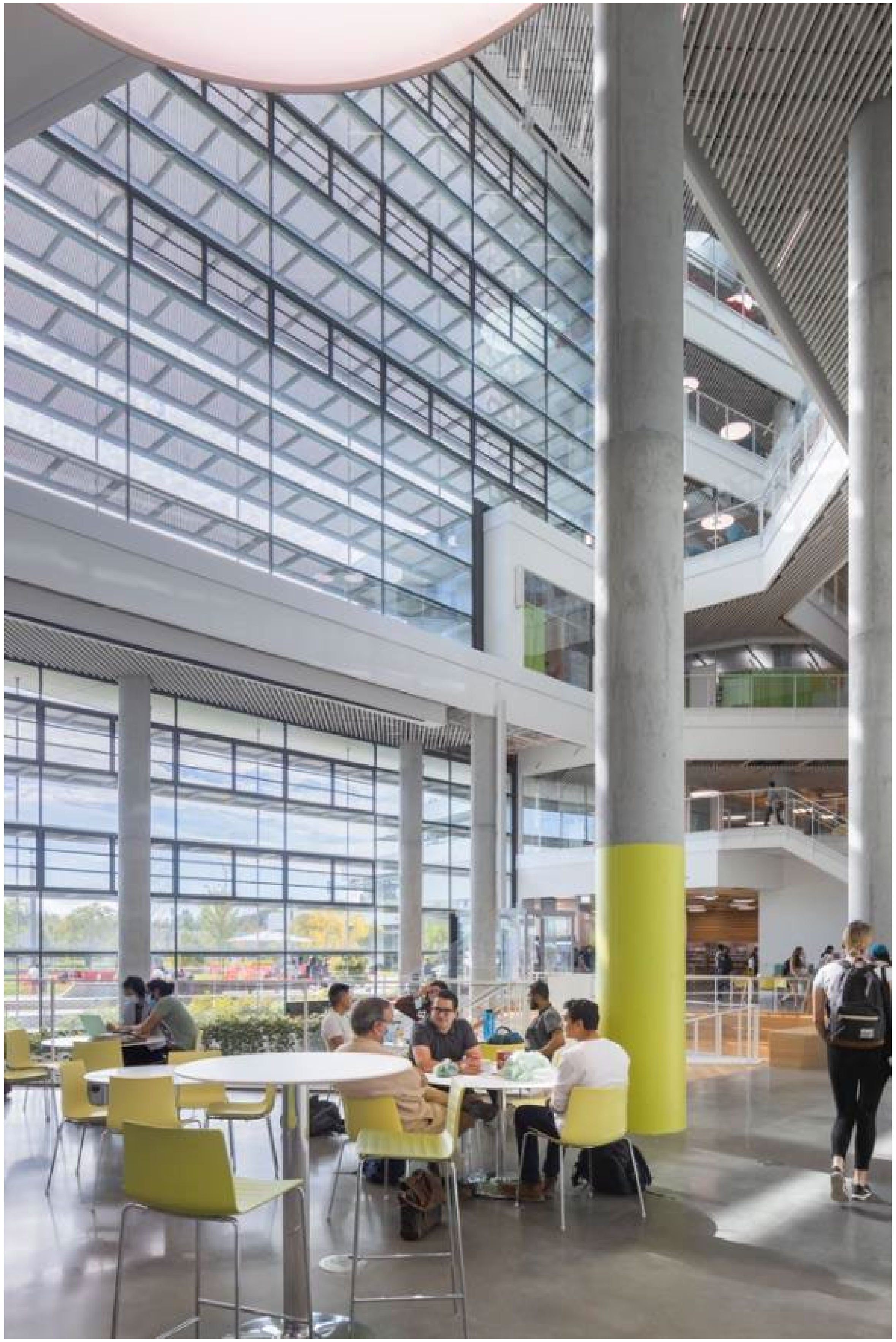
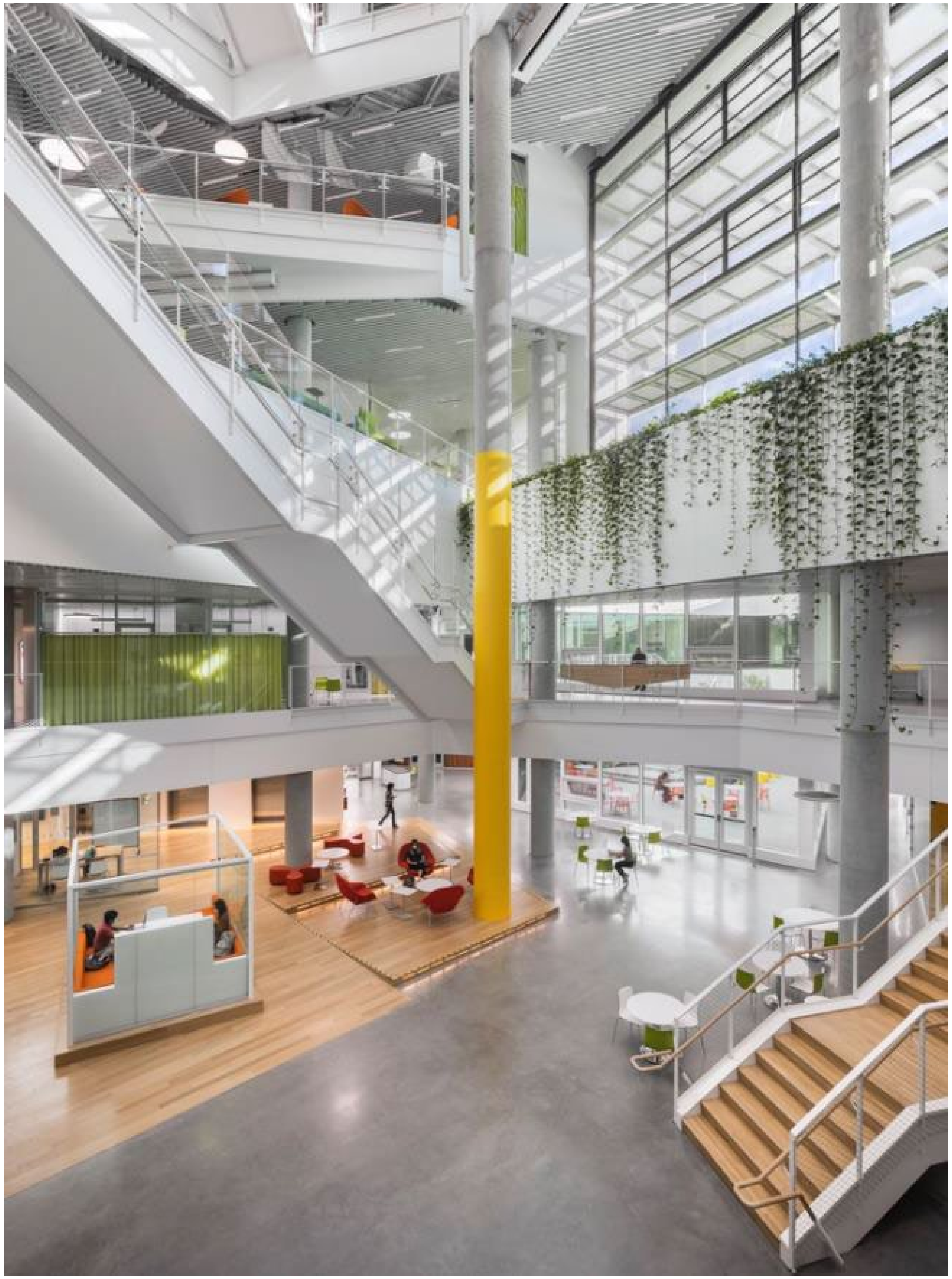
Designed to Last

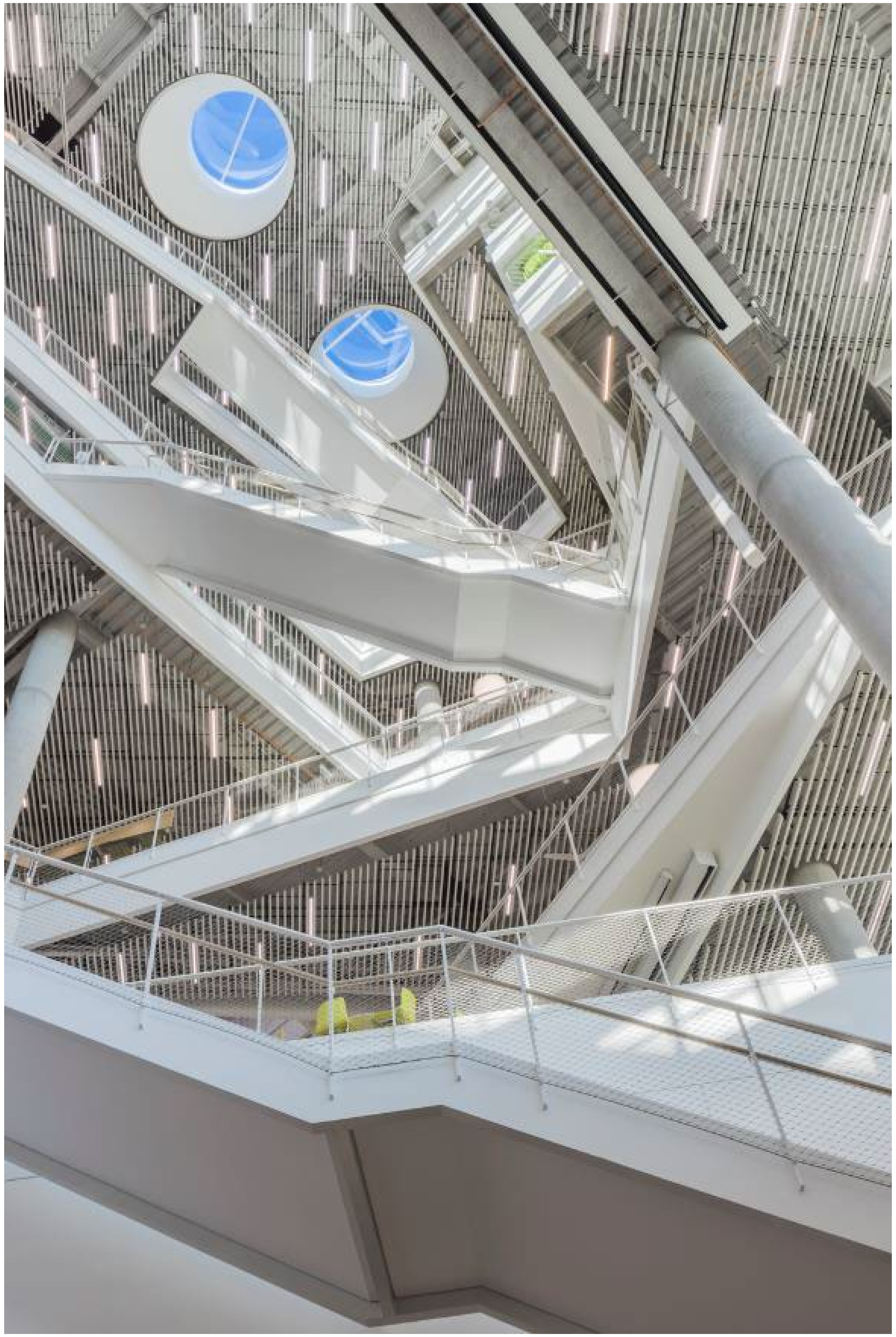
Robust and resilient design

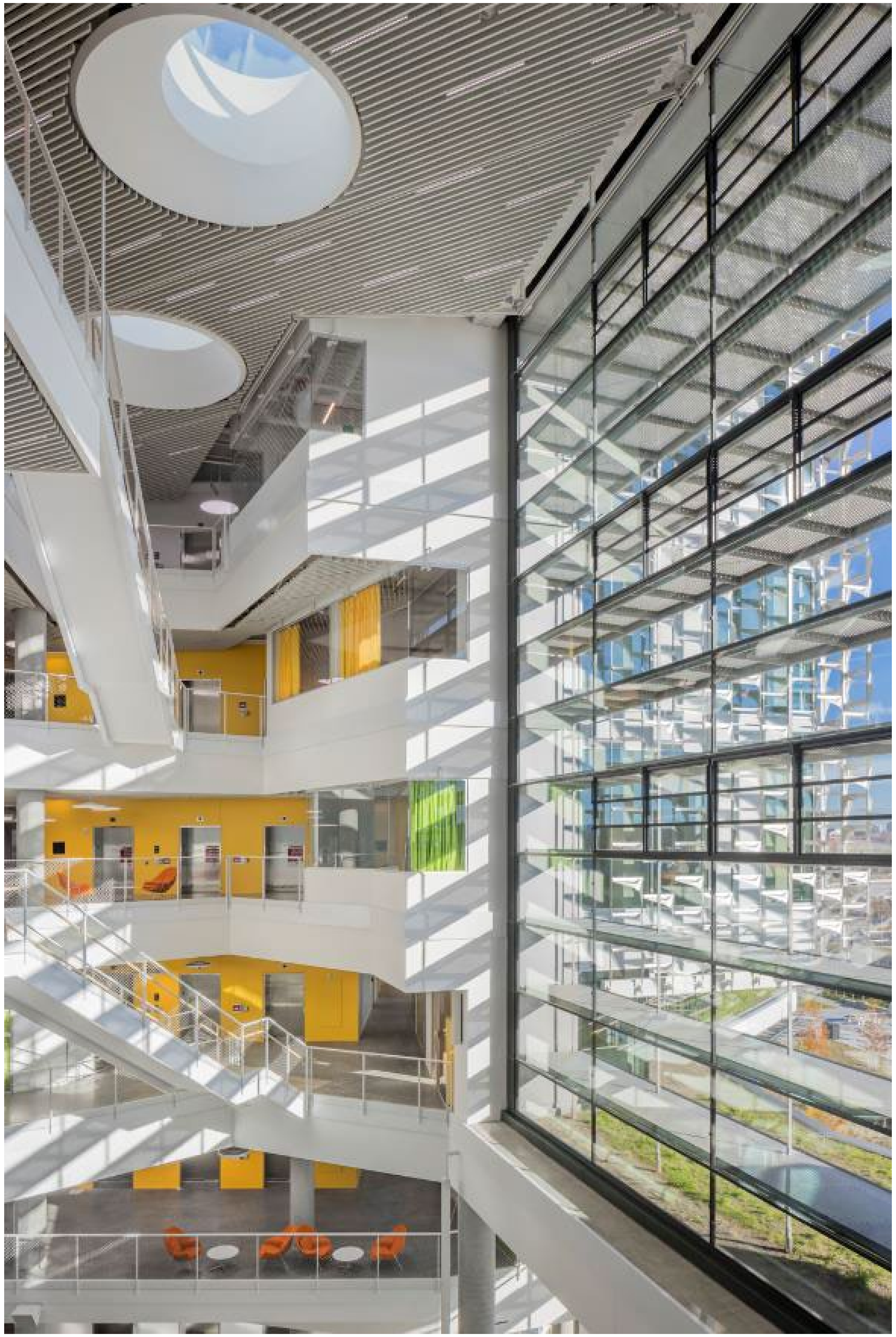
PROGRAM DIAGRAM

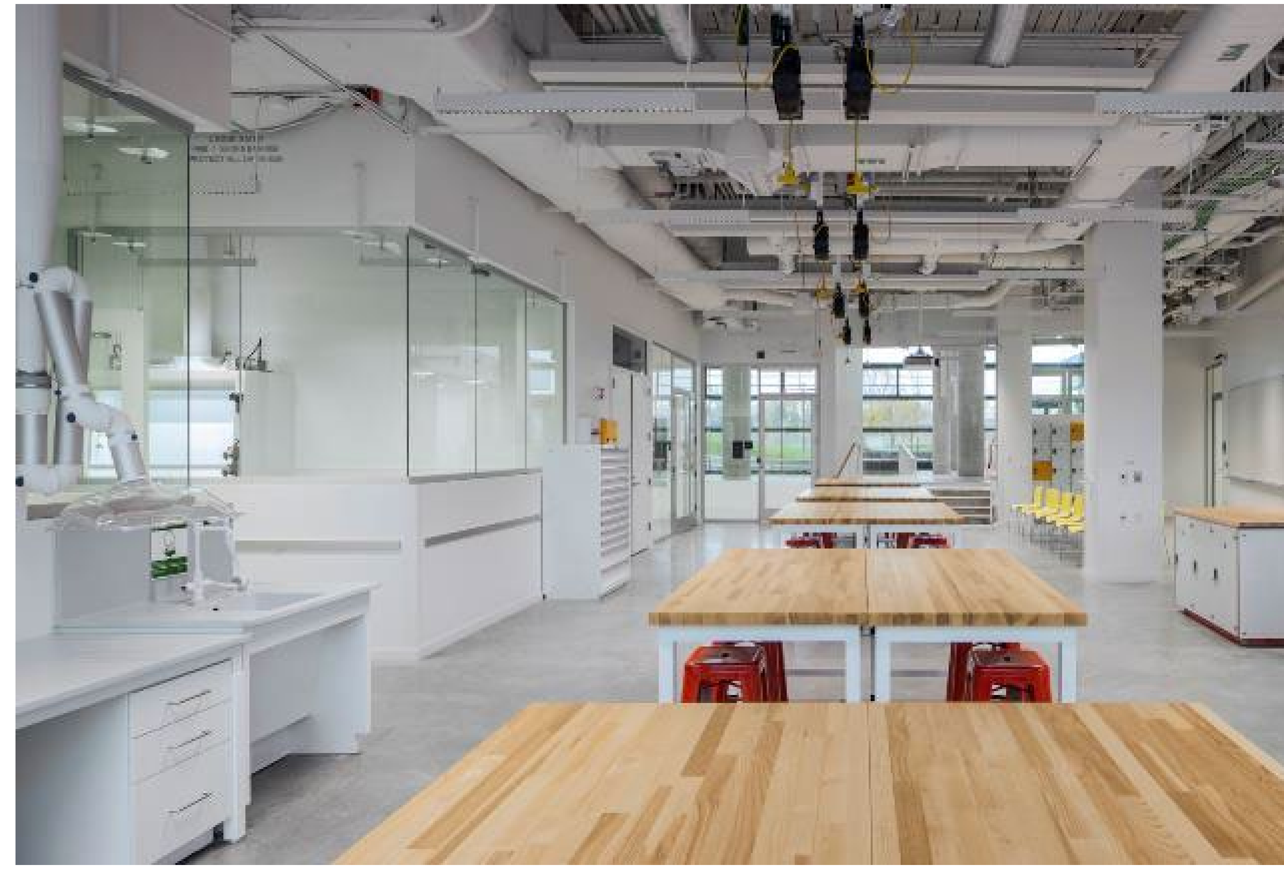


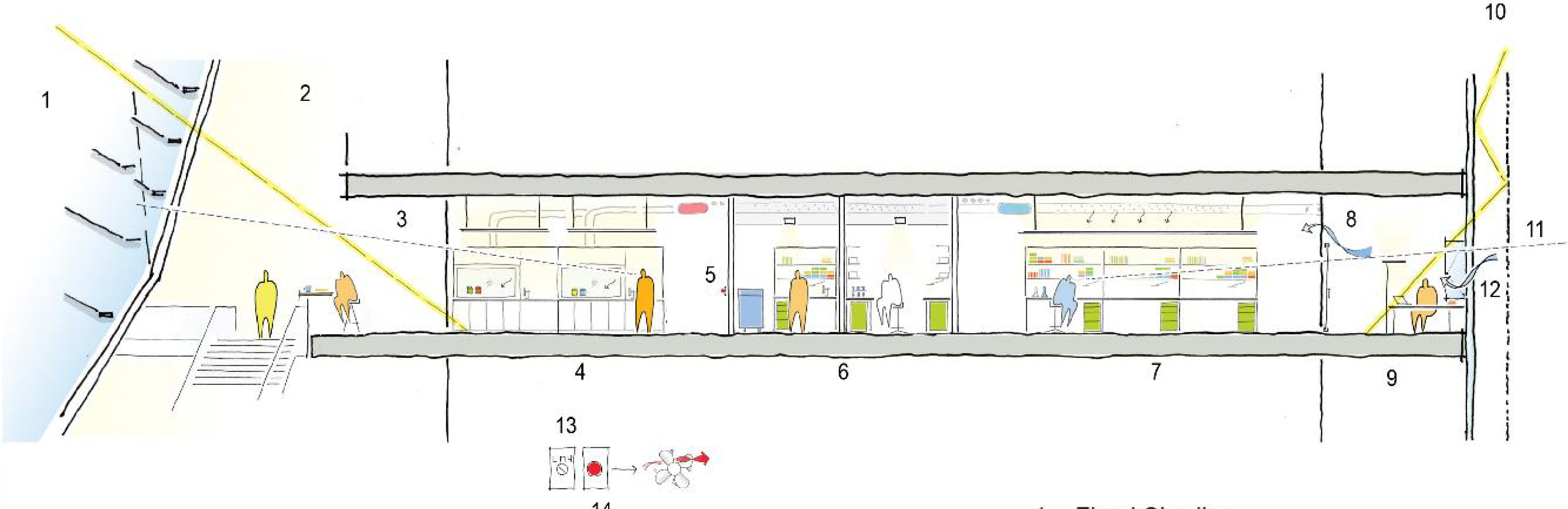

MAKER SPACE
MAIN ATRIUM
ENVIRONMENTAL
TEACHING LAB

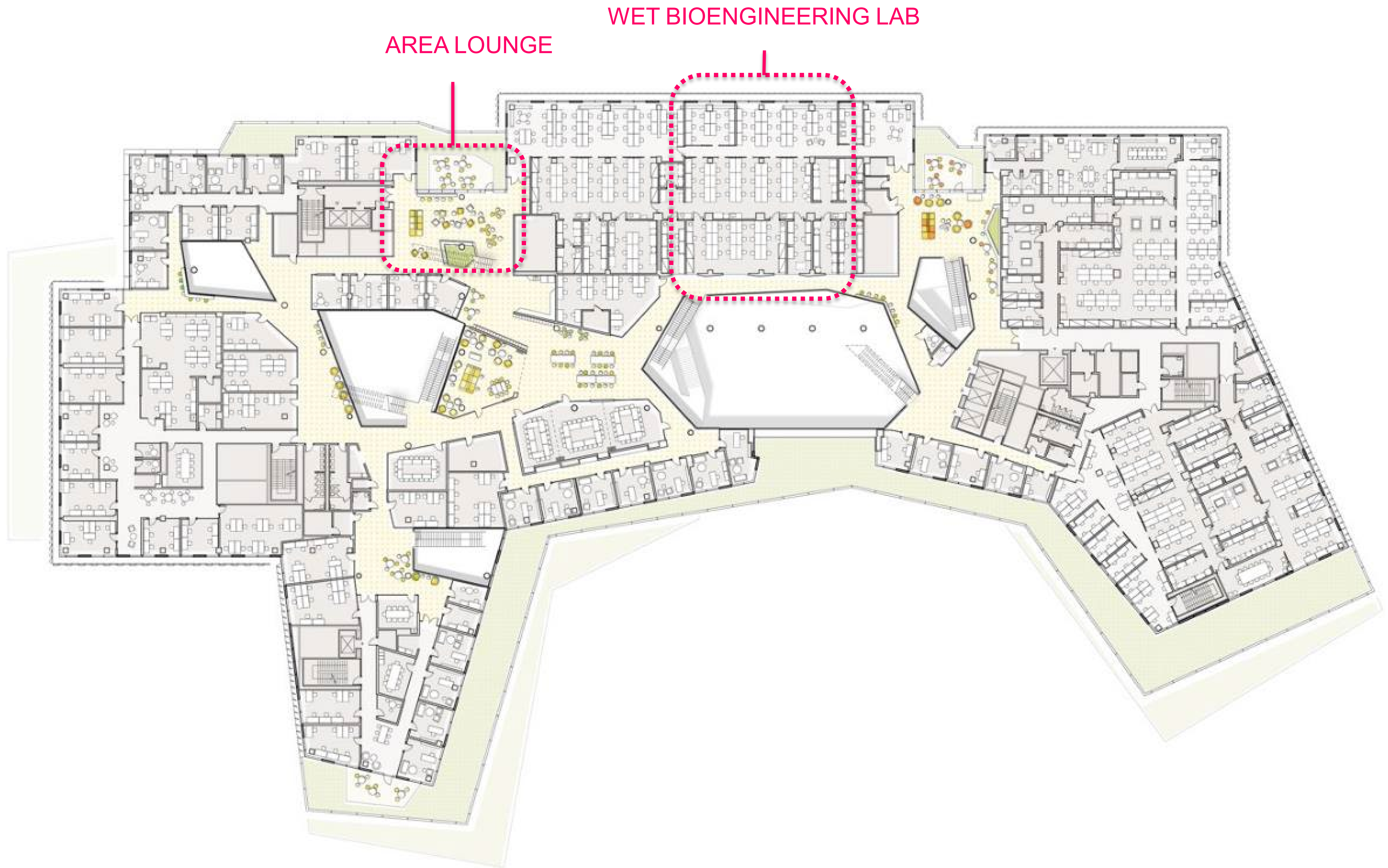






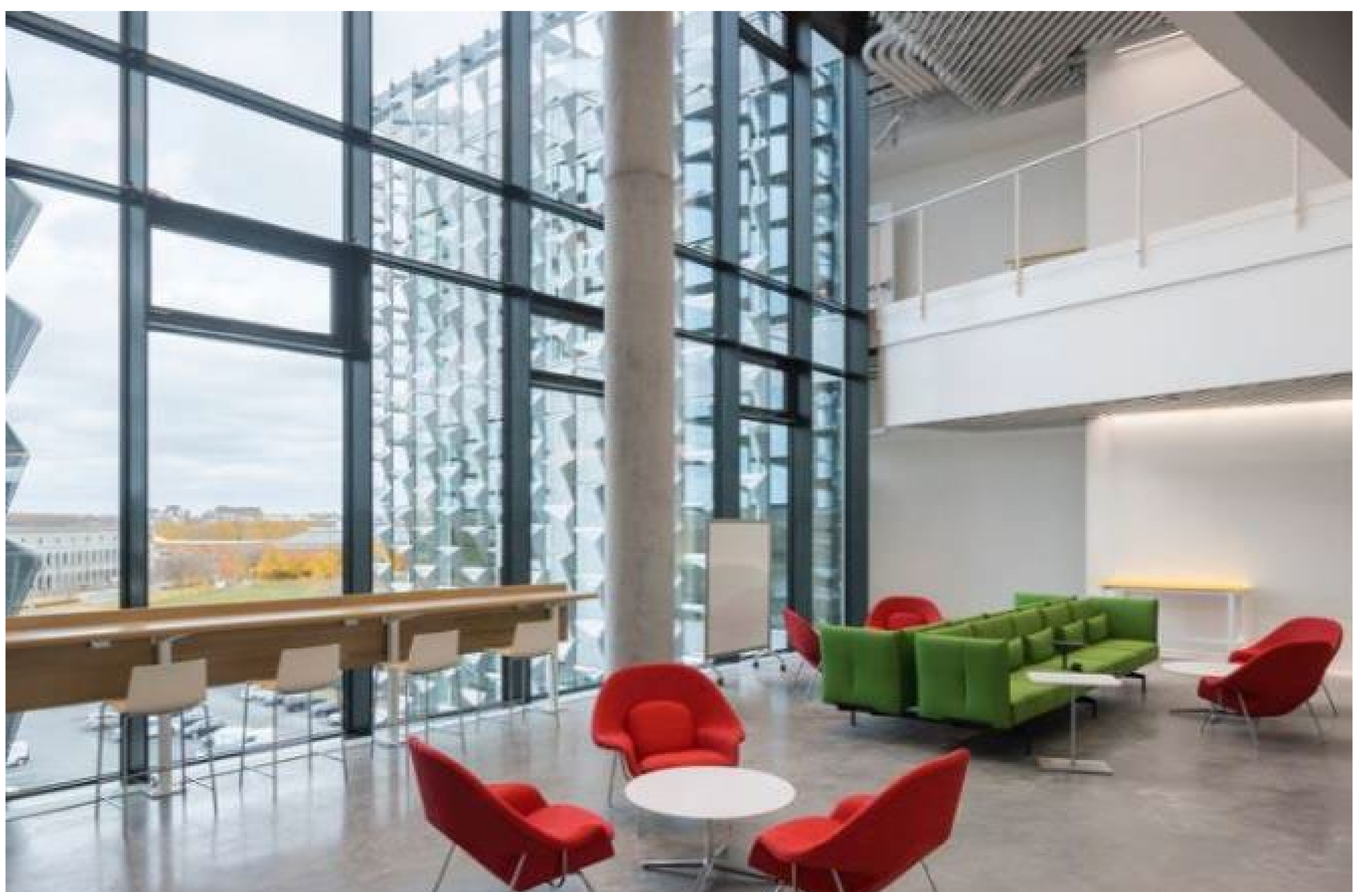


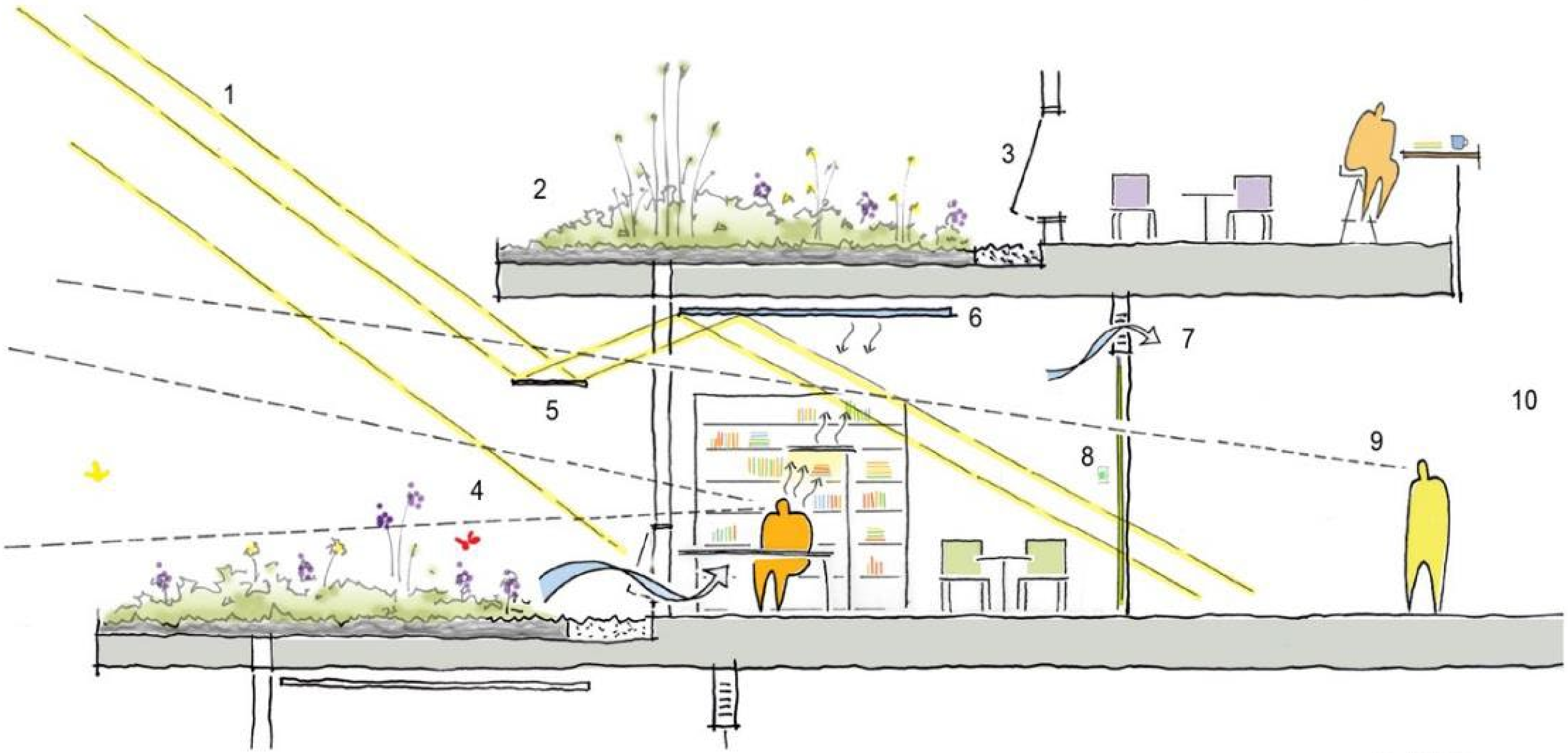
1 – Fixed Shading
2 – Atrium
3 – View
4 – Hoods or benches
5 – ACH Dial
6 – Support Spaces
7 – Lab Benches
8 – Transfer Air
9 – Natural Ventilation
10 – Light redirection at north facade
11 – View
12 – Operable windows at lab offices
13 – Air change rate (low, med, high)
14 – Emergency (max)


WET BIOENGINEERING LAB
AREA LOUNGE

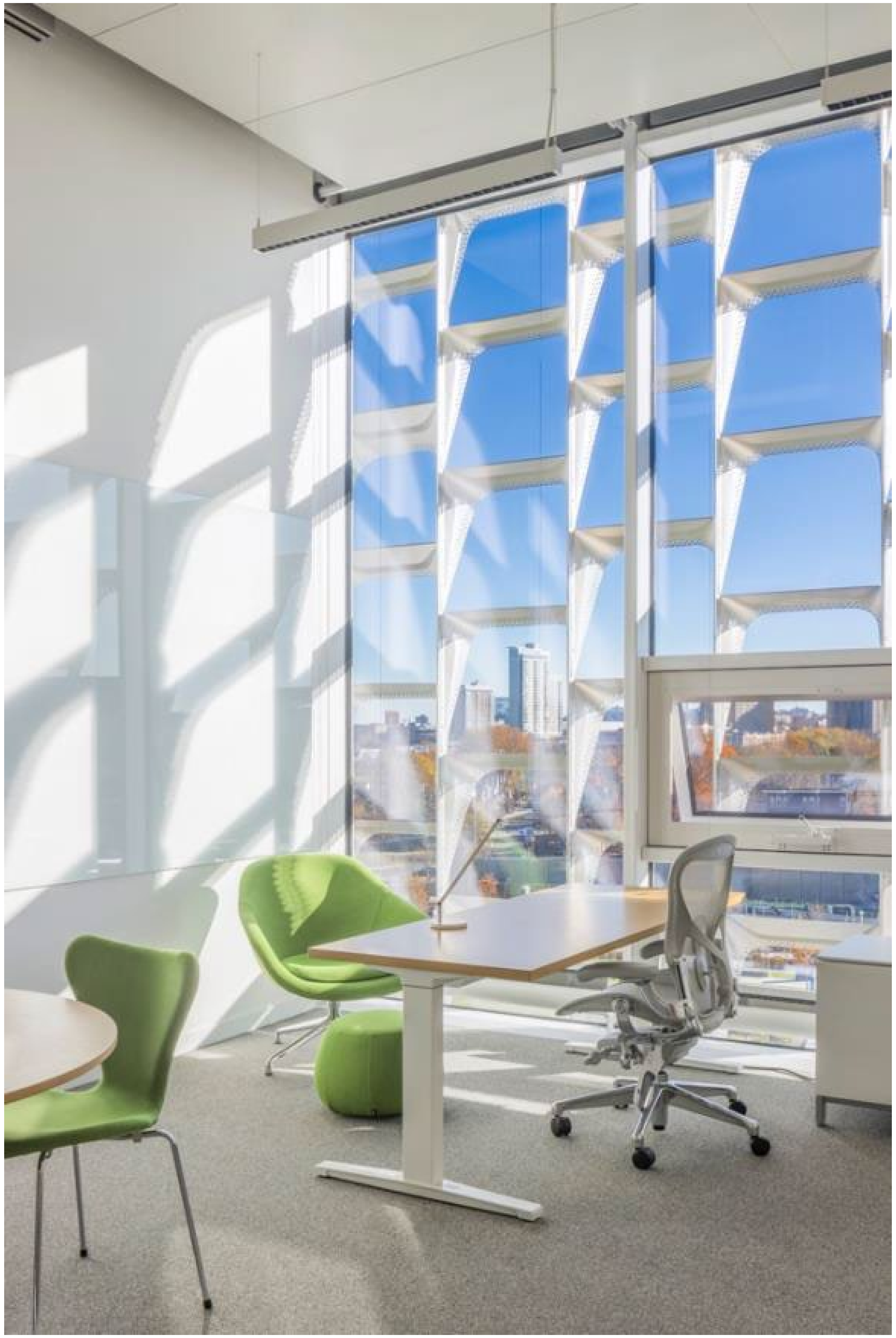

EXIT

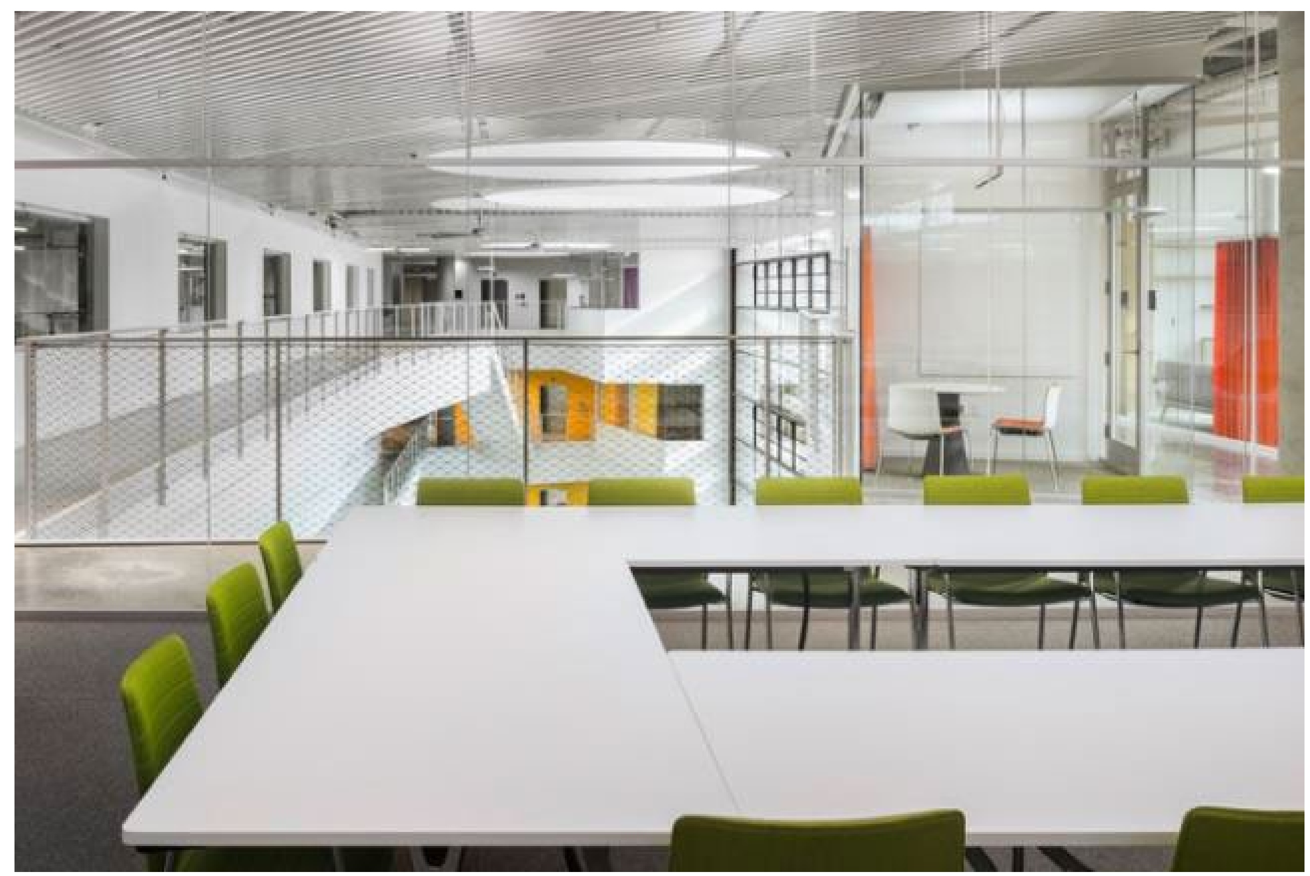


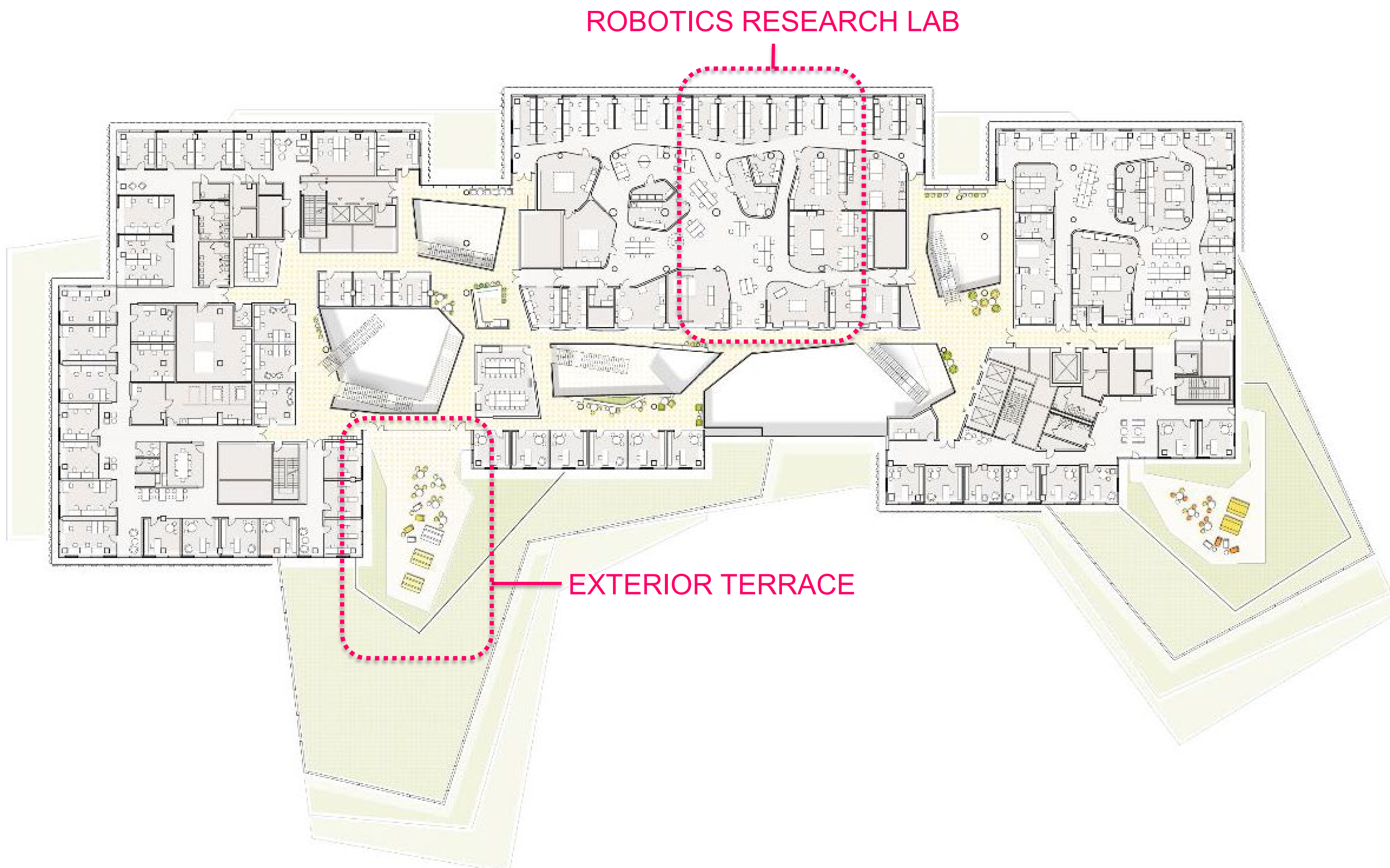



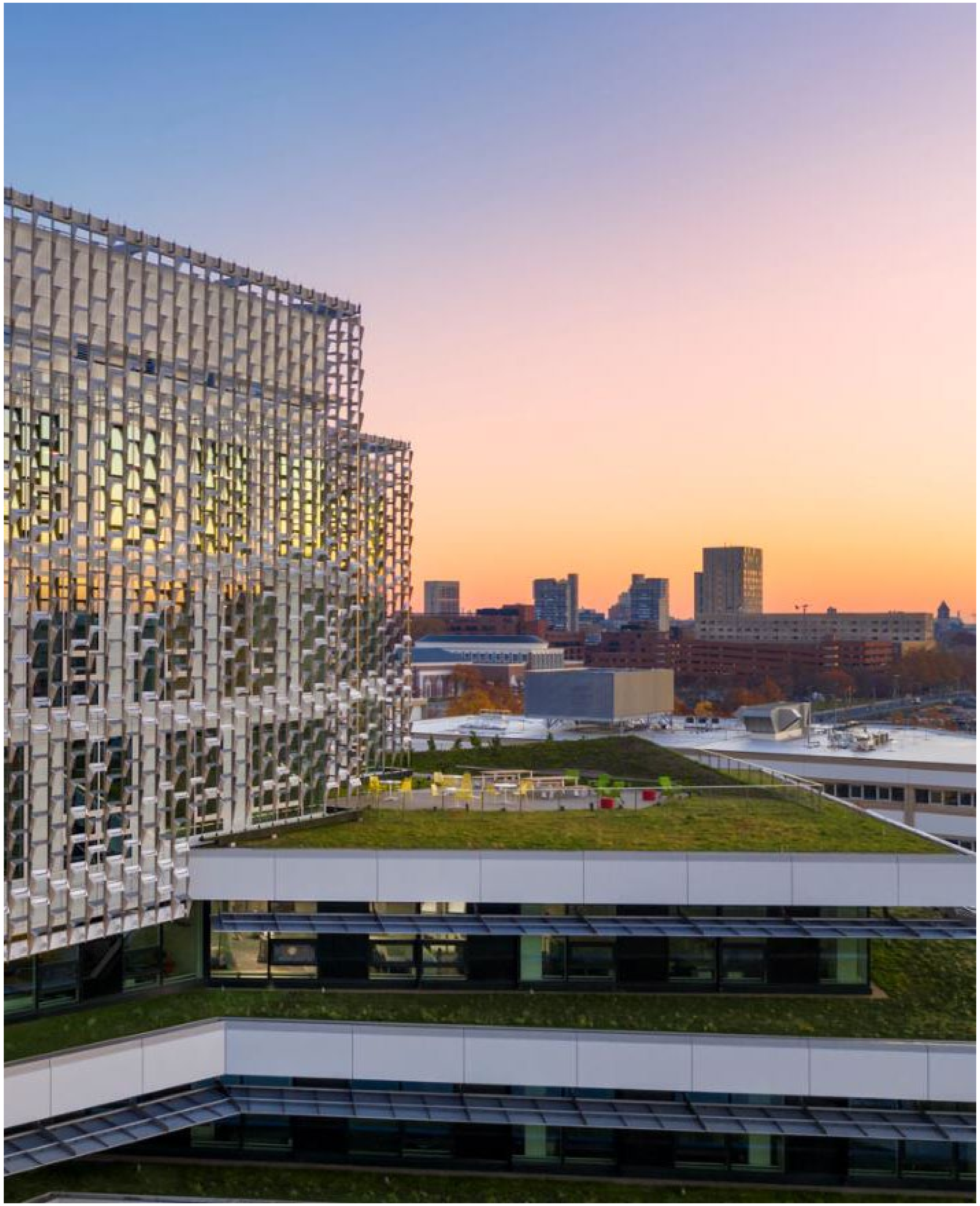
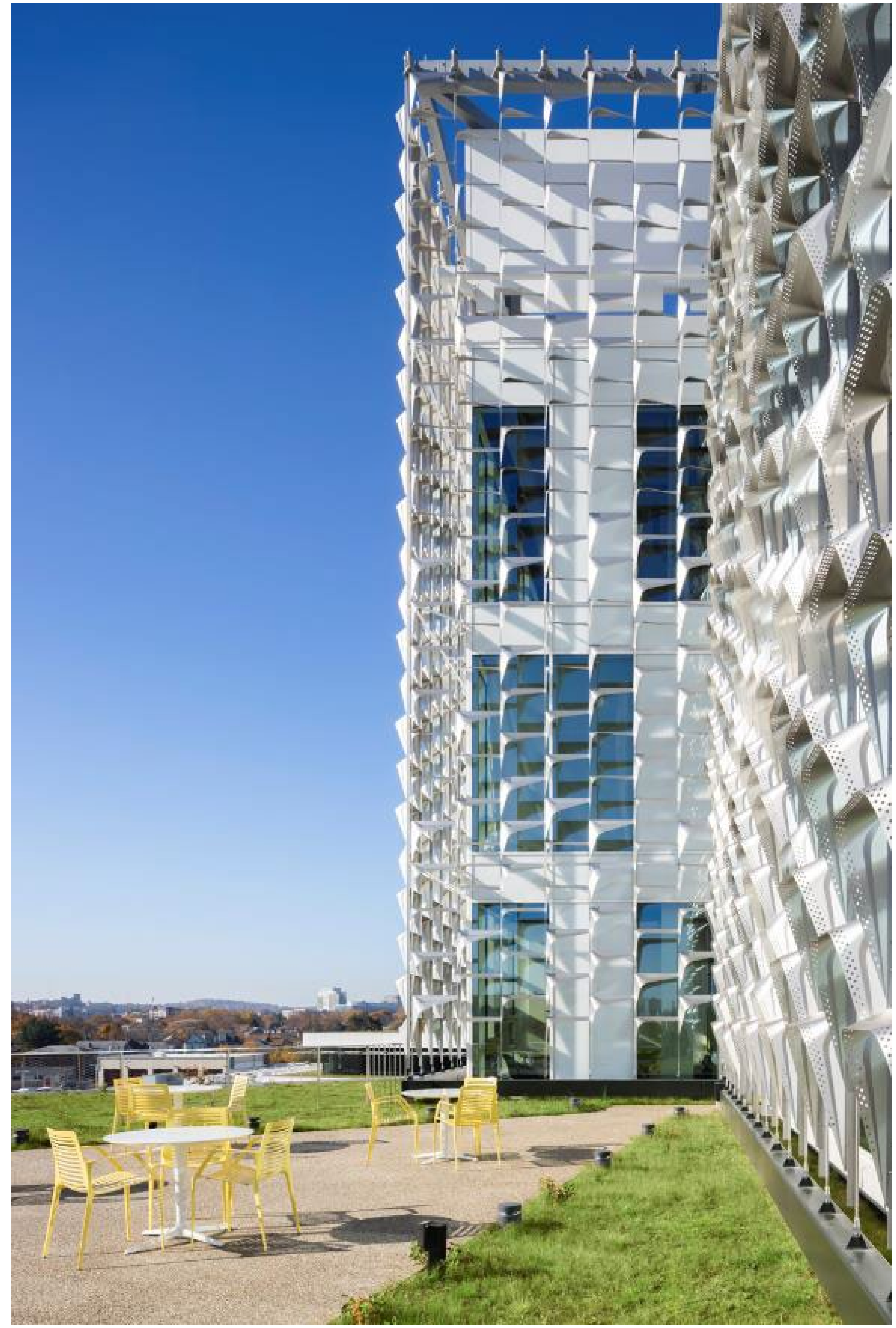


1 – Sunlight
2 – Green roof terrace
3 – Operable windows
4 – View
5 – Fixed solar shading/ lightshelf
6 – Radiant Ceiling
7 – Transfer Air
8 – Open window indicator light
9 – View
10 – Atrium






ROBOTICS RESEARCH LAB
EXTERIOR TERRACE

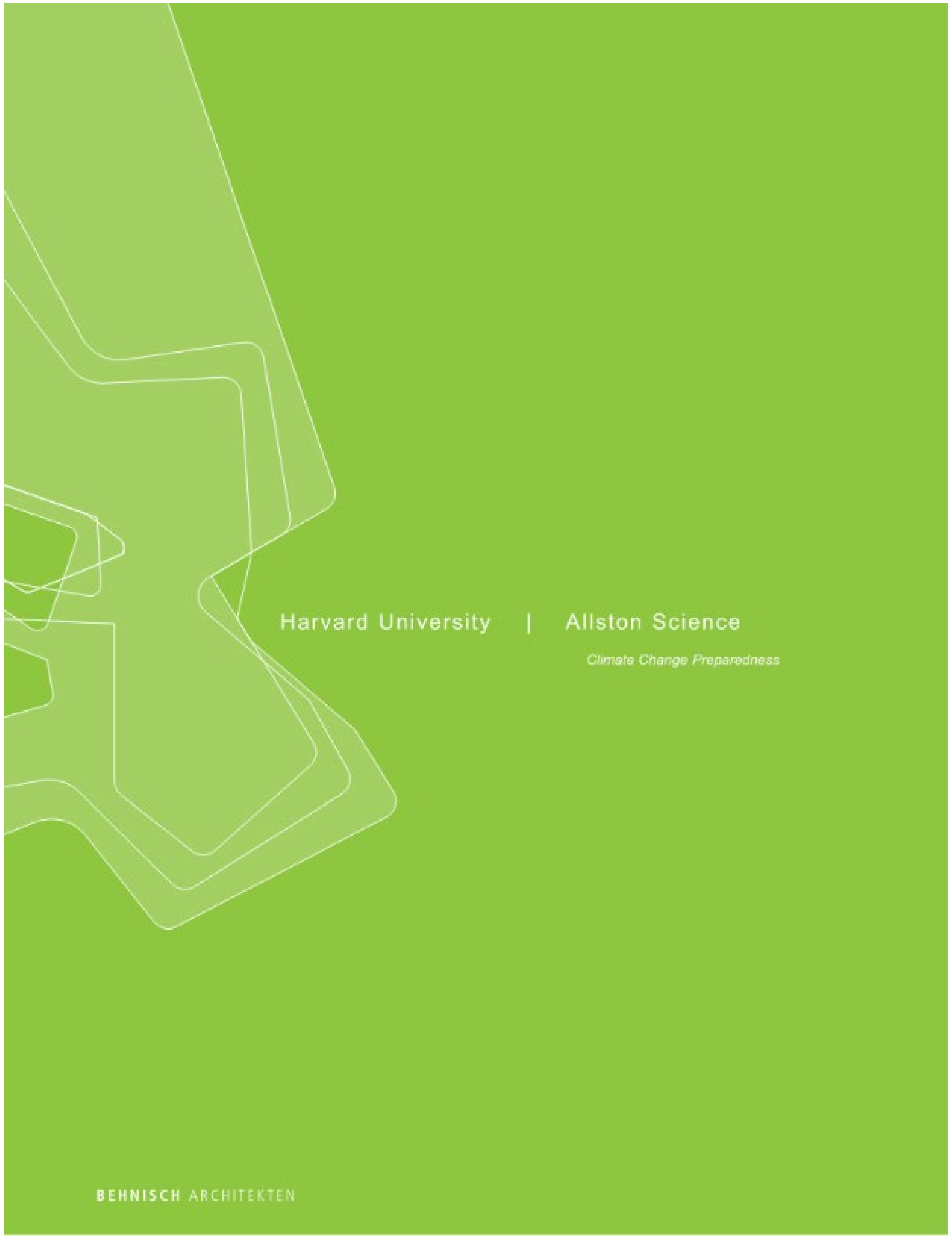


TABLE OF CONTENTS

Designing for Resilience

Threats
External
Internal

Assets
Human
Property
Intellectual

Criteria / Outcome
Survive
Recover
Scenario Planning

Design
Passive
Active

ALLSTON SCIENCE

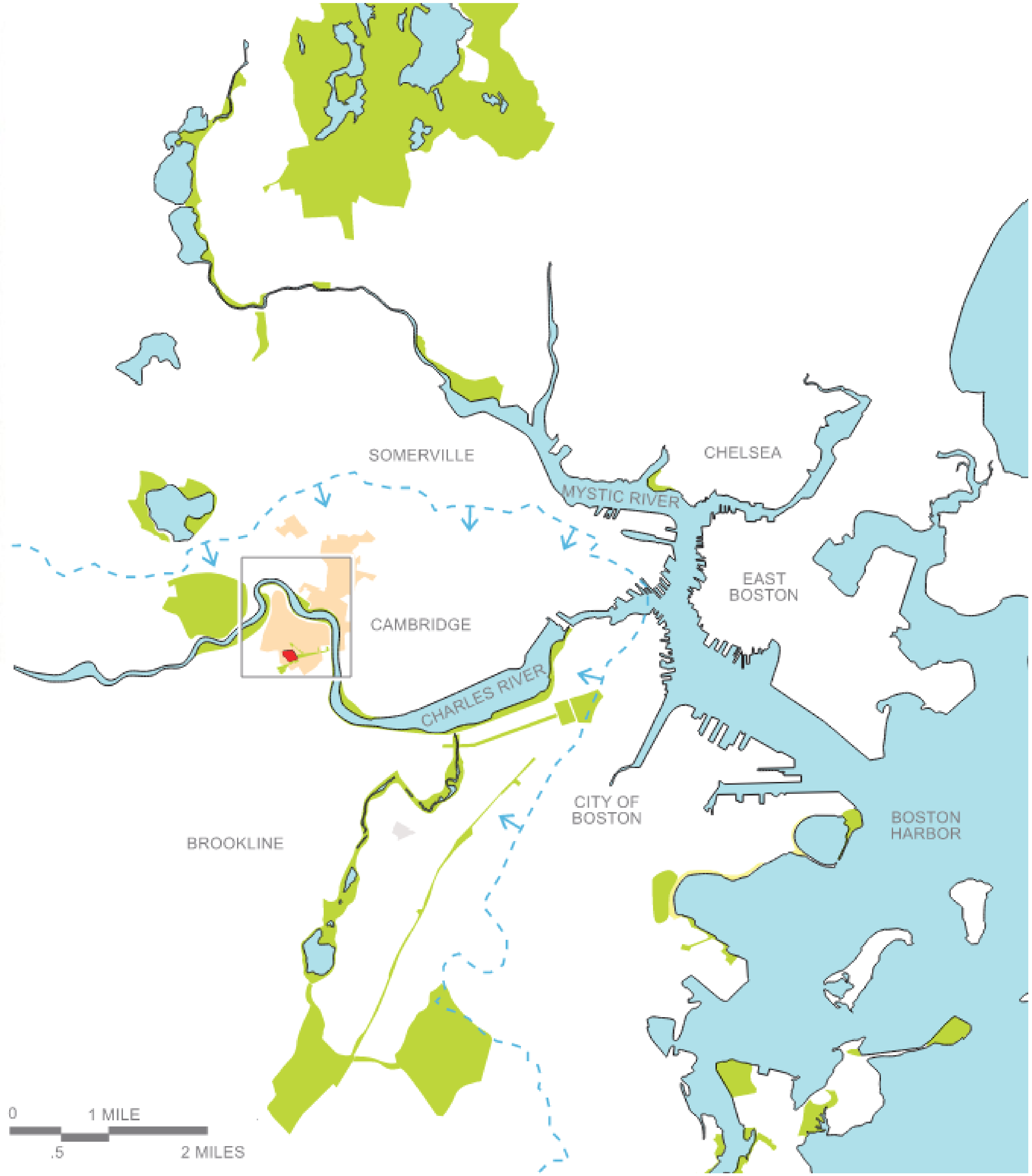
HARVARD UNIVERSITY

EXISTING AND FUTURE GREEN SPACES

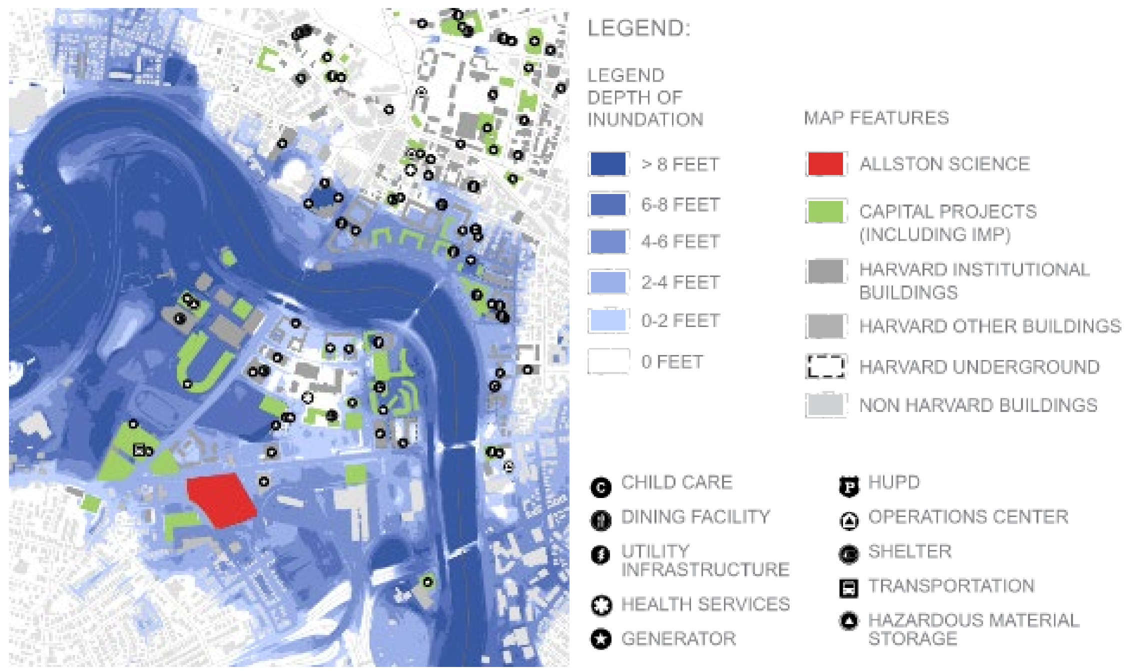
INSTITUTIONAL MASTERPLAN ALLSTON CAMPUS

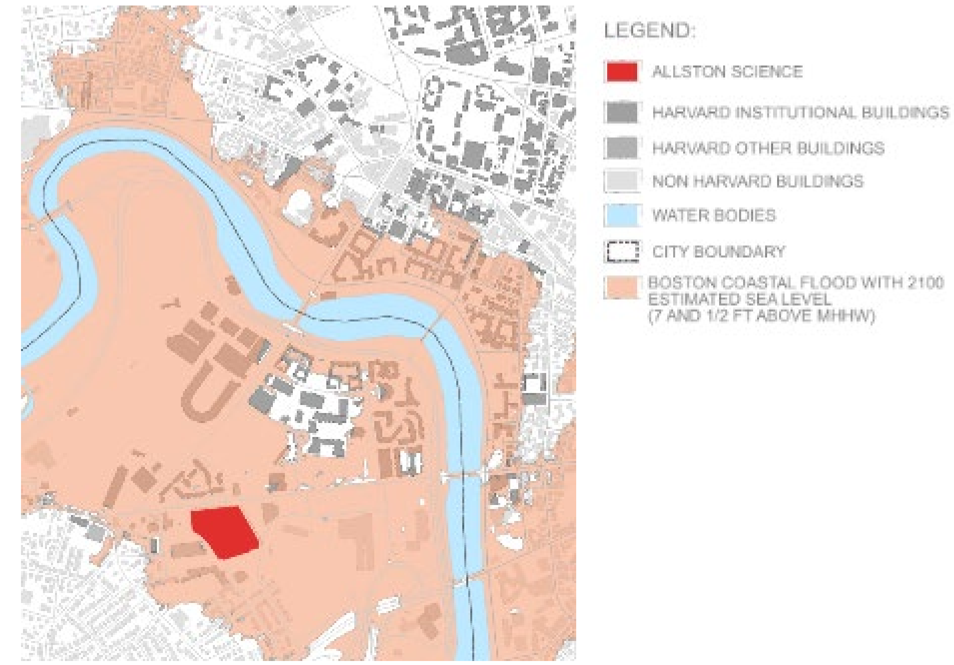
CHARLES RIVER WATERSHED

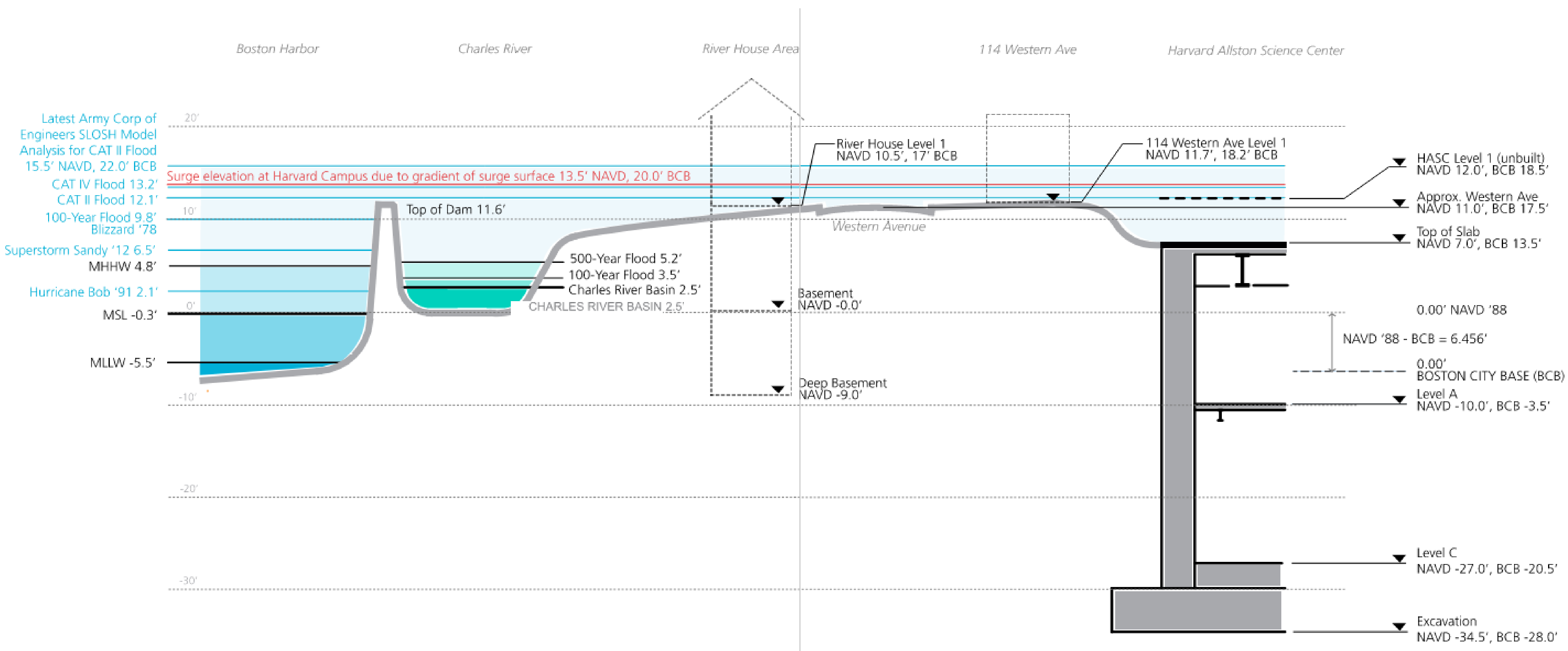
0 1000' 500' 2000'



Maps based on: Institutional Master Plan for Harvard University's Campus in Allston (2013)


LEGEND:
LEGEND DEPTH OF INUNDATION
> 8 FEET
6-8 FEET
4-6 FEET
2-4 FEET
0-2 FEET
0 FEET
MAP FEATURES
ALLSTON SCIENCE
CAPITAL PROJECTS (INCLUDING IMP)
HARVARD INSTITUTIONAL BUILDINGS
HARVARD OTHER BUILDINGS
HARVARD UNDERGROUND
NON HARVARD BUILDINGS
CHILD CARE
DINING FACILITY
UTILITY INFRASTRUCTURE
HEALTH SERVICES
GENERATOR
HUPD
OPERATIONS CENTER
SHELTER
TRANSPORTATION
HAZARDOUS MATERIAL STORAGE


LEGEND:
ALLSTON SCIENCE
HARVARD INSTITUTIONAL BUILDINGS
HARVARD OTHER BUILDINGS
NON HARVARD BUILDINGS
WATER BODIES
CITY BOUNDARY
BOSTON COASTAL FLOOD WITH 2100 ESTIMATED SEA LEVEL (7 AND 1/2 FT ABOVE MHHW)


Boston Harbor
Charles River
River House Area
114 Western Ave
Harvard Allston Science Center
Latest Army Corp of Engineers SLOSH Model Analysis for CAT II Flood 15.5' NAVD, 22.0' BCB
Surge elevation at Harvard Campus due to gradient of surge surface 13.5' NAVD, 20.0' BCB
CAT IV Flood 13.2'
CAT II Flood 12.1'
100-Year Flood 9.8' Blizzard '78
Superstorm Sandy '12 6.5'
MHHW 4.8'
Hurricane Bob '91 2.1'
MSL -0.3'
MLLW -5.5'
20'
10'
0'
-10'
-20'
-30'
Top of Dam 11.6'
500-Year Flood 5.2'
100-Year Flood 3.5'
Charles River Basin 2.5'
CHARLES RIVER BASIN 2.5'
River House Level 1 NAVD 10.5', 17' BCB
Basement NAVD -0.0'
Deep Basement NAVD -9.0'
Western Avenue
114 Western Ave Level 1 NAVD 11.7', 18.2' BCB
HASC Level 1 (unbuilt) NAVD 12.0', BCB 18.5'
Approx. Western Ave NAVD 11.0', BCB 17.5'
Top of Slab NAVD 7.0', BCB 13.5'
0.00' NAVD '88
NAVD '88 - BCB = 6.456'
0.00' BOSTON CITY BASE (BCB)
Level A NAVD -10.0', BCB -3.5'
Level C NAVD -27.0', BCB -20.5'
Excavation NAVD -34.5', BCB -28.0'

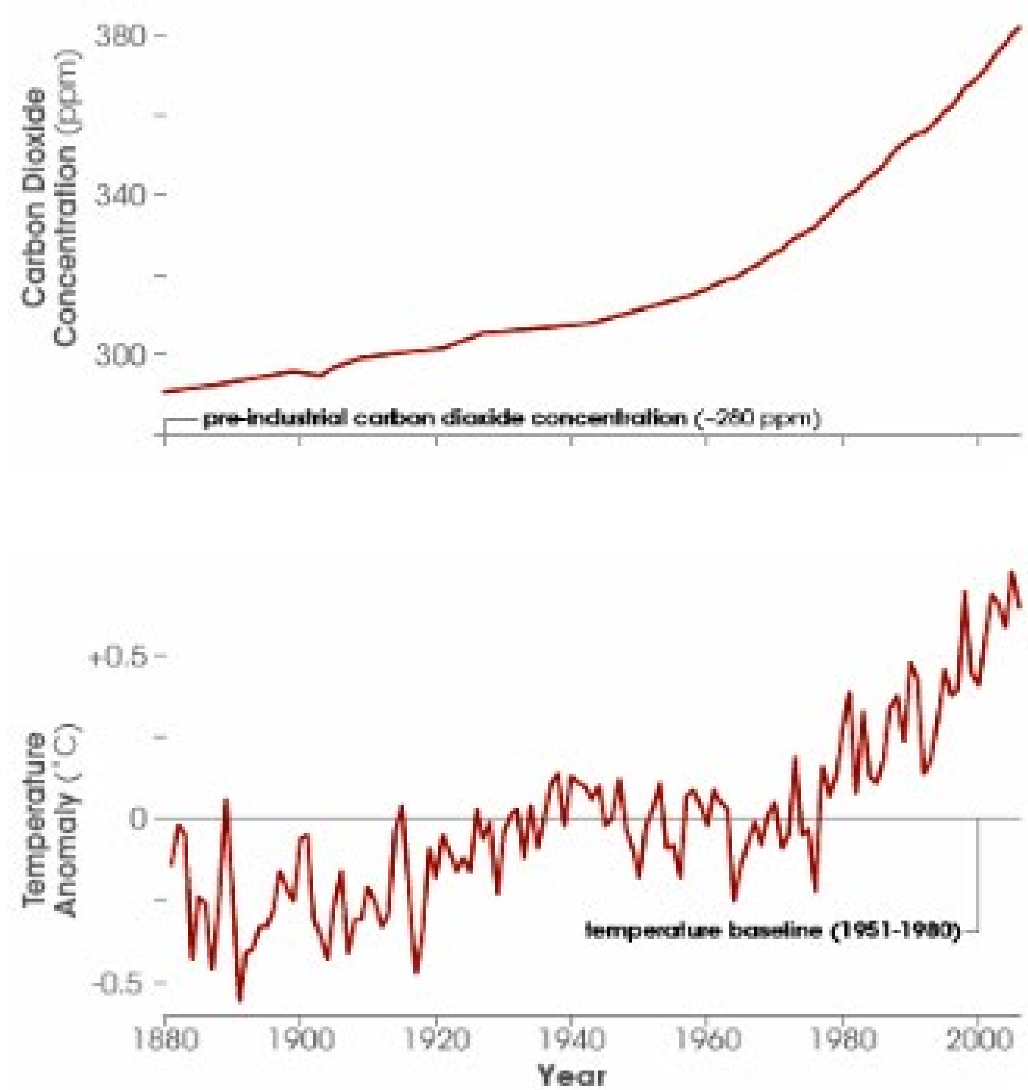
PERVIOUS AND IMPERVIOUS SURFACES IN ALLSTON[1]

PERVIOUS SURFACE

IMPERVIOUS SURFACE

ALLSTON SCIENCE SITE

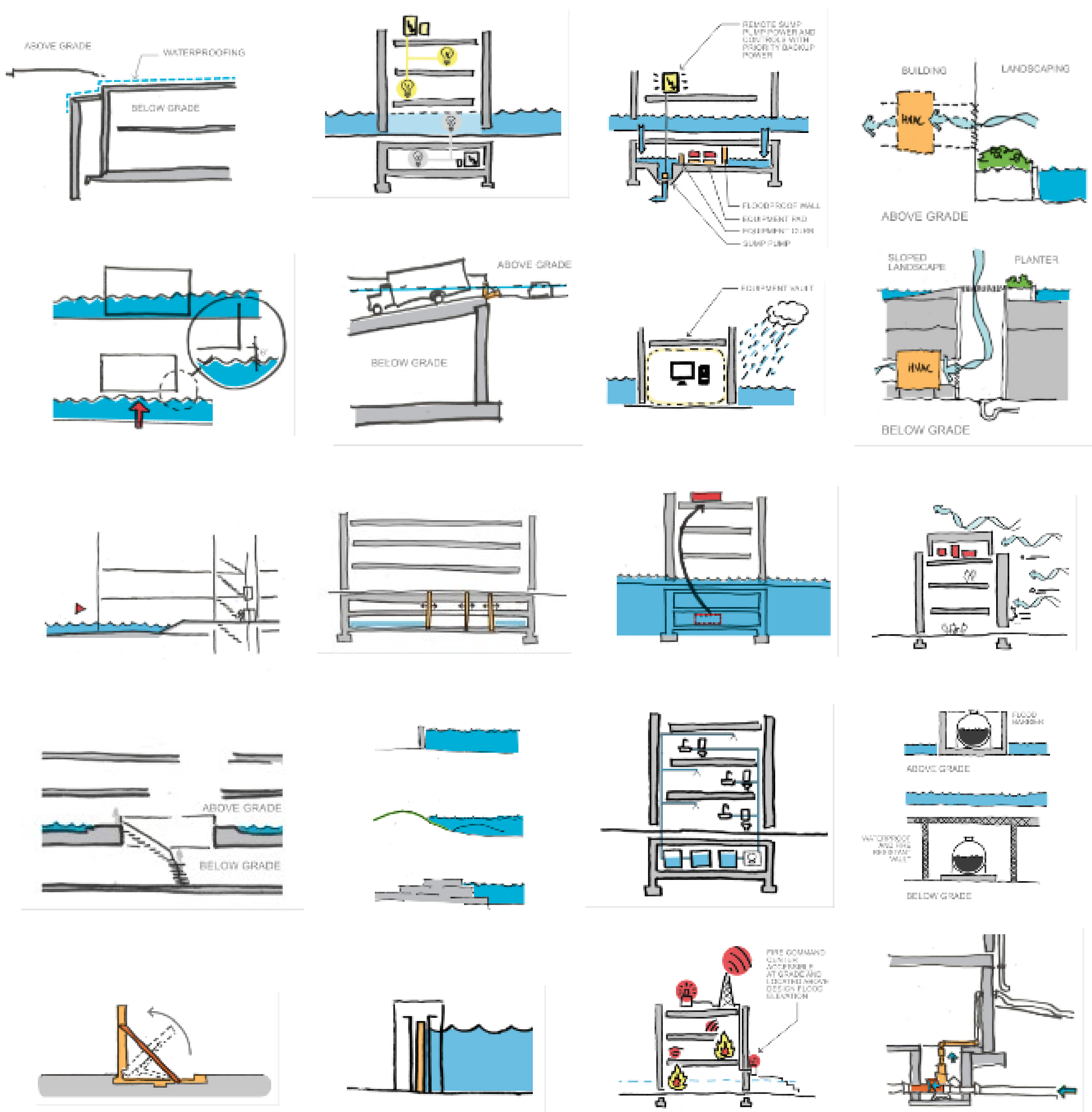
RELATIONSHIP BETWEEN CO_2 AND TEMPERATURE CHANGE IN NEW ENGLAND[2]



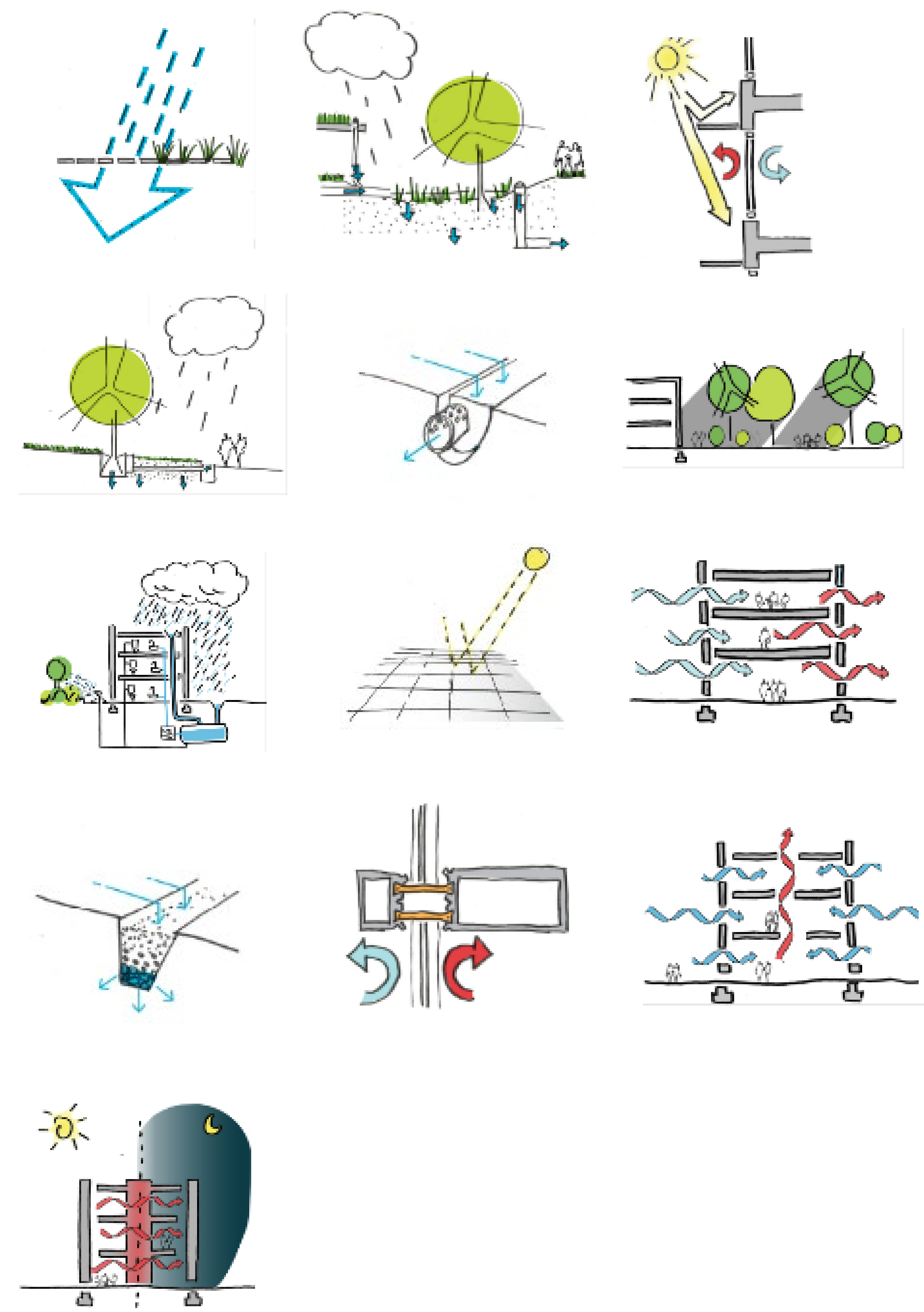
1. Gravelin, J., Newman, J., Sheehan, T., Slaughter, S., Springer, M., Wilson, A., (2013) "Building Resilience in Boston: "Best Practices" for Climate Change Adaptation and Resilience for Existing Buildings," Green Ribbon Commission, page 25, Retrieved from http://www.greenribboncommission.org/downloads/Building_Resilience_in_Boston

2. Commonwealth of Massachusetts, Executive Office of Energy and Environmental Affairs and the Adaptation Advisory Committee (2011). Massachusetts Climate Change Adaption Report , page 12

ROBUST CLIMATE CHANGE PREPAREDNESS STRATEGIES



RESILIENT CLIMATE CHANGE PREPAREDNESS STRATEGIES

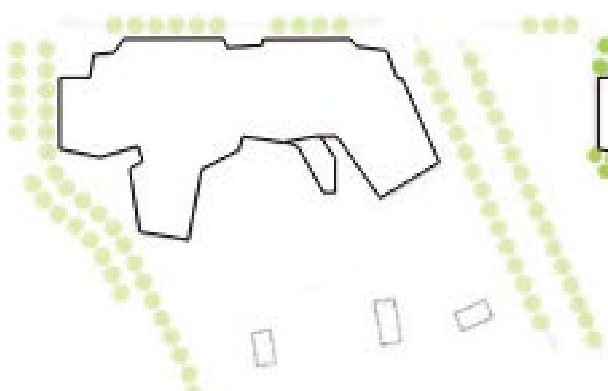



WESTERN AVE
KEY
Extent of Foundation
Passive Flood Proofing Boundary
Deployable Flood Barrier
Perimeter Building Entrances
Wet Flood-proofing

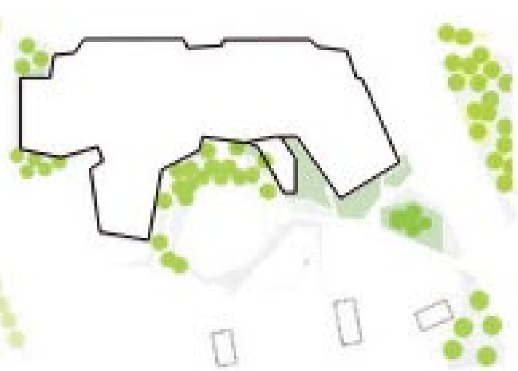
82% Increase in Vegetated Area
61% Native Plantings
150k Tons of contaminated soil properly disposed of

Before

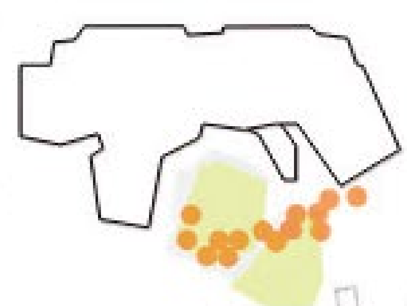
After



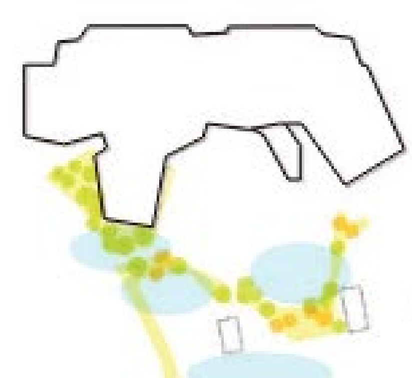
Urban Street Trees



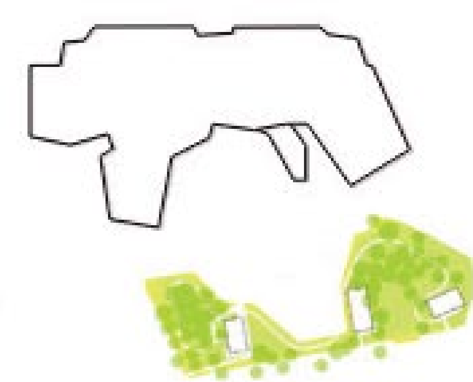
Plaza Groves



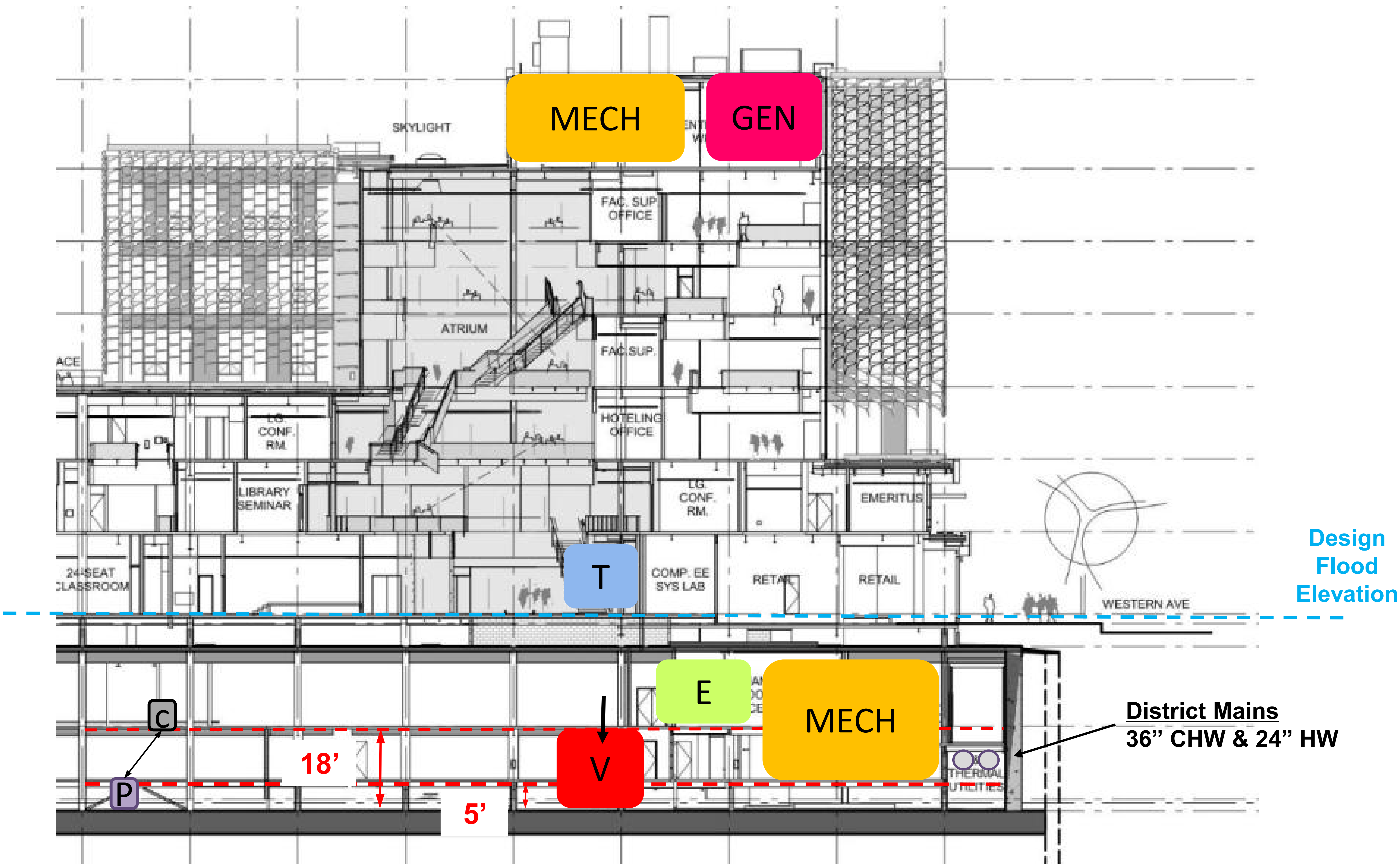
Lawn & Event Space

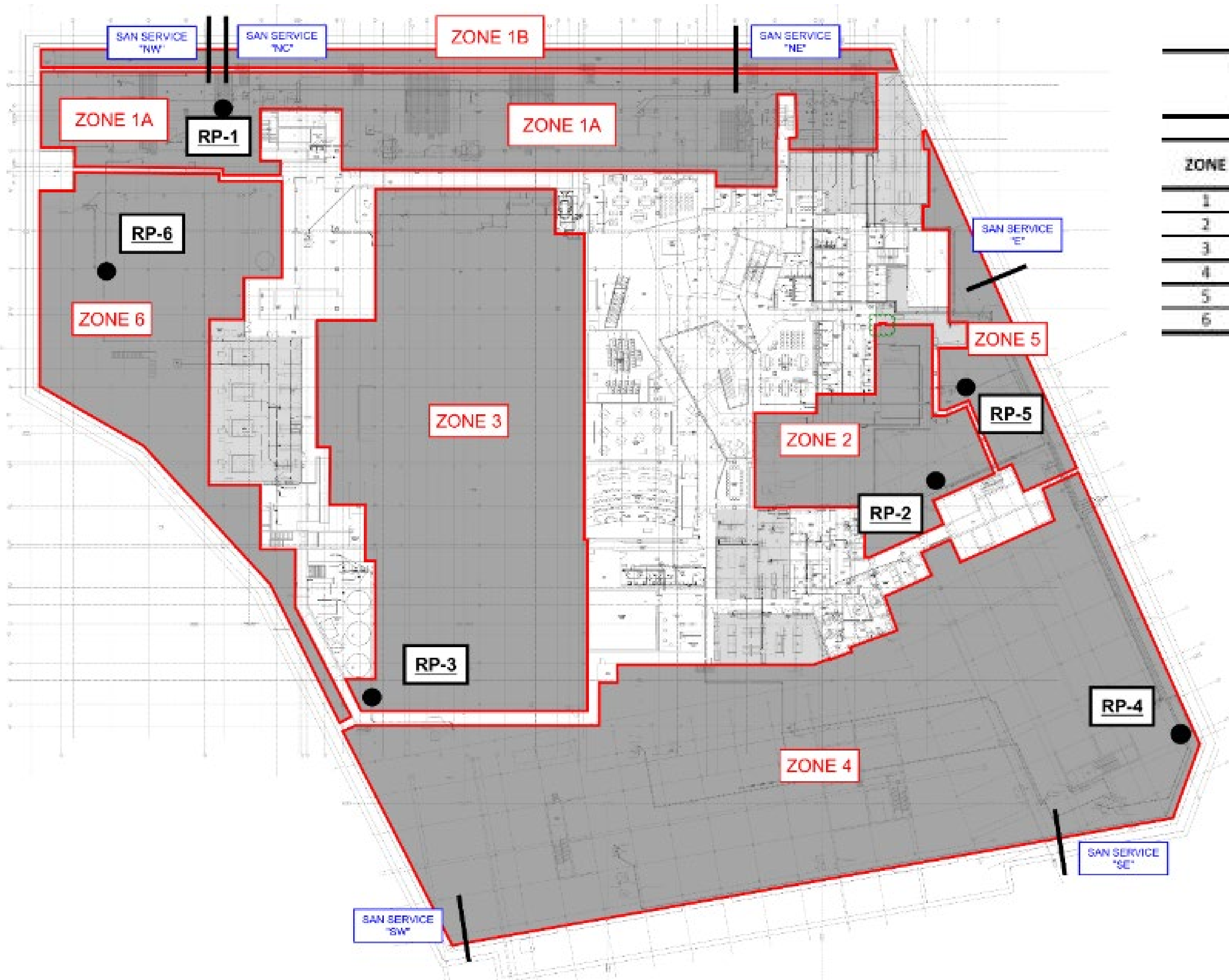


Bio-swale & Storm-water Gardens



Harvard Arboretum Tree Nursery


MECH
GEN
SKYLIGHT
FAC. SUP. OFFICE
ATRIUM
FAC SUP.
HOTELING OFFICE
LG. CONF. RM.
LIBRARY SEMINAR
LG. CONF. RM.
EMERITUS
24-SEAT CLASSROOM
T
COMP. EE SYS LAB
RETAIL
RETAIL
WESTERN AVE
Design Flood Elevation
E
MECH
C
P
V
18'
5'
THERMAL UTILITIES
District Mains
36" CHW & 24" HW



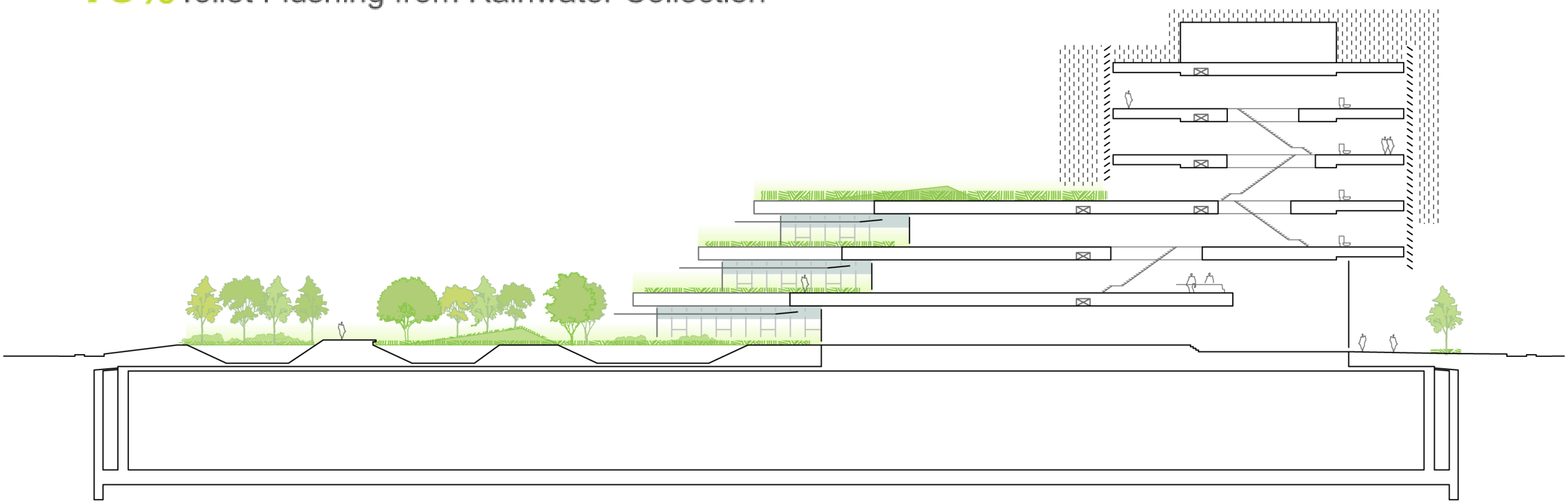
RESILIENCY PUMPING ZONES

ZONE	LOCATION	APROXIMATE AREA (SF)	PUMP
1	MECHANICAL ROOM	32,500	RP-1
2	UNDER LOADING DOCK	10,000	RP-2
3	FUTURE GARAGE	40,700	RP-3
4	SOUTH BASEMENT	66,000	RP-4
5	EAST BASEMENT	6,800	RP-5
6	WEST BASEMENT	20,500	RP-6

Area	Area at Mat Slab	% of total	Volume (cf)- based on water depth (ft)				Gallons at each depth				GPM to Pump out in 24 hours				GPM to pump out in 48 hours			
			0.5	1	3	5	0.5	1	3	5	0.5	1	3	5	0.5	1	3	5
1	6,500																	
2	26,000	18%	16,250	32,500	97,500	162,500	121,550	243,100	729,300	1,215,500	84.41	168.82	506.46	844.10	42.20	84.41	253.23	422.05
3	20,500	12%	10,250	20,500	61,500	102,500	76,670	153,340	460,020	766,700	53.24	106.49	319.46	532.43	26.62	53.24	159.73	266.22
4	40,700	23%	20,350	40,700	122,100	203,500	152,218	304,436	913,308	1,522,180	105.71	211.41	634.24	1,057.07	52.85	105.71	317.12	528.53
5	66,000	37%	33,000	66,000	198,000	330,000	246,840	493,680	1,481,040	2,468,400	171.42	342.83	1,028.50	1,714.17	85.71	171.42	514.25	857.08
6	10,000	6%	5,000	10,000	30,000	50,000	37,400	74,800	224,400	374,000	25.97	51.94	155.83	259.72	12.99	25.97	77.92	129.86
7	6,800	4%	3,400	6,800	20,400	34,000	25,432	50,864	152,592	254,320	17.66	35.32	105.97	176.61	8.83	17.66	52.98	88.31
TOTAL	176,500		88,250	176,500	529,500	882,500	660,110	1,320,220	3,960,660	6,601,100	458	917	2,750	4,584	229	458	1,375	2,292
Entire	252,000		126,000	252,000	756,000	1,260,000	942,480	1,884,960	5,654,880	9,424,800	655	1,309	3,927	6,545	327	655	1,964	3,273

71% Lab Water from Rainwater Collection

73% Toilet Flushing from Rainwater Collection



Storm-water Management

Slow Water
through landscape planting and green roof terrace cascade

Store Water
with storm water gardens and collection tanks

Use Water
filter water and distribute to building systems

Release Water
filter solids and reduce phosphorus, then release to city

Water Reuse Strategies

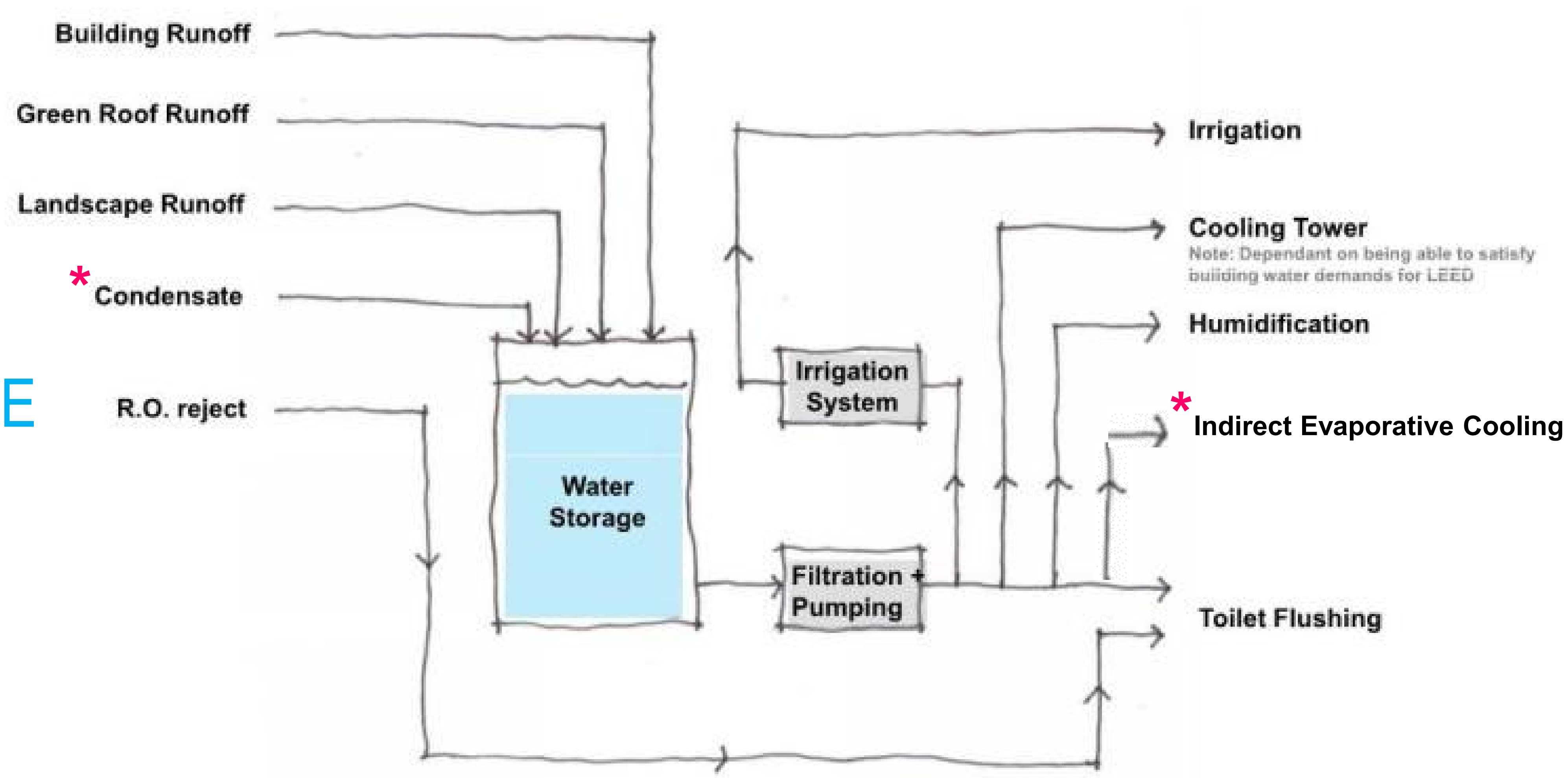
HVAC Condensate
Pumped to District Energy Facility cooling towers

Irrigation
Drip irrigation system for landscape and interior planters

Toilet Flushing

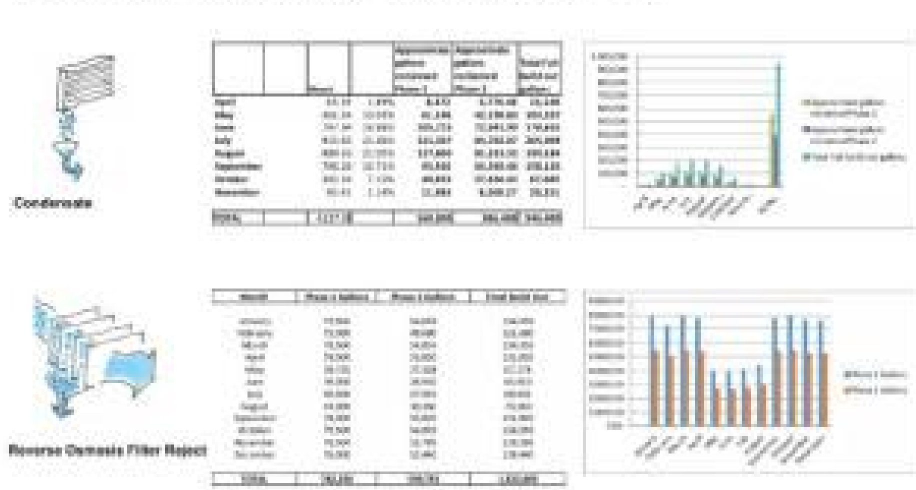
RO/DI
Process water for lab-use and indirect evaporative cooling

SOURCE

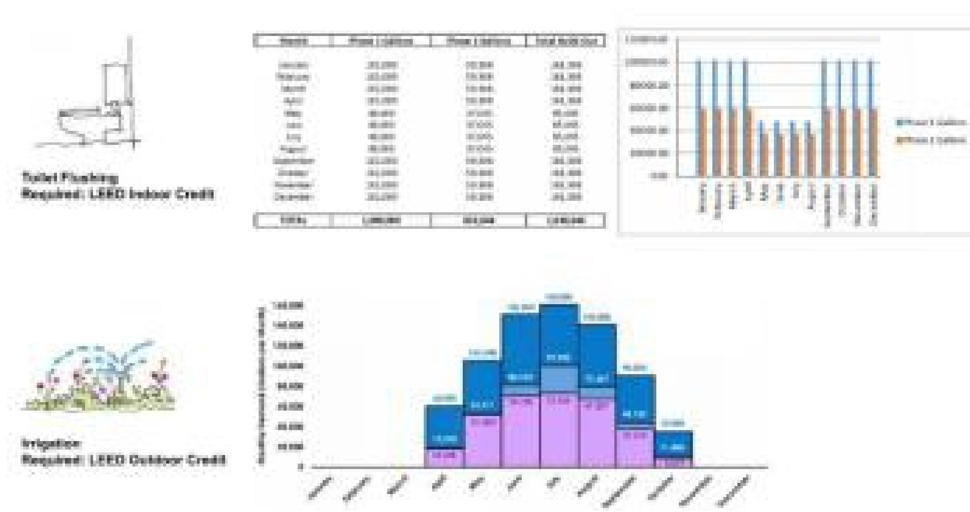


DEMAND

Sources of Water from the Building – Phase 1 and Full Build Out



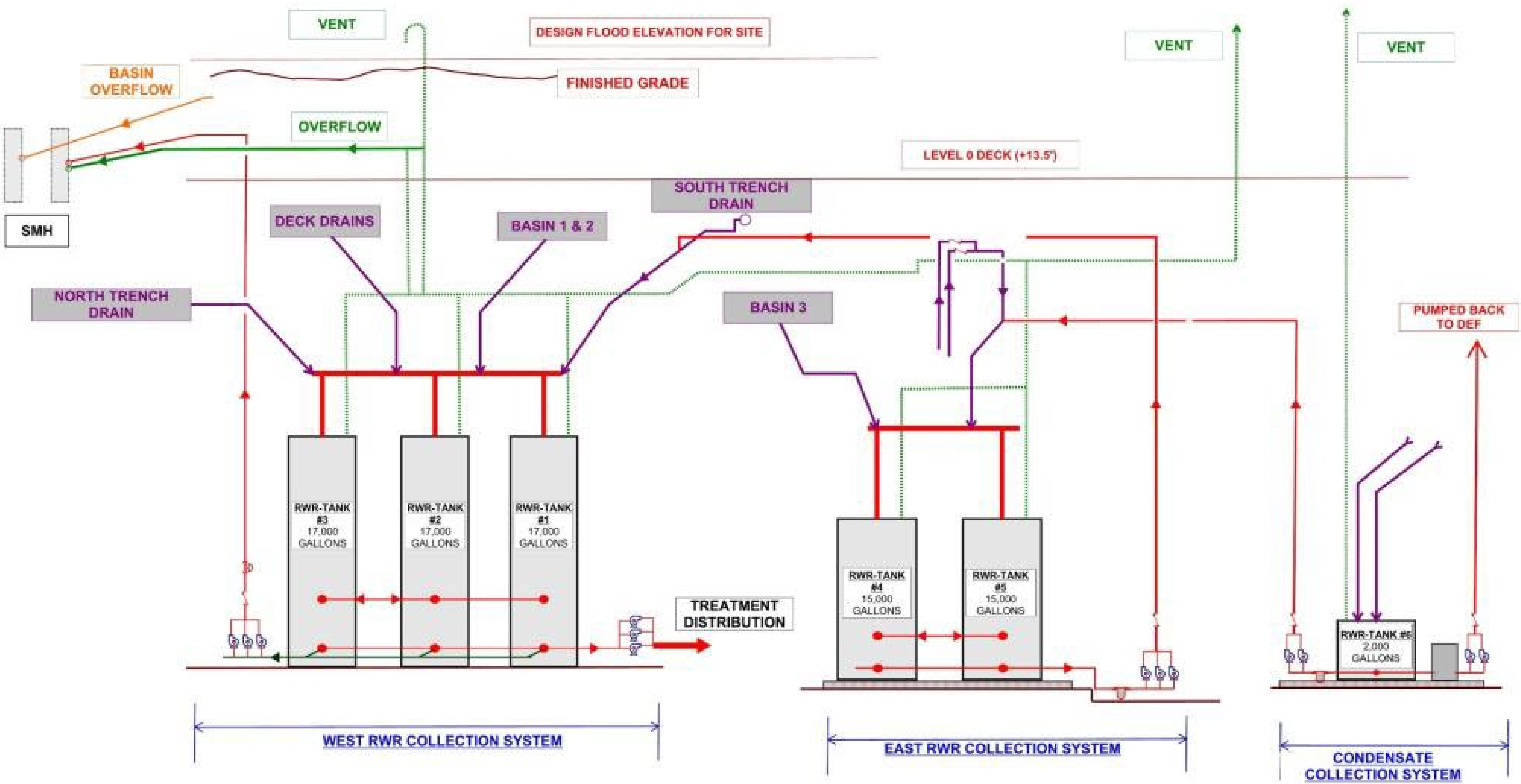
Uses of Water - Phase 1 and Full Build Out

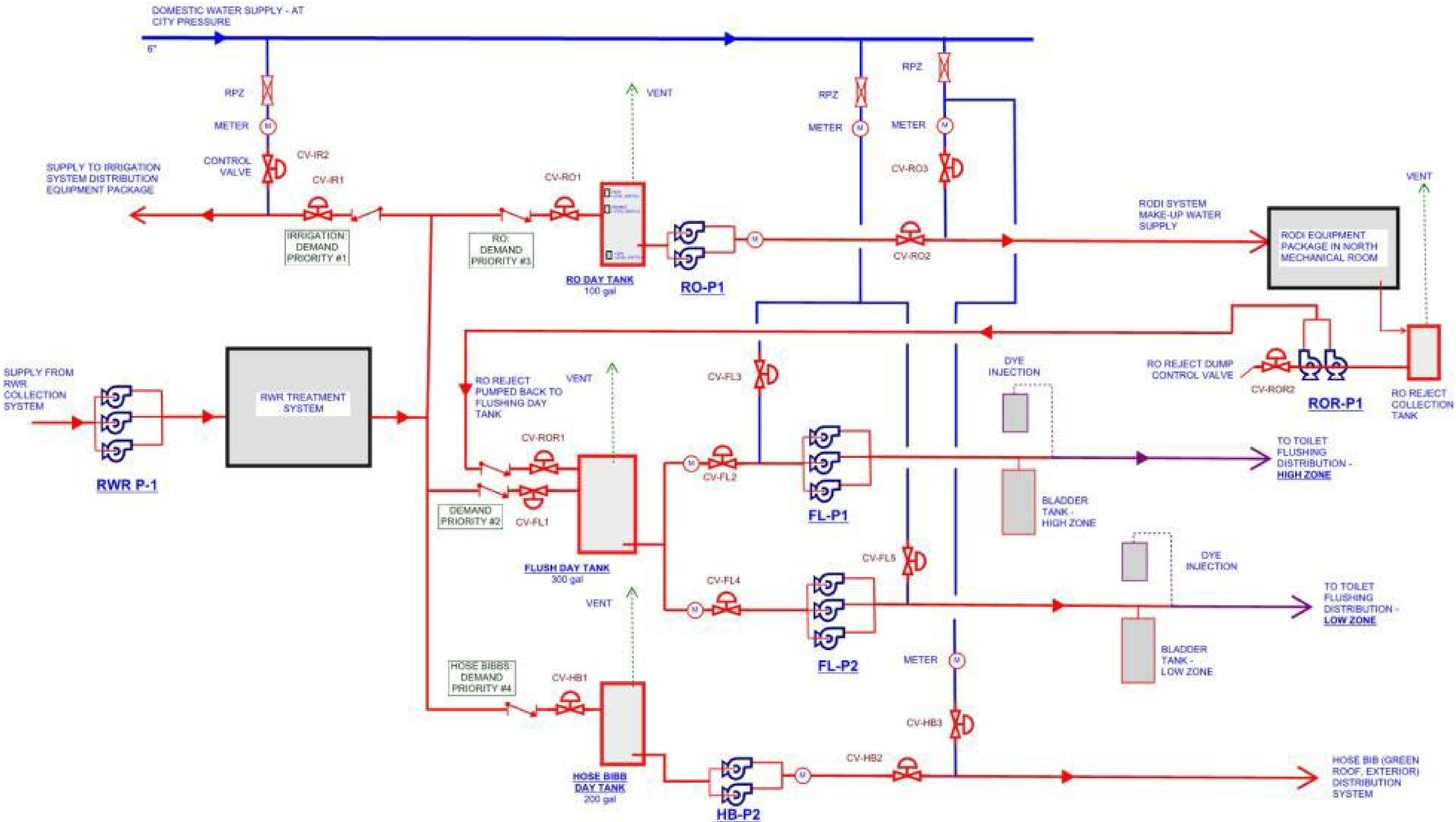


100-yr Flood Design Protection

100% Storm-water Managed On-site


78,000 Gallon Water Collection System

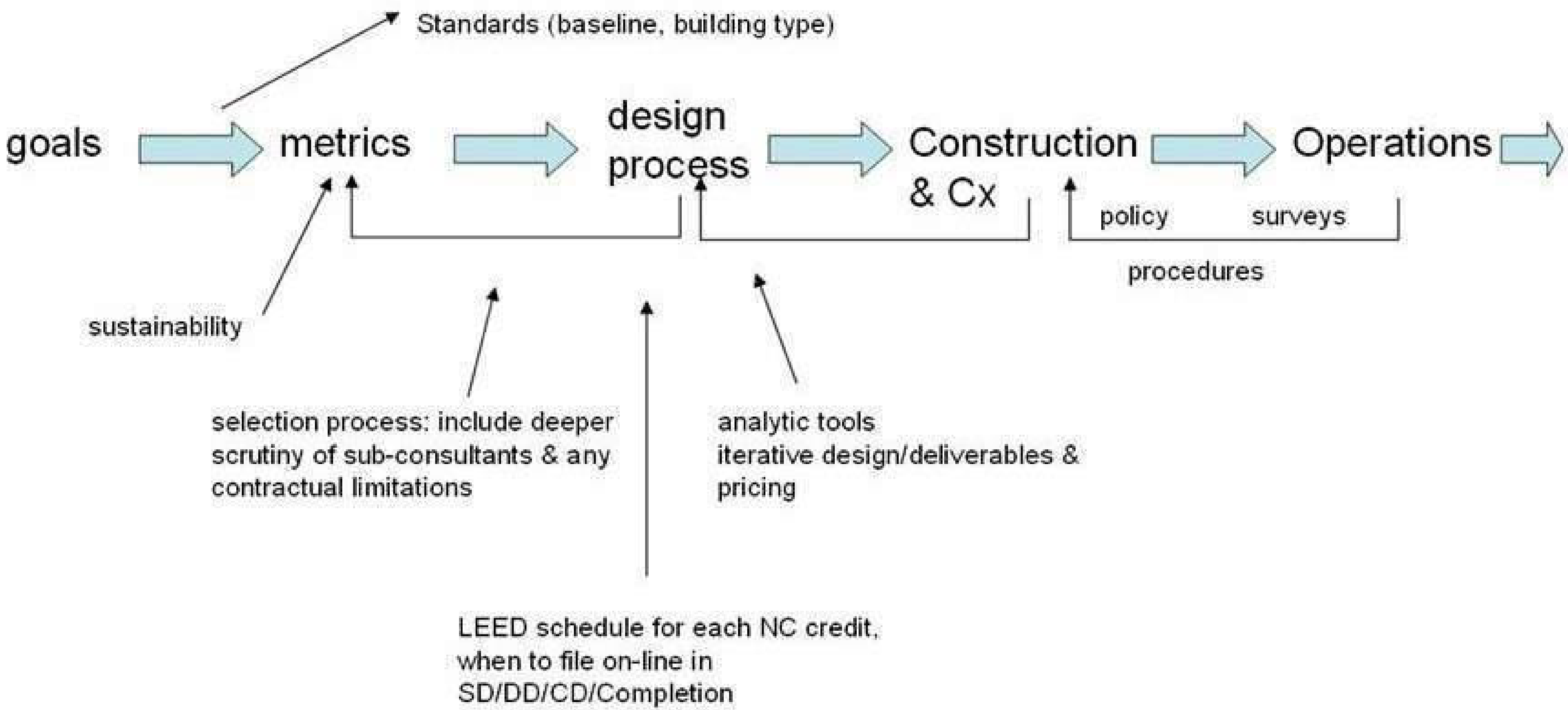

VENT
DESIGN FLOOD ELEVATION FOR SITE
BASIN OVERFLOW
FINISHED GRADE
OVERFLOW
VENT
VENT
LEVEL 0 DECK (+13.5')
SOUTH TRENCH DRAIN
SMH
DECK DRAINS
BASIN 1 & 2
NORTH TRENCH DRAIN
BASIN 3
PUMPED BACK TO DEF
RWR-TANK #3 17,000 GALLONS
RWR-TANK #2 17,000 GALLONS
RWR-TANK #1 17,000 GALLONS
TREATMENT DISTRIBUTION
RWR-TANK #4 15,000 GALLONS
RWR-TANK #5 15,000 GALLONS
RWR-TANK #6 2,000 GALLONS
WEST RWR COLLECTION SYSTEM
EAST RWR COLLECTION SYSTEM
CONDENSATE COLLECTION SYSTEM



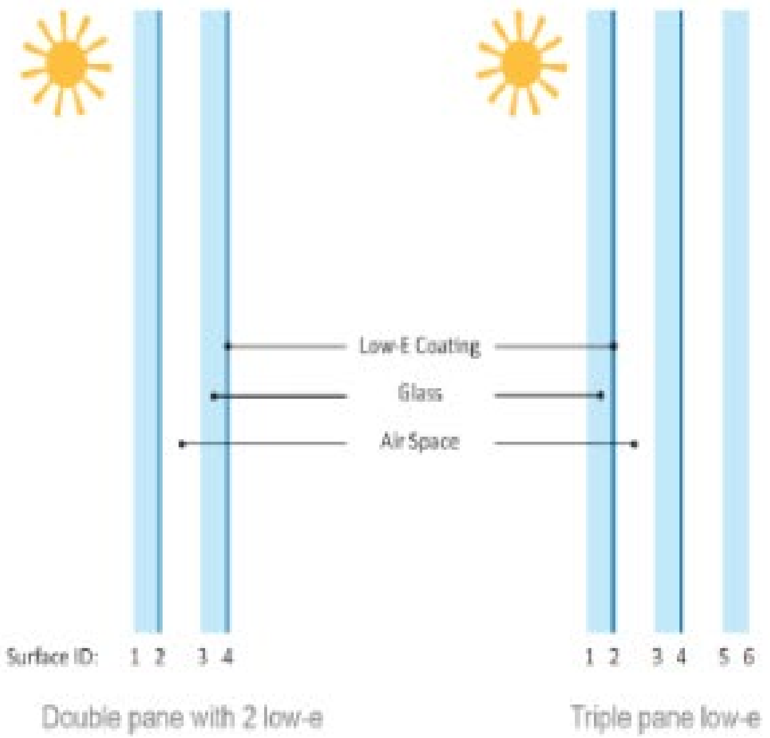
RAIN WATER RECLAIM DISTRIBUTION RISER

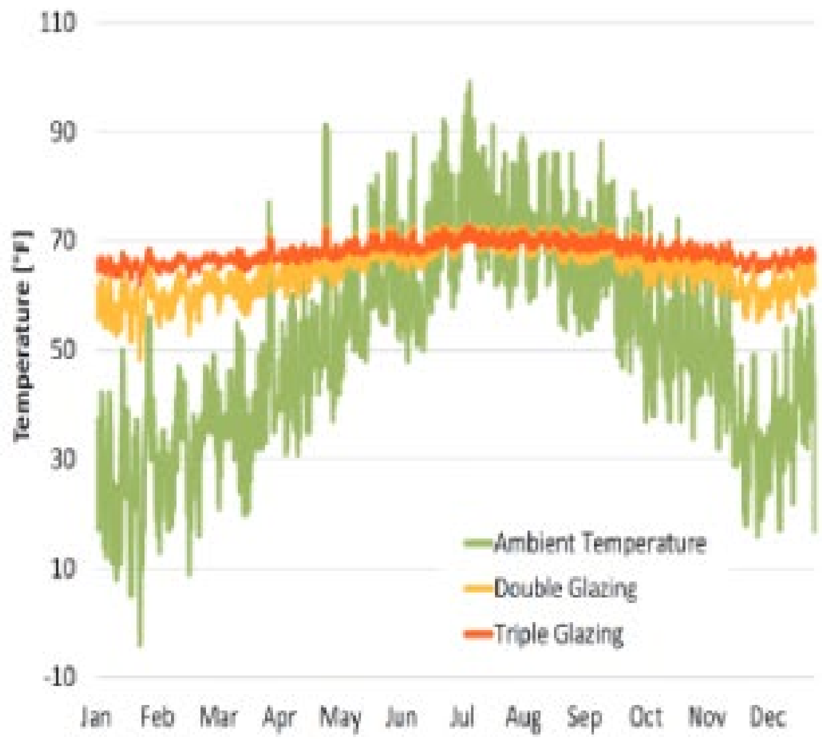
Systems Design Process

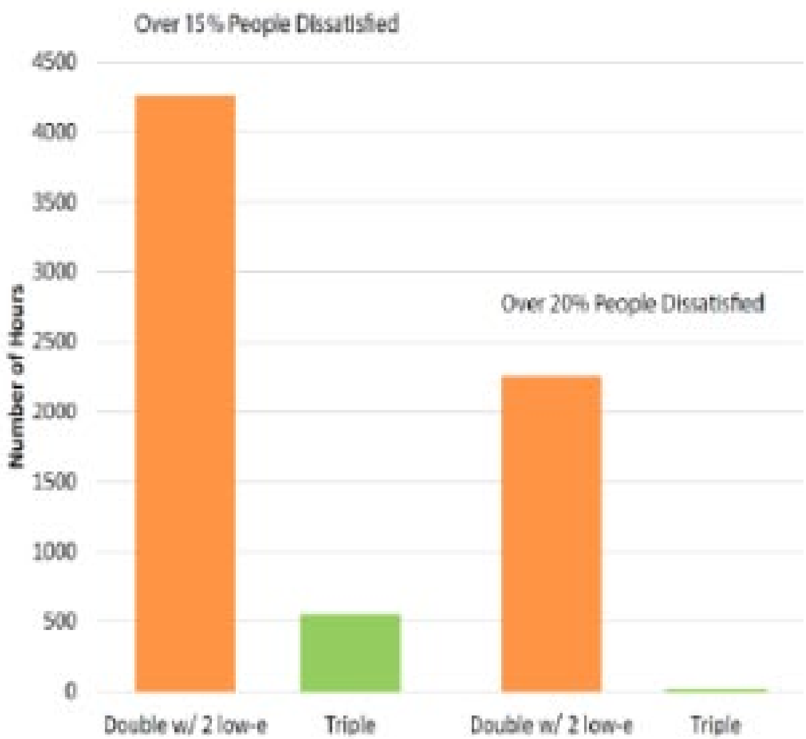
Building design, program and metrics establish the load	Efficient building systems meet the load	Primary energy systems supply energy to buildings	People run the systems
Ventilation Rates	Daylighting	Electricity	Schedules
Building Shape	Lighting	Steam	Controls
Orientation	HVAC	Hot Water	Maintenance
Glass location	Heat Recovery	Chilled Water	Setpoints
Glass area & type	Optimized Ventilation	Cogeneration	Windows
Insulation values	Building Automation	Solar Thermal	Equipment
Thermal mass	Domestic Hot Water	Photovoltaics	Education
Building Volume		Bio-Mass	Commissioning
Passive Solar			Re-commissioning
Minimize load as a first priority	Use efficient, cost- effective systems	Produce and distribute energy efficiently	Operate the building well


Standards (baseline, building type)
goals
metrics
design process
Construction & Cx
Operations
policy
surveys
procedures
sustainability
selection process: include deeper scrutiny of sub-consultants & any contractual limitations
analytic tools
iterative design/deliverables & pricing
LEED schedule for each NC credit, when to file on-line in SD/DD/CD/Completion

Architectural Energy Conservation
Double Glazing vs Triple Glazing



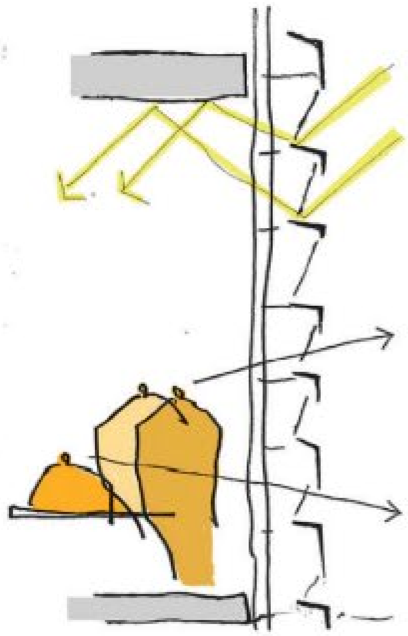


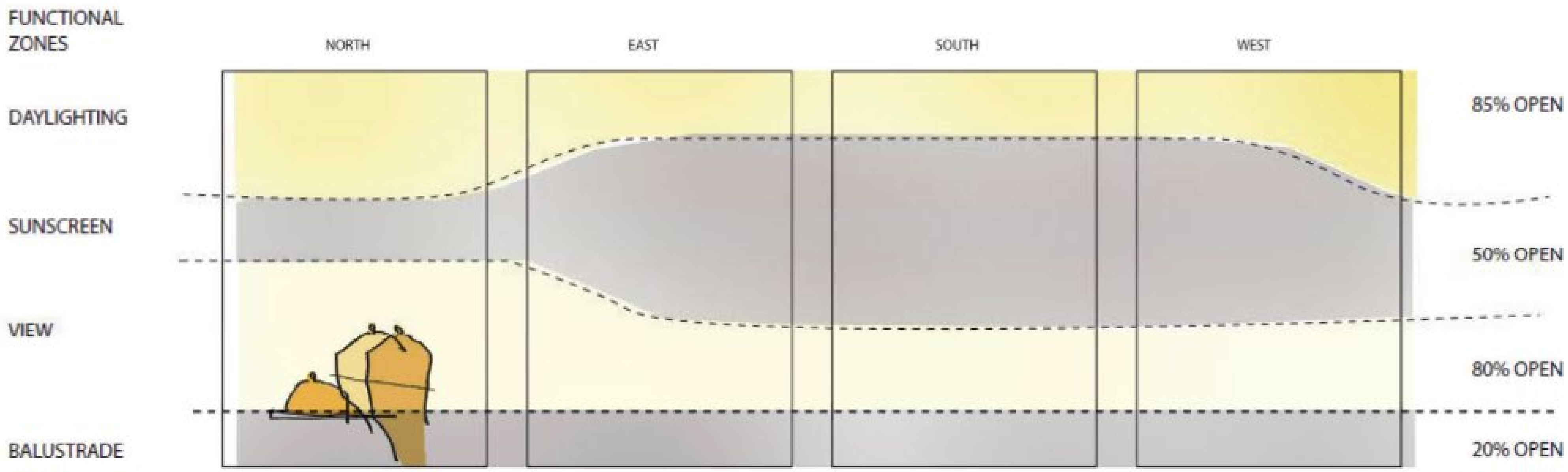


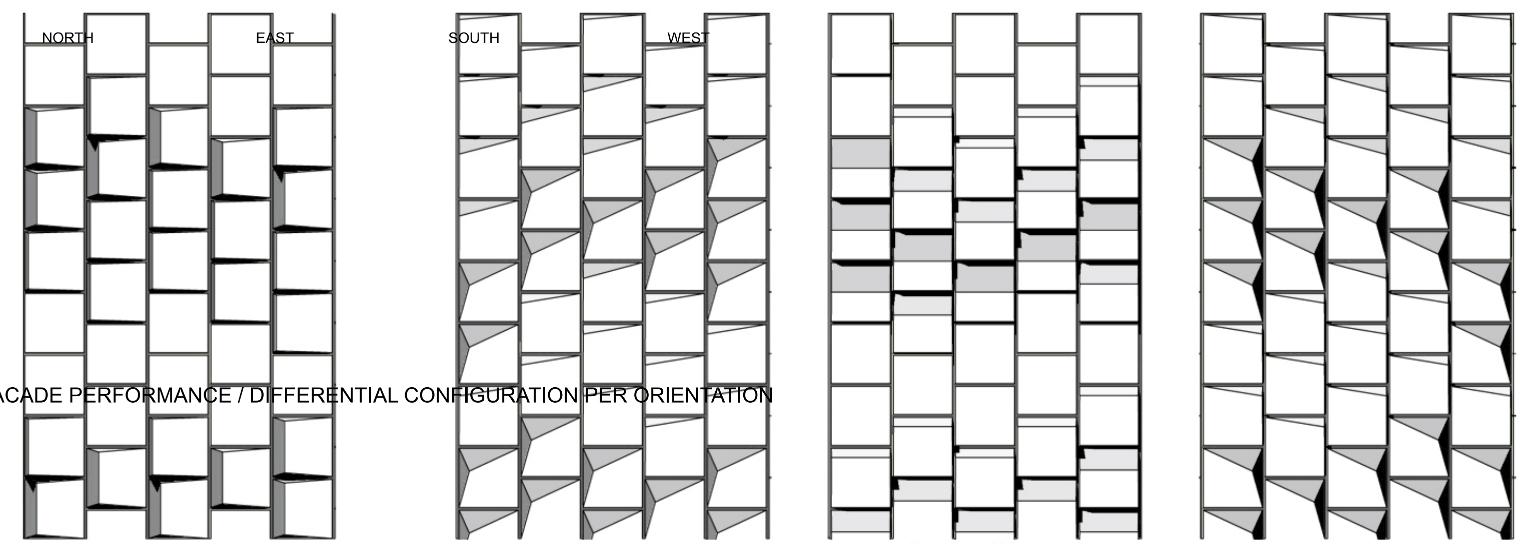
$45k Yearly Savings vs. Double-Glazed

65 Metric Tons of CO²e Reduction Yearly

DIFFERENTIAL CONFIGURATIONS PER ORIENTATION

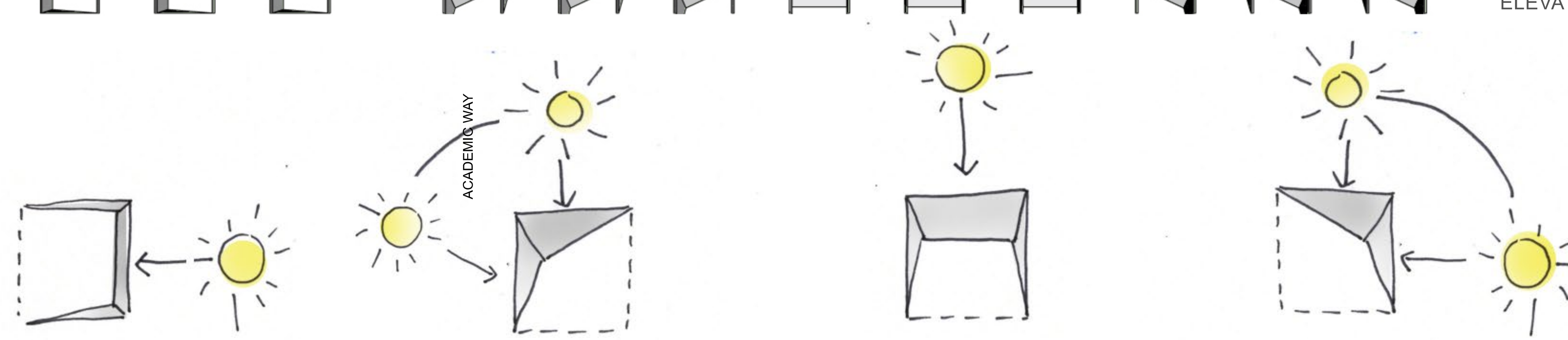






FACADE PERFORMANCE / DIFFERENTIAL CONFIGURATION PER ORIENTATION

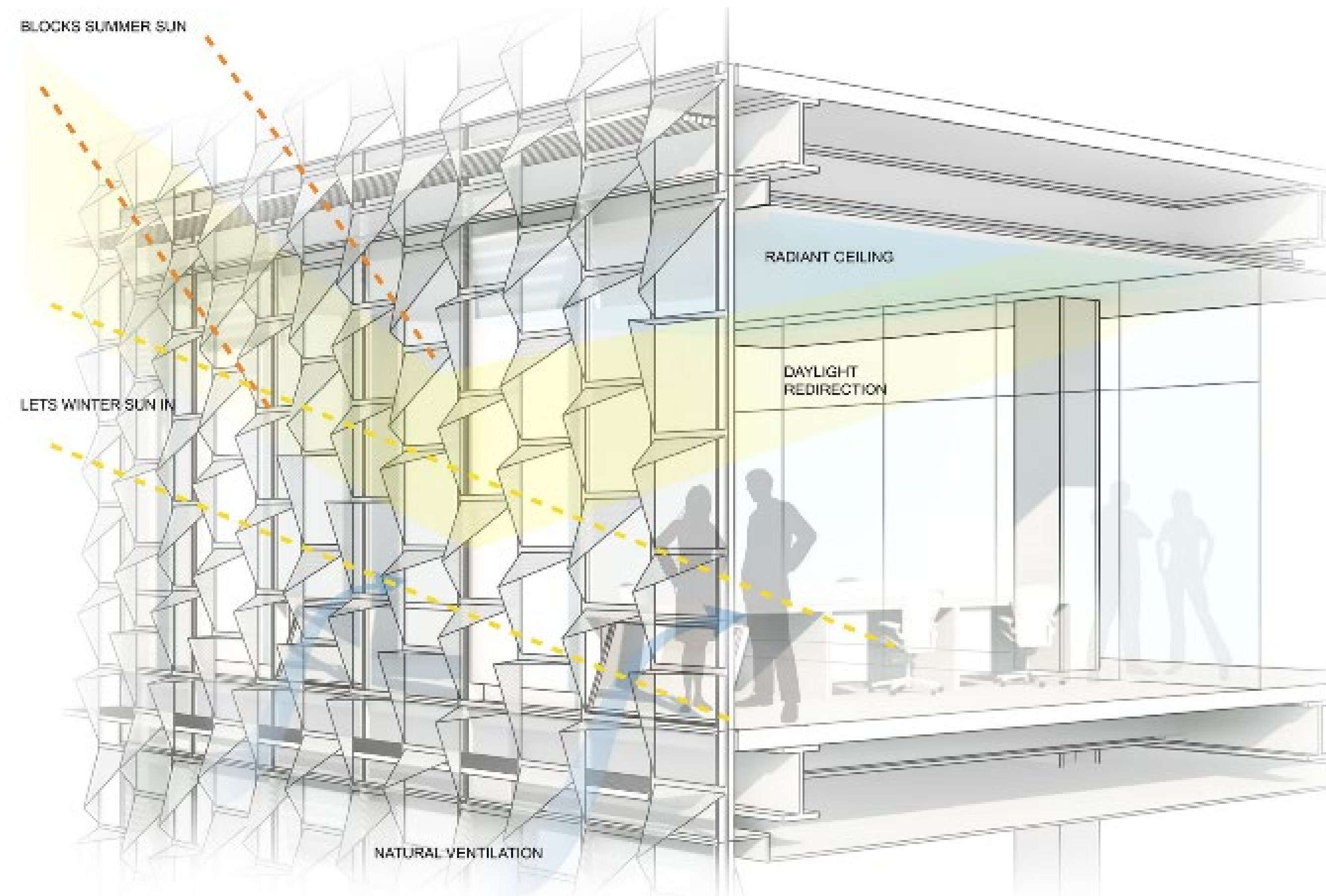
ELEVATION



NORTH ELEVATION, SCALE 1/32” = 1’-0”

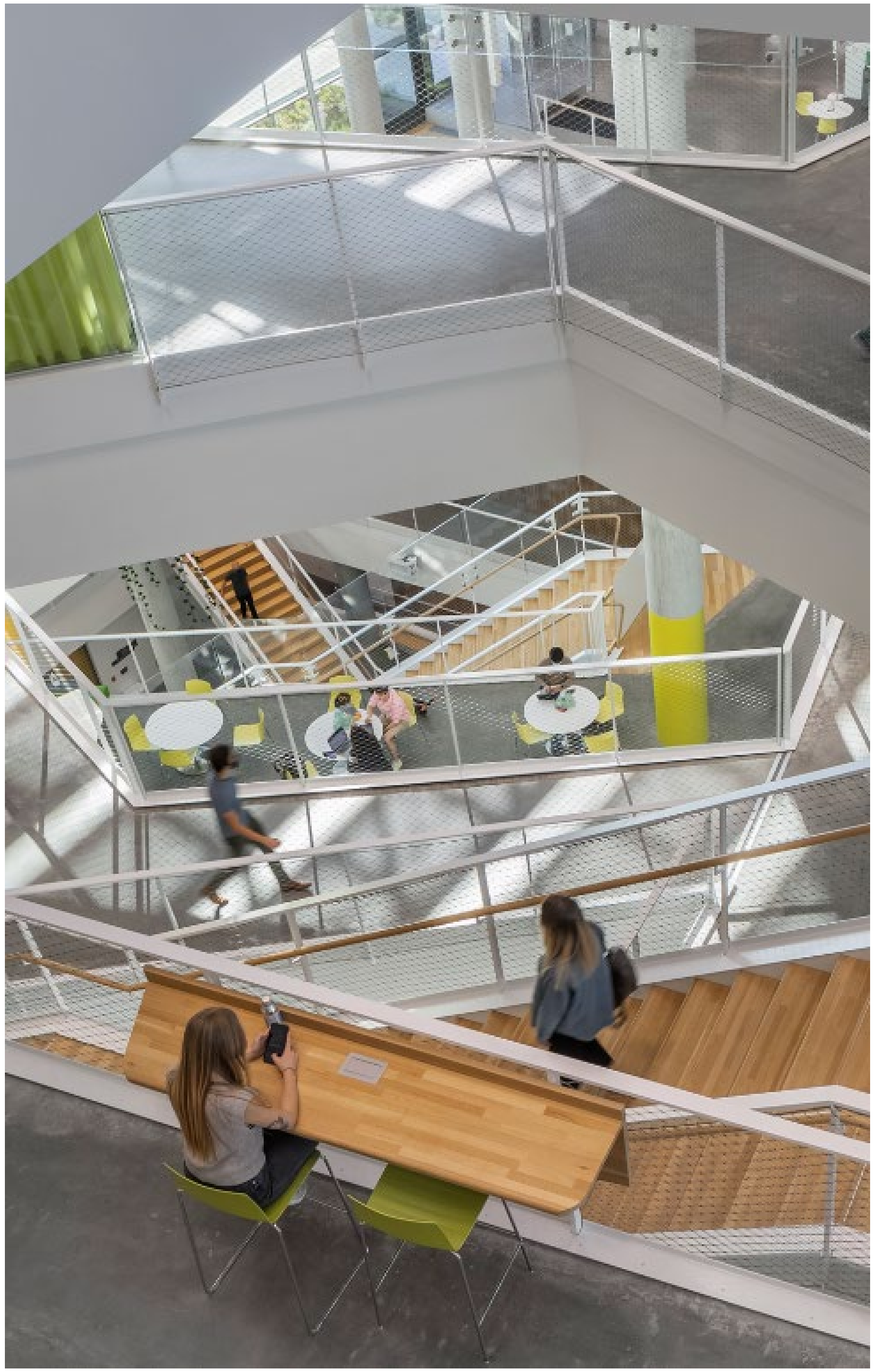
MODULE SHAPE PER ORIENTATION

14 Shade Profiles
12k Individual Shades
1.5 mm-thick Stainless Steel



Energy Conservation Techniques

- Minimize ventilation rates
- Dedicated outside air system
- Hydronic heating / sensible cooling
- Natural ventilation / air cascade
- Controlled lighting / daylighting
- Heat recovery



Minimize Ventilation Rates

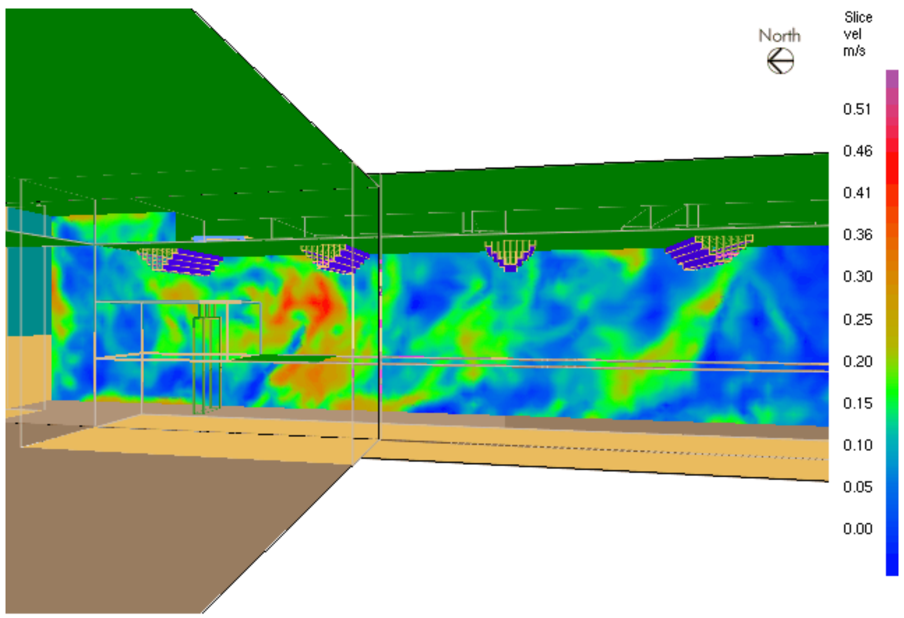
- Work closely with EH&S
- Define present / future fume hood density
- Evaluate applicable Codes / Standards
- Define peak / normal / unoccupied air change rates
- Define sensible / latent heat removal capacity by space
- Evaluate active environmental sensing
- Through risk assessment and development of Lab Ventilation Management Plan (LVMP)

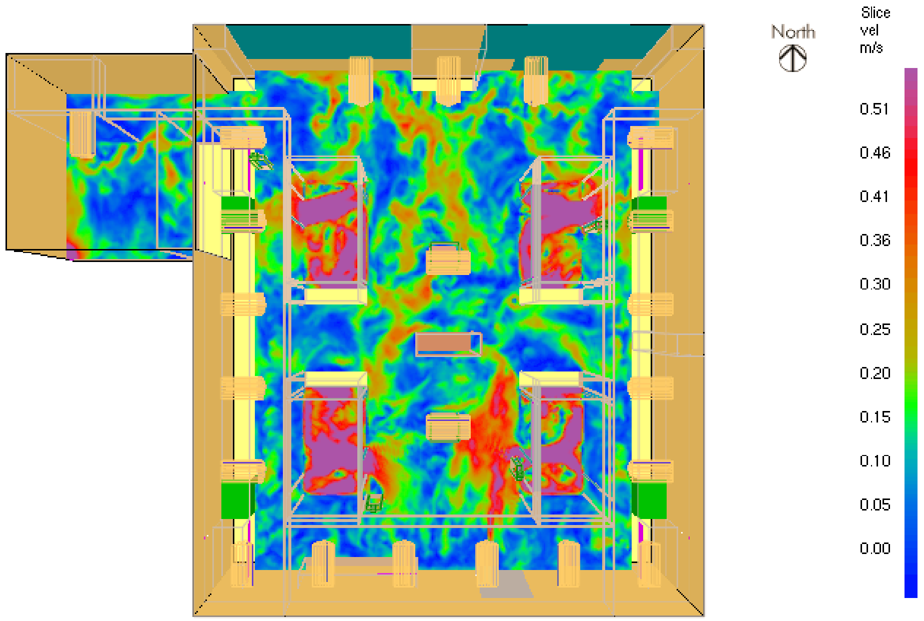
Achieving Reduced Laboratory Airflows

"Performance-Based Ventilation Rate Determination"

***GOAL* =** Equal or Greater safety at reduced airflows

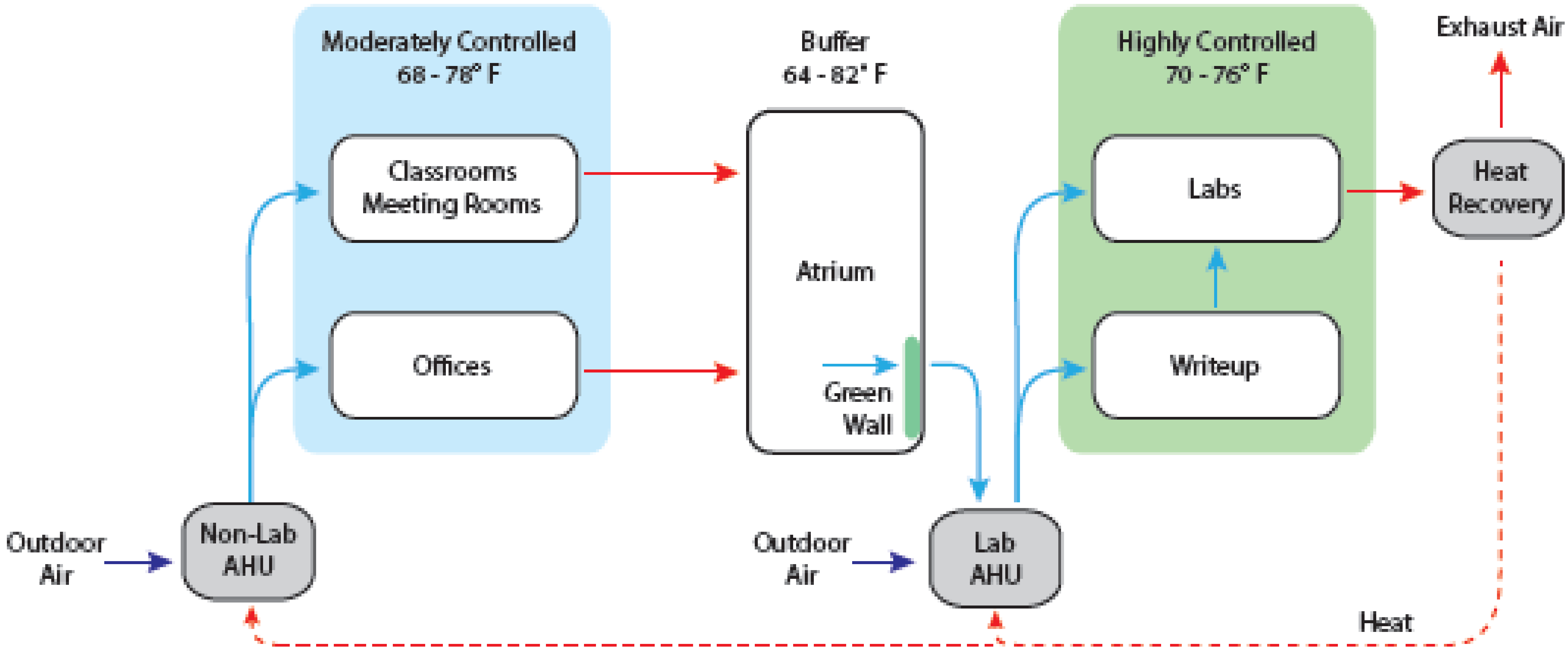
- Dedicated Outside Air Systems / Hydronic Cooling
- Risk Assessments
- Low Flow Hoods (ASHRAE 110-compliant)
- Design for High Ventilation Effectiveness
- Use Local Capture Devices wherever Possible
- CFD airflow analsys





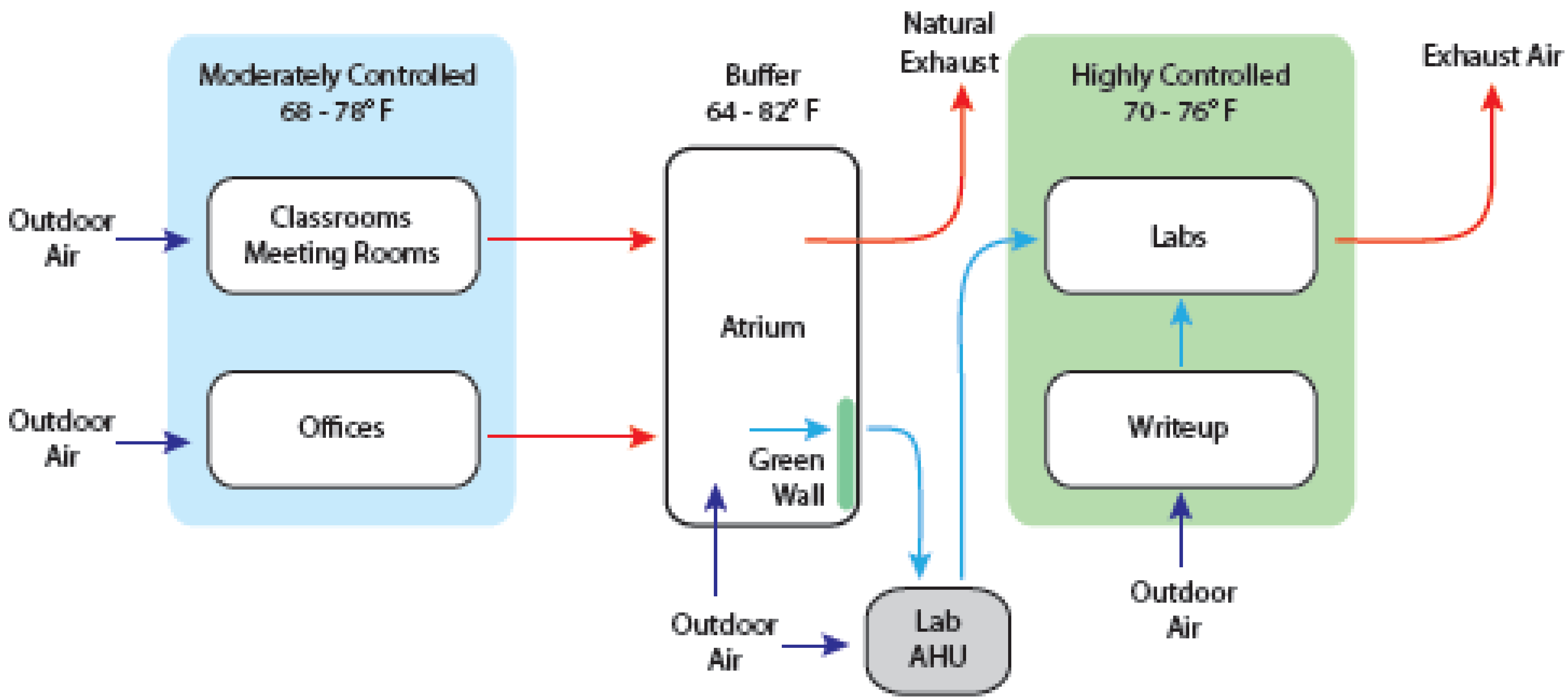
Building Airflow Concept

Mechanical Ventilation Air Cascade



Building Airflow Concept

Natural Ventilation Air Cascade

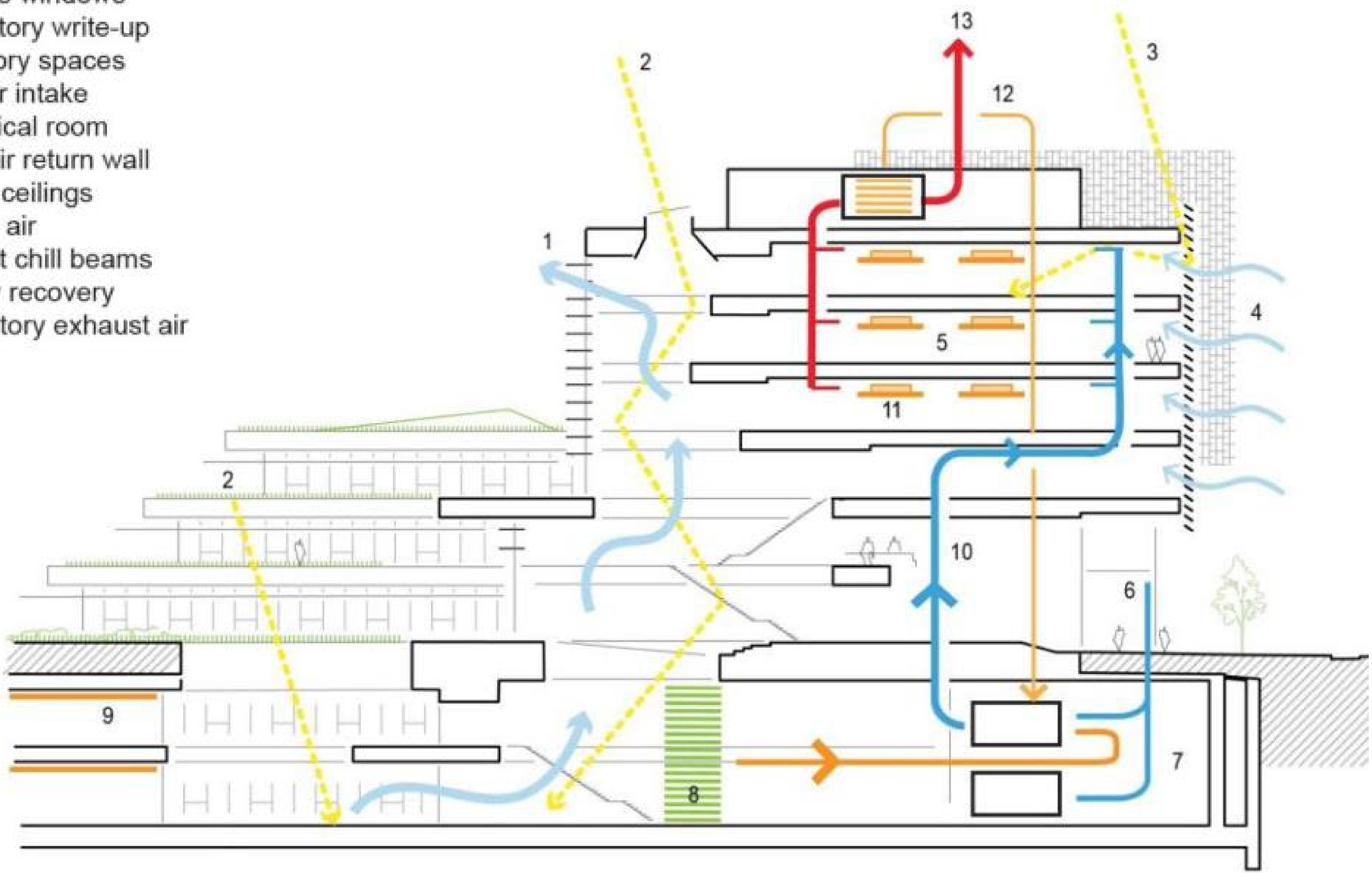


Overview of Air Systems

1 – Natural ventilation
2 – Daylight
3 – Daylight redirection at Screen Facade
4 – Operable windows at laboratory write-up
5 – Laboratory spaces
6 – Fresh air intake
7 – Mechanical room
8 – Atrium air return wall
9 – Radiant ceilings
10 – Supply air
11 – Radiant chill beams
12 – Energy recovery
13 – Laboratory exhaust air

50% Regularly occupied spaces can be naturally ventilated

100% Dedicated outdoor air ventilation with air cascade

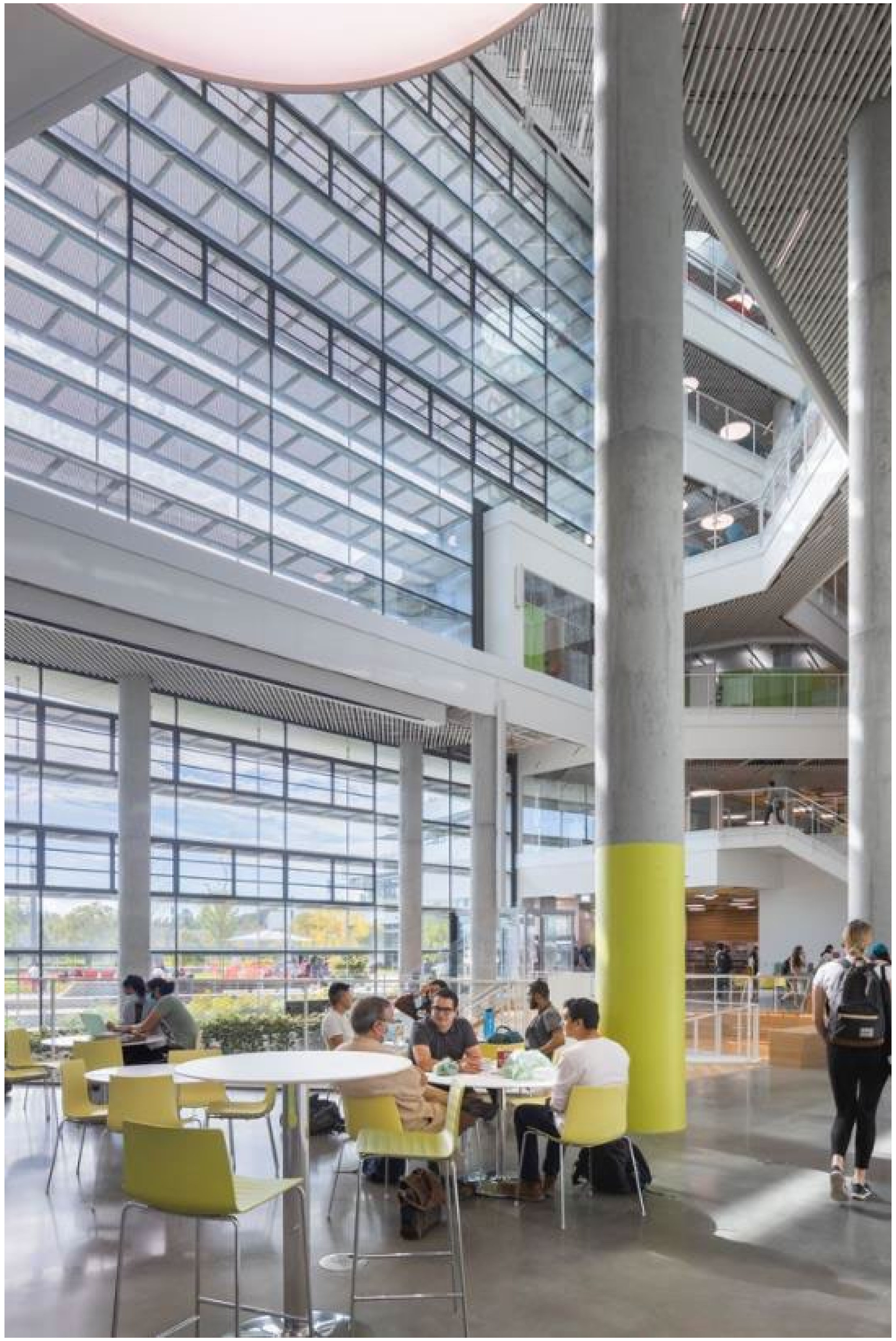


Sensible Only Cooling Systems – Design Approach

Laboratories	⇒	Chilled Beams
Offices	⇒	Radiant Ceilings
Atrium	⇒	Radiant Floor Slab
Classrooms	⇒	Radiant Ceilings / Displacement Ventilation

Sensible Only Cooling Systems

Hydronic (radiant) Heating/Cooling System



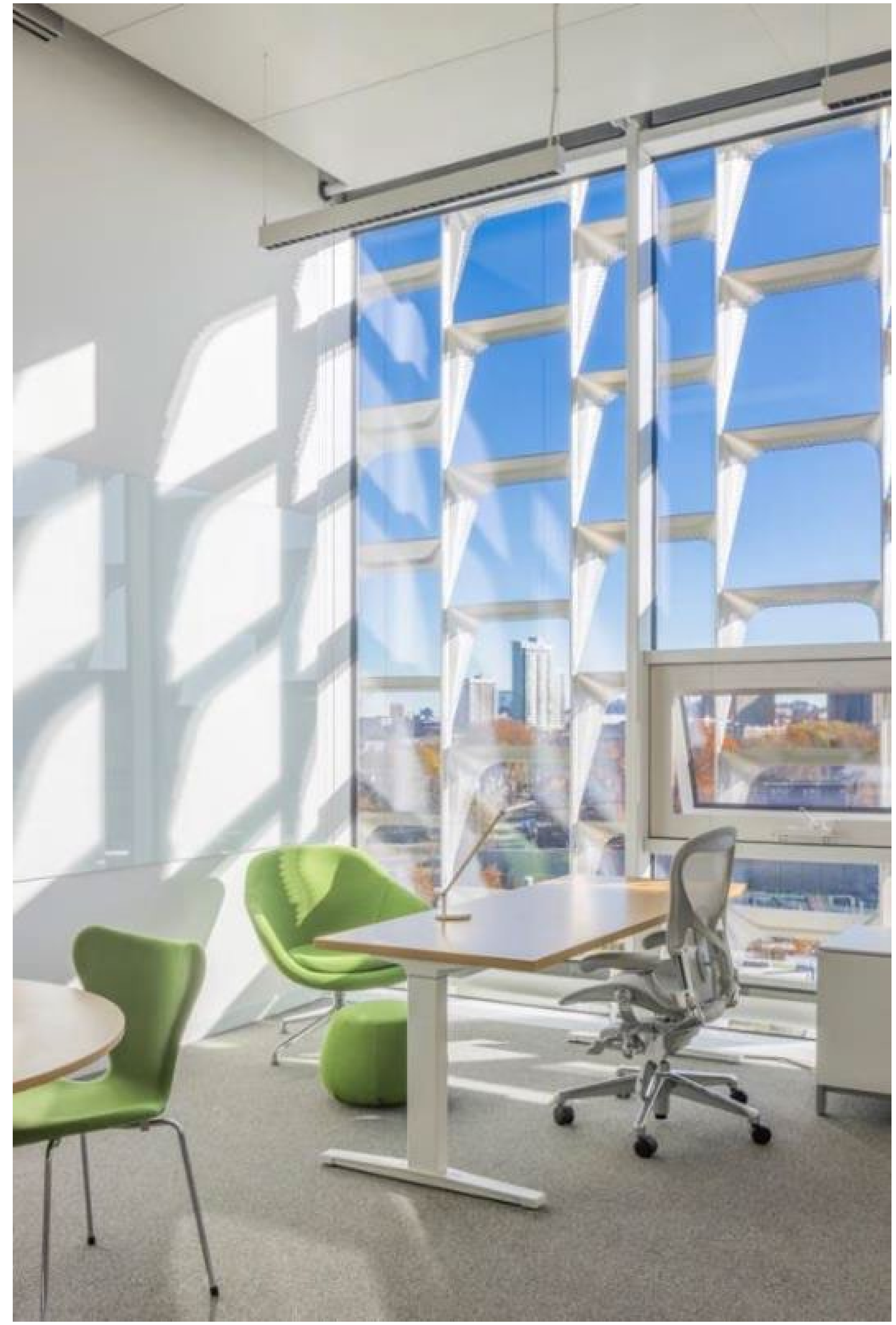
Classroom Radiant Ceilings

Atrium and Public Spaces Radiant Composite Concrete Floors

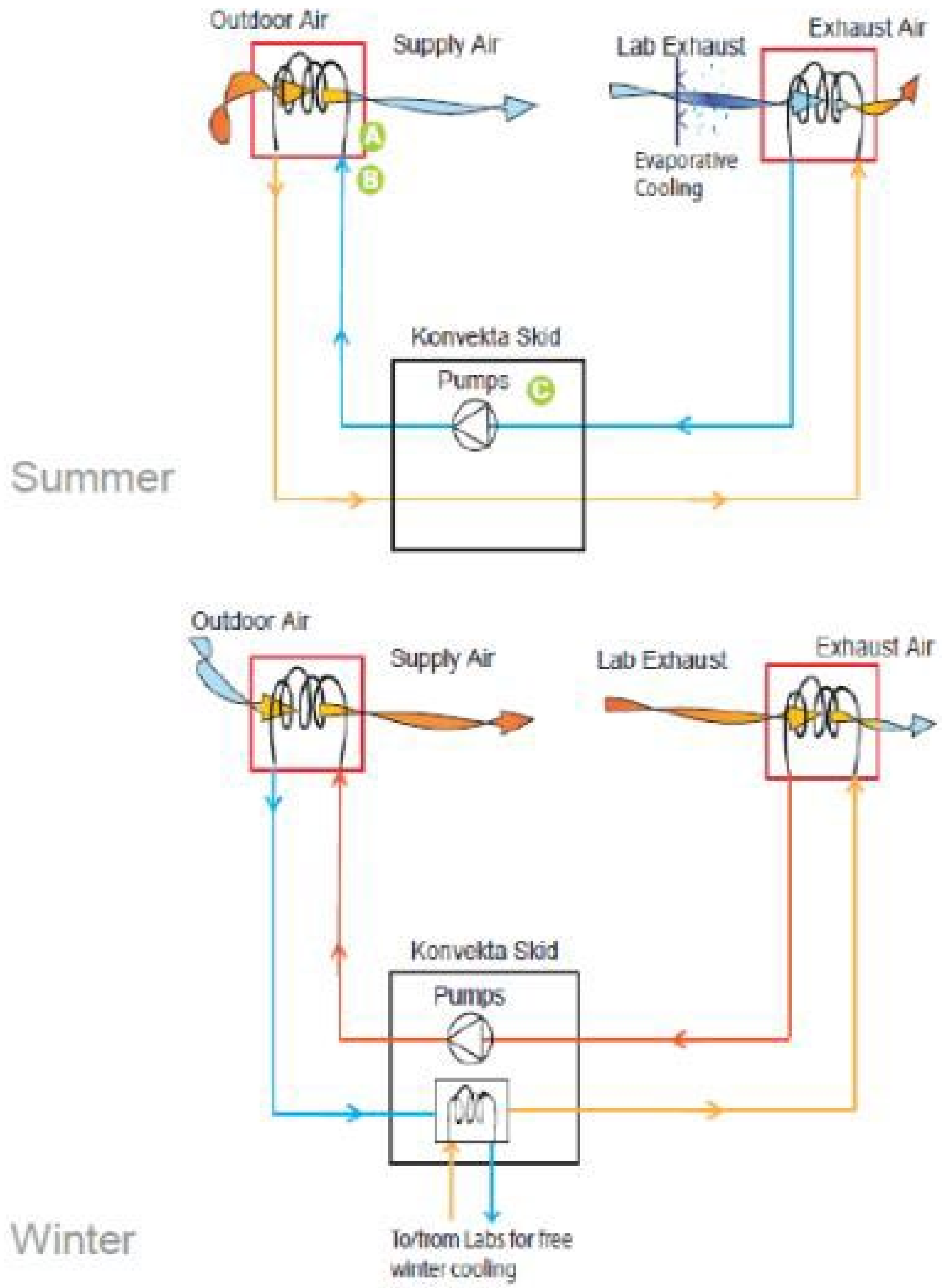
Hydronic (radiant) Heating/Cooling System

Imaging Suite Radiant Panels

Office Radiant Panels



Heat Recovery System IDEC / Konvekta

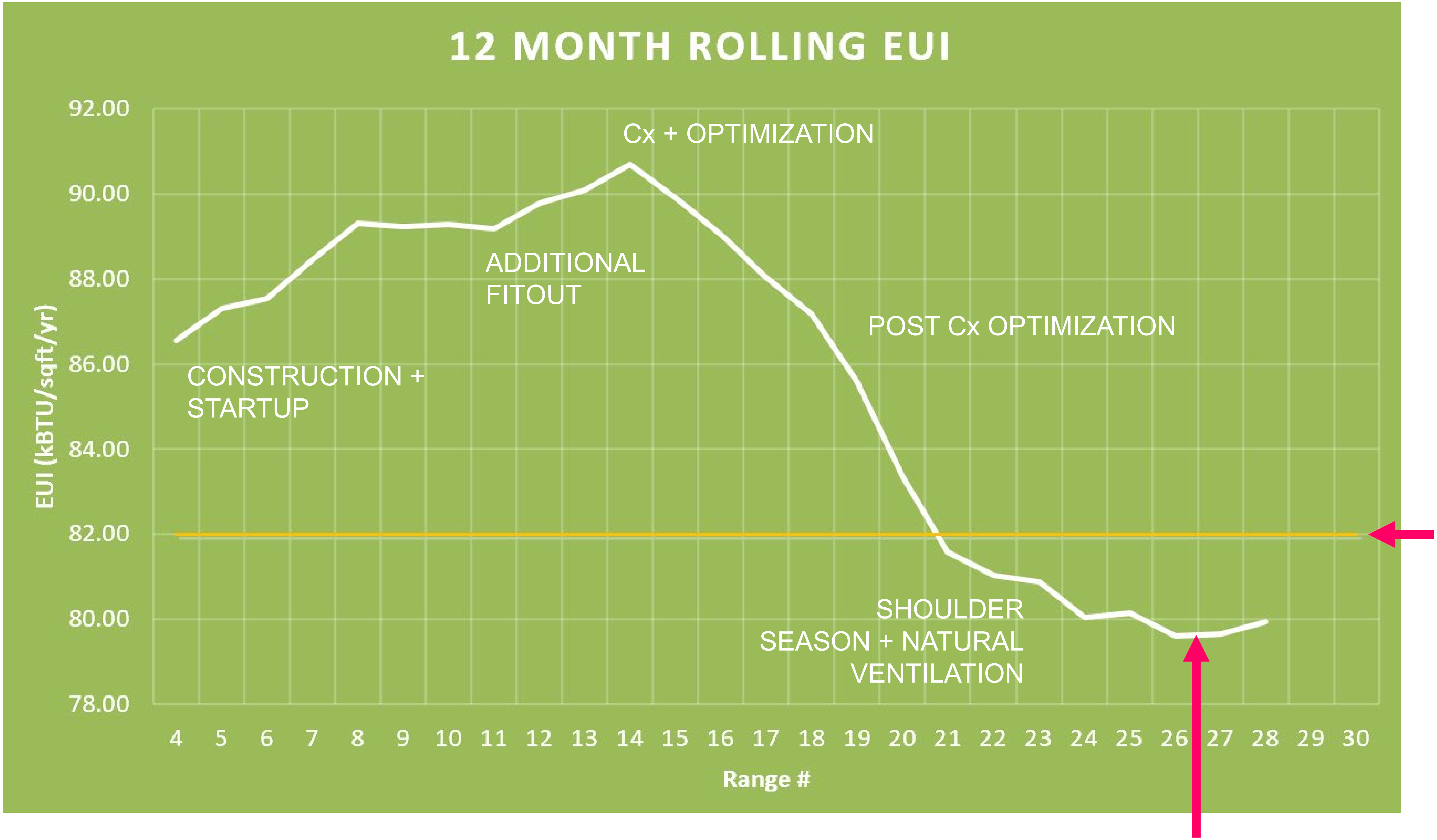


90% Heat Recovery Efficiency

<$200k Per Metric Ton CO^2e Reduction

300 Metric Tons of CO^2e Reduction Yearly


High Efficiency Heat Recovery Systems
Automatic Operable Atrium Windows
Bike Shelters & Multi-Modal Infrastructure
Renewable Energy Production (Rooftop PV)
Passive Flood & Sea Level Rise Protection
Light Well for Below-Grade Spaces
Optimized Solar Shading
Manual Operable Lab and Office Windows
High R-Value Lab Envelope
Daylight Redirection & Shading Wing
Regenerative Pollinator Landscape with Native Plantings
Green Roof Terraces
Stormwater Management, Storage, and Reuse
Protected Bike and Walking Paths connect Allston neighborhood to Greater Boston Parks
Harvard Arboretum Tree Nursery
Public Green



OCTOBER 2023

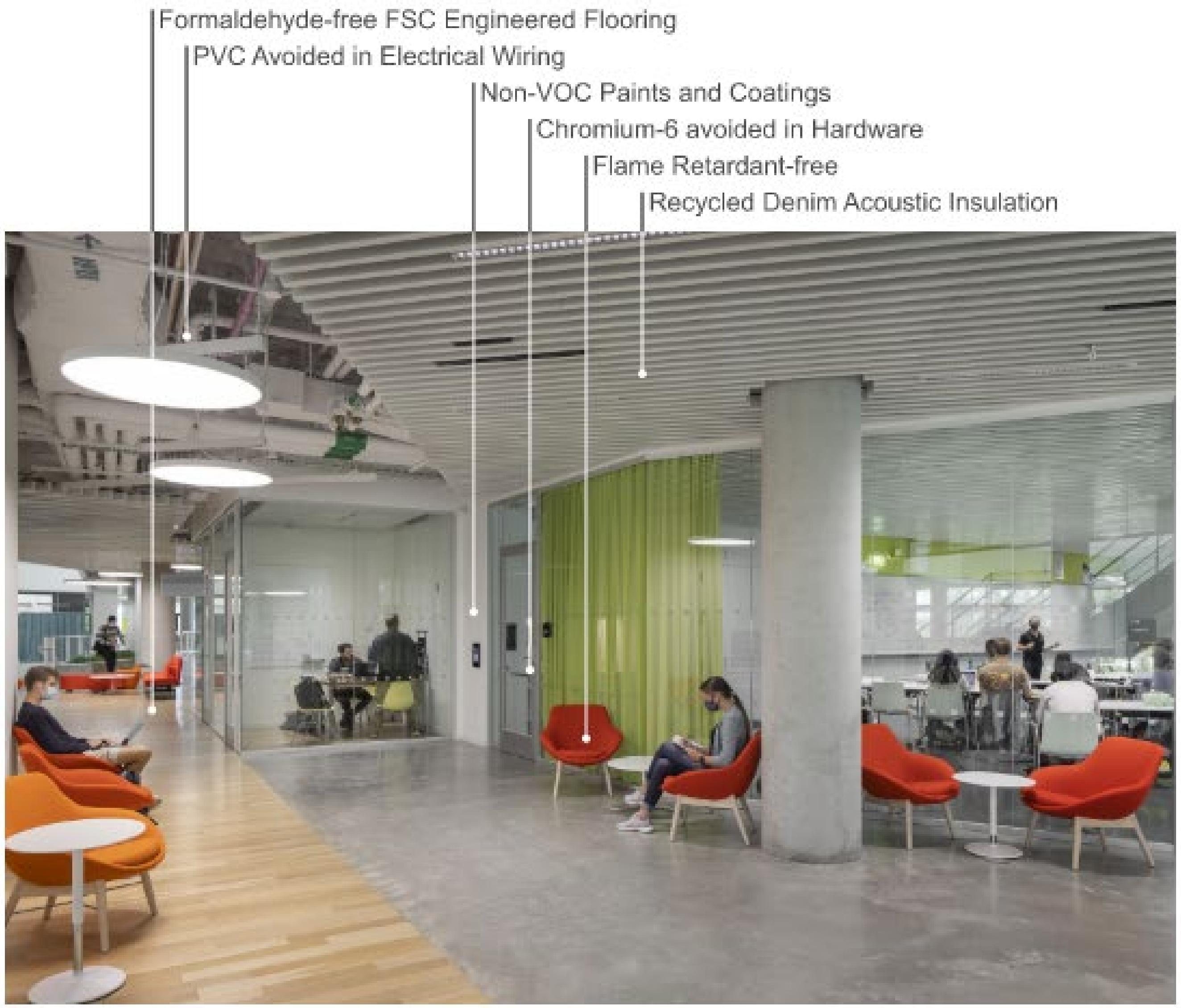
1,700 ILFI Red List & Harvard HBA Compliant Materials

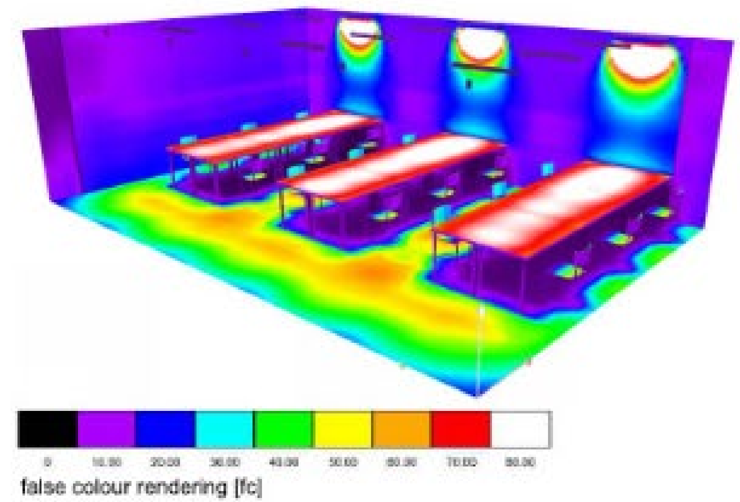
57 EPDs Collected

127 Third Party Certified Materials

1,200+ Companies disclosed product ingredients

6,000+ Materials Evaluated, creating safer global supply chains





Light Level Study


Circadian Lighting Spectrum

Artificial lighting level studies were conducted on all occupied spaces. The building lighting is equipped with circadian lighting and daylight responsive controls.

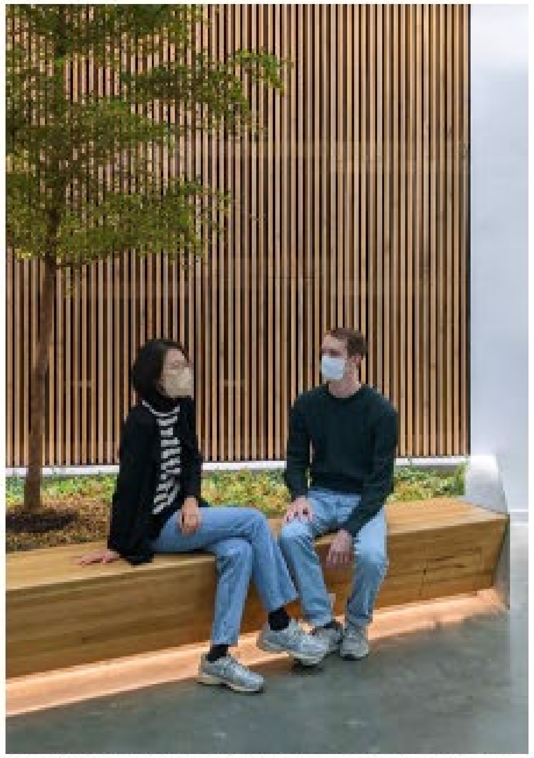
Thermostats were modified to improve user controls and indicate when conditions are ideal to open windows, or when windows should be closed, optimizing thermal efficiency and natural ventilation.


Design team and contractor site visit to observe reclaimed oak raw material and processing

100% FSC Certified Wood

30+ Salvaged Materials Incorporated into Building

93% Construction Waste Diverted from Landfills



Reclaimed Oak Floors, Benches, and Air Intake Diffuser Walls


2023 AIA COTE® Top Ten Award
2023 Vitruvian Award (Façade Tectonics Institute),Outstanding Façade Integration
2022 i2SL Overall Lab Buildings and Projects Award
2022 FSC Leadership Awards Winners Advance Responsible Forest Management
2022 The Chicago Athenaeum, American Architecture Award
2022 The Chicago Athenaeum, Green Good Design Award
2021 ENR (Engineering New Report) Best Project in the Education and Research
2021 AN Best of Design Award, Green Building, winner
2021 Built Environment Plus Award: Green Building of the Year 2021
2021 AIA New England Awards: Honor Award for Design Excellence
g
2021 SEFA Lab of the Year
2021 Prix Versailles, University Campuses, World Special Prize for an Exterior
2021 ABB Leaf Award, Best Façade Design & Engineering Project
2021 WAN Award, category: Education, shortlist
2021 WAN Award, Best Overall Sustainable Project
2018 R+D Awards Honorable Mention: Hydroformed Shading
Thank you!

Energy Conservation Measures

- Reduced ventilation rates in laboratories (4 ach occupied/2 ach occupied vs. 6/4 ach)
- Building orientation with major facades facing north/south
- Above-grade atriums allowing daylight penetration into floorplate
- Below-grade courtyards allowing daylight penetration into floorplate
- Internal program/partitioning (glass partitions) for daylight penetration into floorplate
- Write-up space portioned from laboratories, reducing overall ventilation quantity
- Air cascade: non-lab ventilation provides make-up air to laboratory AHUs
- High-performance runaround heat recovery
- Indirect evaporative cooling (via runaround heat recovery)
- Optimized Fixed exterior shading for solar control

Energy Conservation Measures

- High-performance glazing: reduced SHGC, two low-e coatings for reduced U-value, well-insulated frame
- Natural ventilation in all non-laboratory spaces
- Dedicated outside air ventilation in all spaces, with local heating/cooling
- Radiant cooling/heating in many spaces using low-energy heating/cooling sources
- Reduced duct velocities for reduced fan static pressure
- Increased laboratory exhaust stack height for reduced exhaust velocity
- Wind-responsive laboratory exhaust velocity control
- Demand-controlled ventilation (CO_2) in all densely occupied spaces
- Displacement ventilation in all densely occupied spaces
- Low-flow fume hoods

Energy Conservation Measures

- Relaxed temperature criteria for atrium spaces
- Reduced winter relative humidity
- Exposed thermal mass in lower portions of building (concrete)
- Daylight-responsive lighting controls
- Reduced lighting power density (LED lighting)
- Ceiling fans to allow comfort at higher temperatures
- Green roof (podium)
- Reflective roof (upper roof)
- Premium electric motors
- Reduced exterior light power (LED lighting)
- Temperature setback and optimized warm-up
- Low pressure drop AHUs (including coil bypass)

Energy Conservation Measures

- Refrigeration heat recovery for domestic hot water
- Demand-controlled hot water recirculation
- High-efficiency/harmonic suppression transformers
- High-efficiency controlled environmental rooms
- Machine-room-less elevators
- Atriums encourage use of stairs
- Extensive electrical and thermal submetering