Samsara
संसार

Indian Institute of Technology Bombay

Multi-family Building Division

Team Shunya
Building a sustainable future

U.S. Department of Energy
Solar Decathlon
Design Challenge

Hi! We're Team SHUNYA

Welcome to Samsara

A **multi-faceted retrofit** aimed at enhancing livability in **Slum Rehabilitation Housing (SRH)** in Mumbai, India addressing **health and safety**, while fostering **community empowerment** through **affordability and sustainability.**

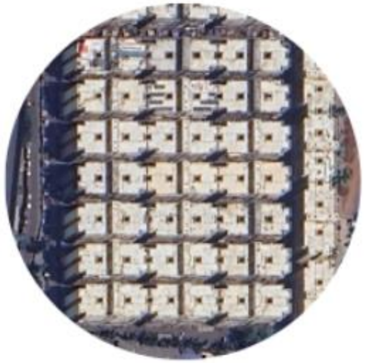
Contests
Introduction
Market
Architecture
Envelope
Grid-Interactivity
Life-Cycle
Health
Engineering
Efficiency
Community

Background

1980's

1990's

2010's



2020's

Cotton Mills pioneered the industrial landscape of Mumbai and India

Several people lost livelihoods due to industrialization and modernization

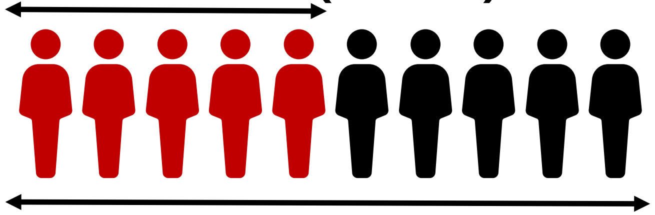
Lack of jobs and high living costs push several people to slums

Slums are redeveloped into Slum Rehabilitation Housing

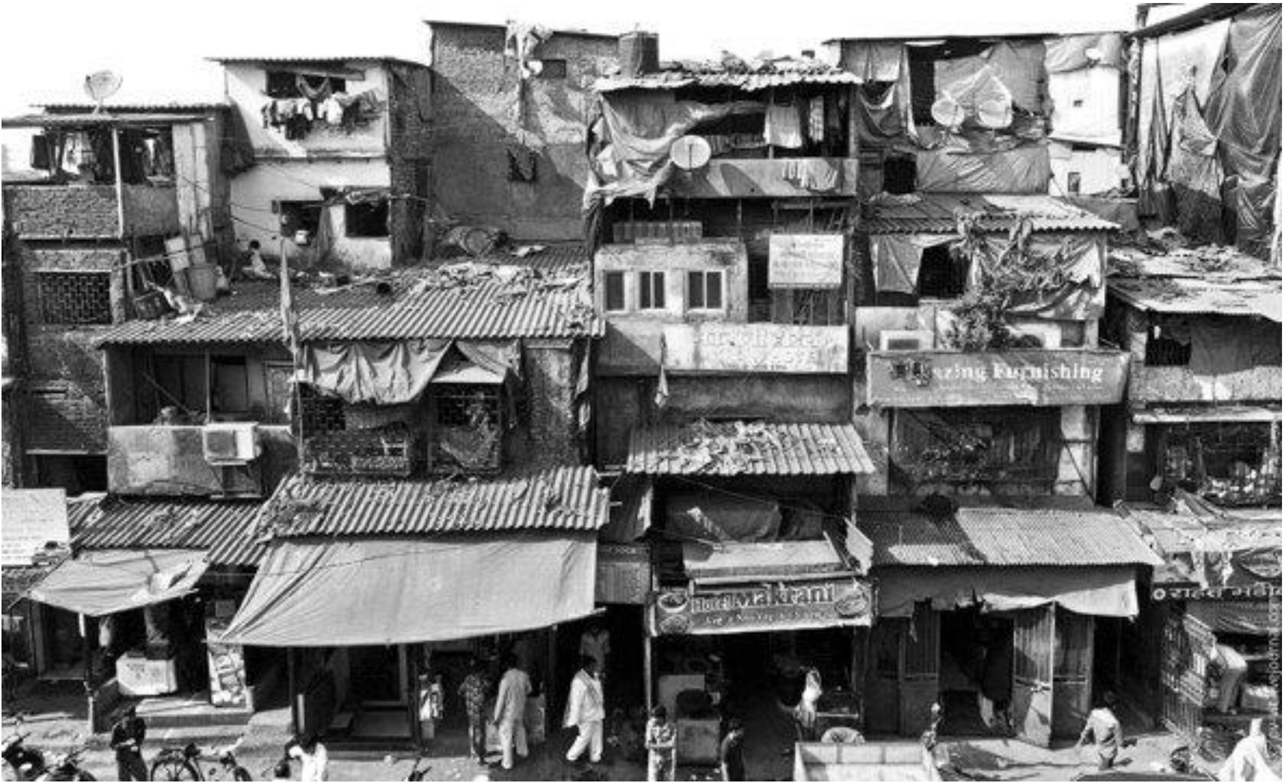
Target Market

Rehabilitated Slum Dwellers in Mumbai, India

10.7 million (52.5 %)



20.5 million (total)



520,645

proposed rehabilitation houses[1]

< $7,200

annual household income [2]

74%

population falls under LIG [3]

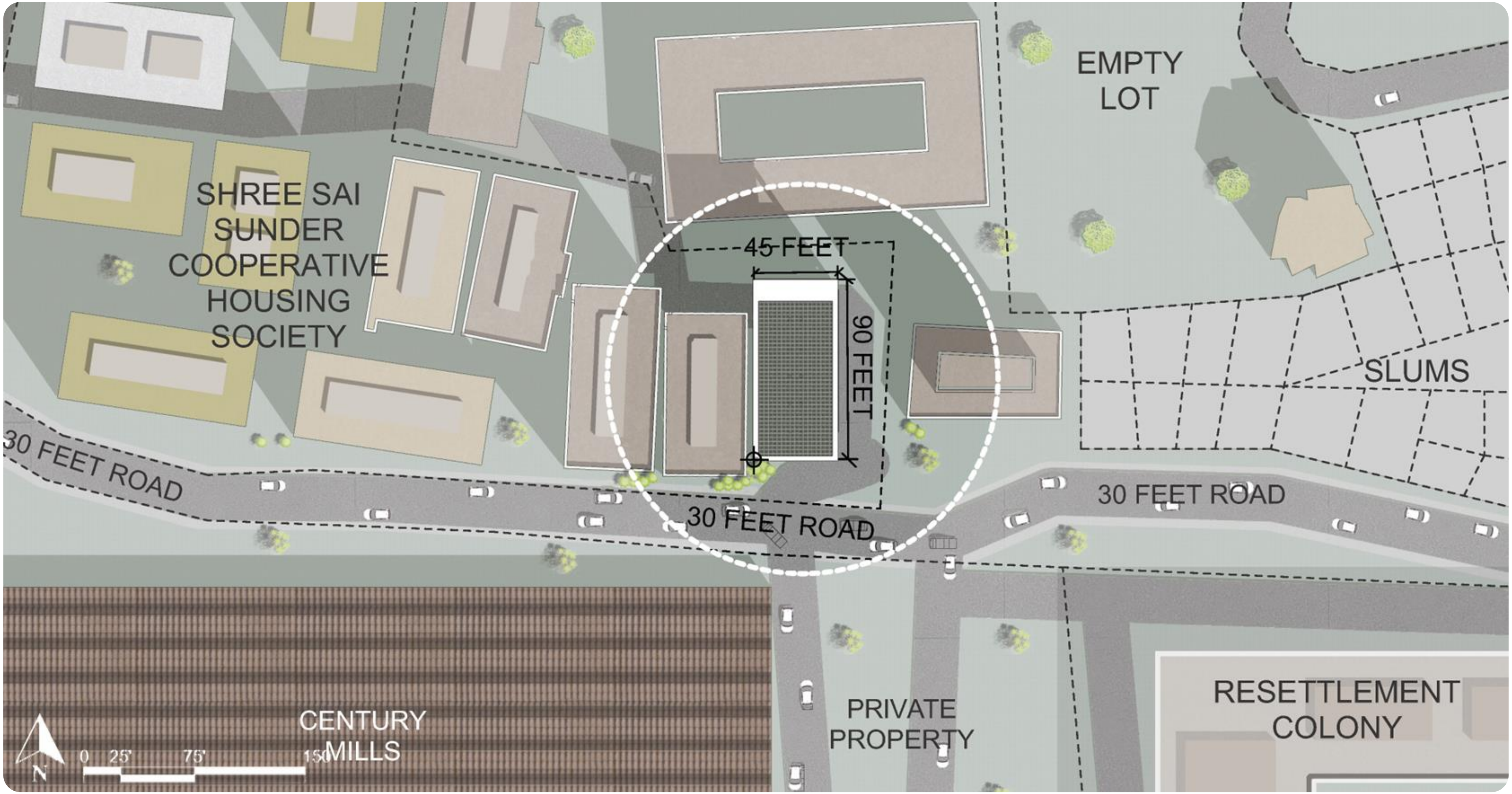
Source: [1] Report of the Technical Urban Group (TG-12) on Urban Housing Shortage 2012-17; Ministry of Housing and Urban Poverty Alleviation, September 2012
[2] https://mumbai.citizenmatters.in/mumbai-sra-slum-rehabilitation-authority-schemes-36432
[3] https://www.researchgate.net/publication/228181985_Working_with_the_Market_A_New_Approach_to_Reducing_Urban_Slums_in_India/figures?lo=1

Context


Commercially Developed Buildings
Slum Rehabilitation Housing (SRH)
Selected Site

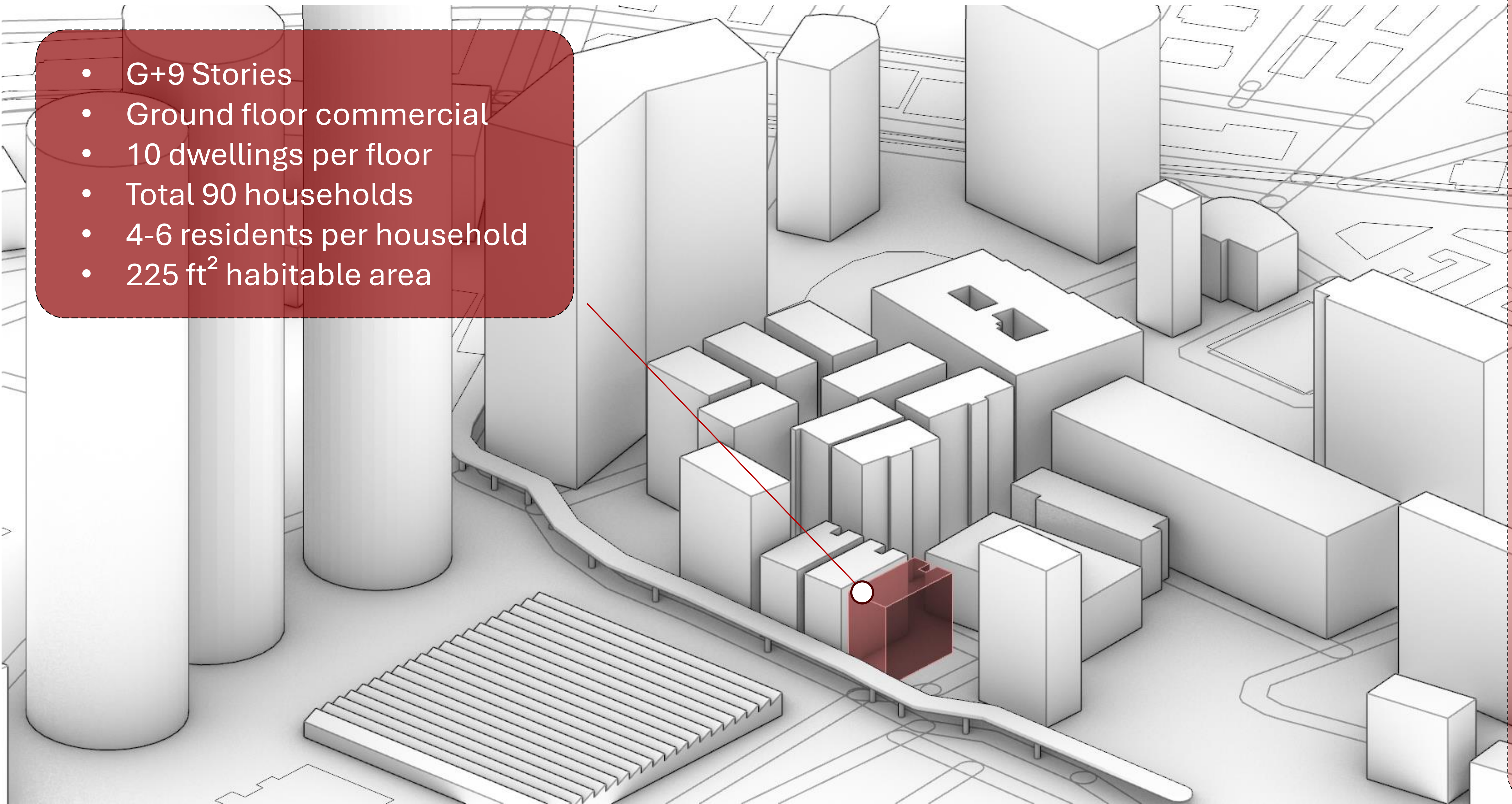
Site Plan

Prabhadevi , Mumbai



Site Context

- G+9 Stories
- Ground floor commercial
- 10 dwellings per floor
- Total 90 households
- 4-6 residents per household
- 225 ft^2 habitable area



Testimonials

Small and congested apartments

"Our family of six can barely move around in this dark room"
- Kamlesh (Software Engineer)

"Sometimes, its more comfortable outside the house than inside"
- Altaf (Taxi Driver)

Passive Performance

Ventilation

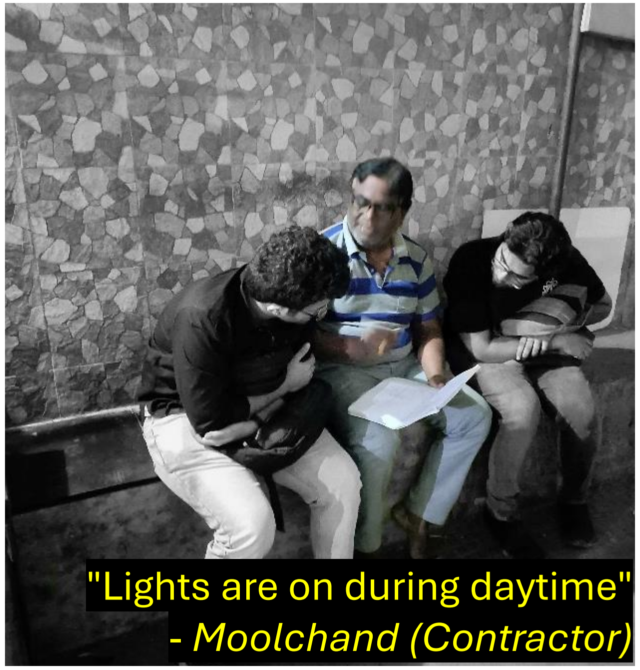
Daylight

Thermal Comfort

Lack of community and green spaces

"We women have no space for social interaction"
- Sarita (Homemaker)

"Kids don't have any spaces for playing and outdoor activities"
- Mahesh (Local Community Leader)



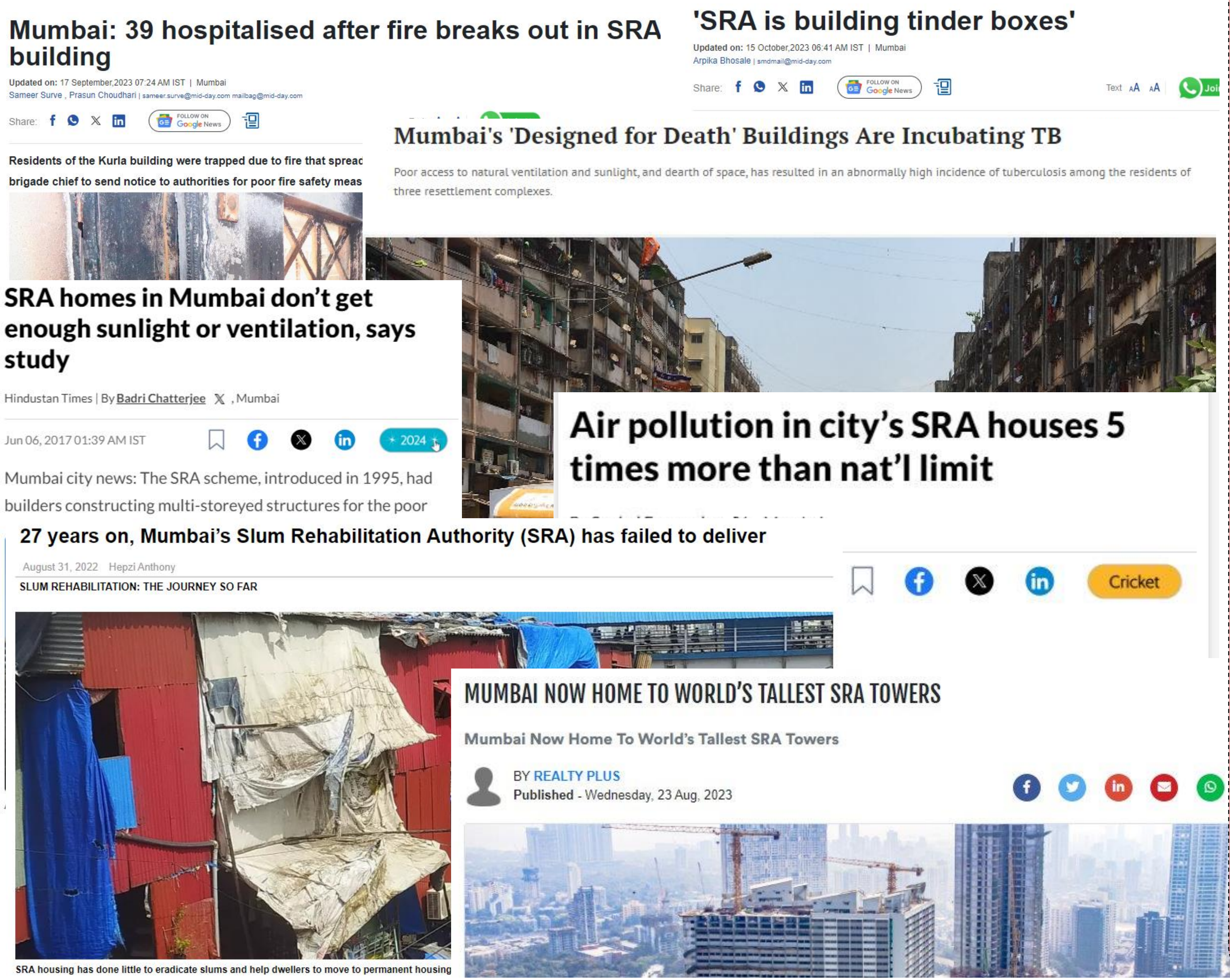
"Lights are on during daytime"
- Moolchand (Contractor)

Health & Safety Stressors

Respiratory Health
- Pollutants
- Foul Smells

Mental Health
- Open spaces
- Sky view factor

Visual Health
- Eye Strain
- Productivity



Mumbai: 39 hospitalised after fire breaks out in SRA building

Updated on: 17 September,2023 07:24 AM IST | Mumbai
Sameer Surve , Prasun Choudhari

Residents of the Kurla building were trapped due to fire that spreac
brigade chief to send notice to authorities for poor fire safety meas

'SRA is building tinder boxes'

Updated on: 15 October,2023 06:41 AM IST | Mumbai
Arpika Bhosale

Mumbai's 'Designed for Death' Buildings Are Incubating TB

Poor access to natural ventilation and sunlight, and dearth of space, has resulted in an abnormally high incidence of tuberculosis among the residents of three resettlement complexes.

SRA homes in Mumbai don't get enough sunlight or ventilation, says study

Hindustan Times | By Badri Chatterjee , Mumbai

Jun 06, 2017 01:39 AM IST

Mumbai city news: The SRA scheme, introduced in 1995, had builders constructing multi-storeyed structures for the poor

Air pollution in city's SRA houses 5 times more than nat'l limit

27 years on, Mumbai's Slum Rehabilitation Authority (SRA) has failed to deliver

August 31, 2022 Hepzi Anthony

SLUM REHABILITATION: THE JOURNEY SO FAR

SRA housing has done little to eradicate slums and help dwellers to move to permanent housing

MUMBAI NOW HOME TO WORLD'S TALLEST SRA TOWERS

Mumbai Now Home To World's Tallest SRA Towers

BY REALTY PLUS
Published - Wednesday, 23 Aug, 2023

Design Goals

Improve the quality of life by supporting healthy, safe, and comfortable habitats, while promoting public spaces that empower and build resilience within all members of the community

Health & Safety

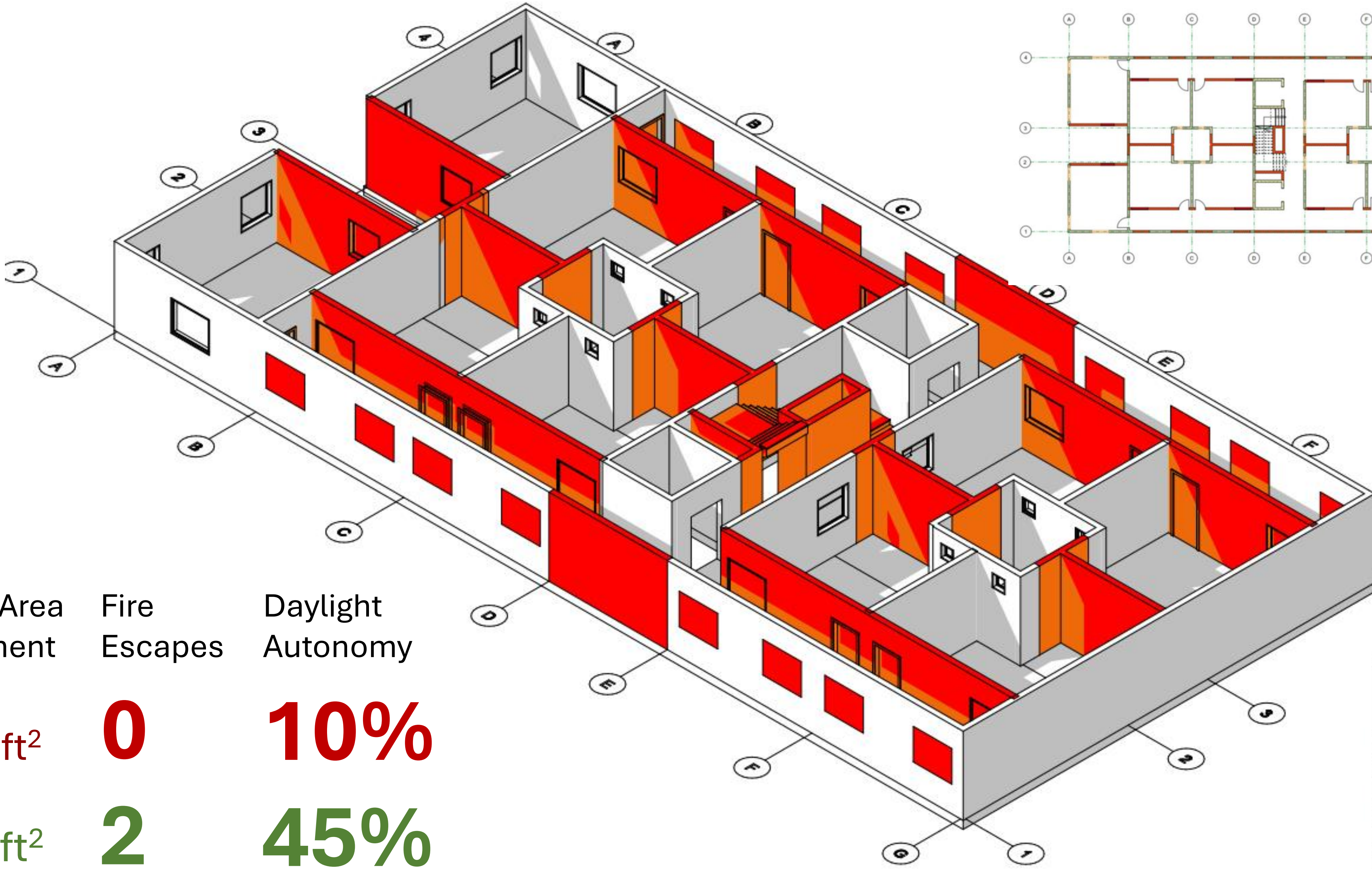
Sustainability

Empowerment

Design Goals

Health & Safety	Sustainability	Empowerment
Daylight Autonomy	Energy Efficiency	Feasibility & Affordability
Air Changes per Hour	Access to Clean Water	Inclusive Public Spaces
Fire Safety	Economic Resilience	Universal Accessibility

Spatial Reconfiguration



Habitable Area per apartment	Fire Escapes	Daylight Autonomy
225 ft^2	0	10%
360 ft^2	2	45%

Axial Force - Earthquake Load (IS 1893-2016)

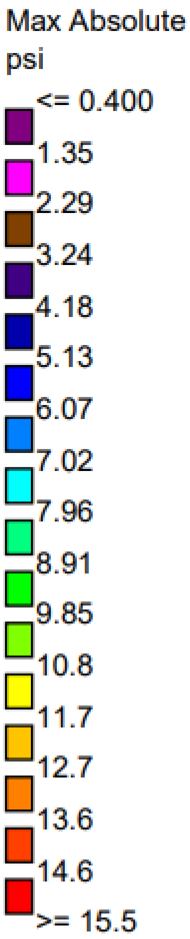
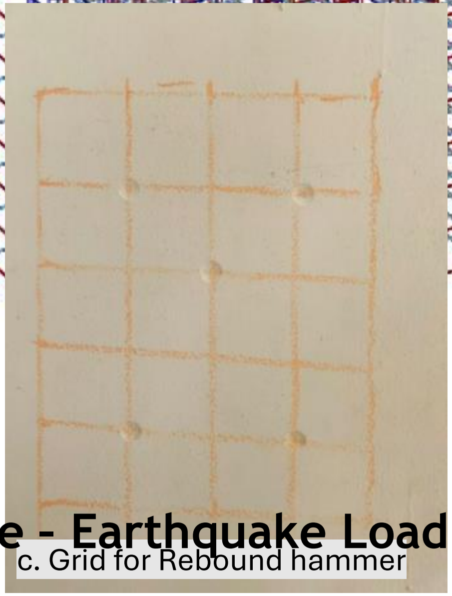


Plate Stress - Wind & Live Loads (IS 875-3:2015)

a. UPV on slab

b. Carbonation depth



c. Grid for Rebound hammer

d. Rebound hammer on column

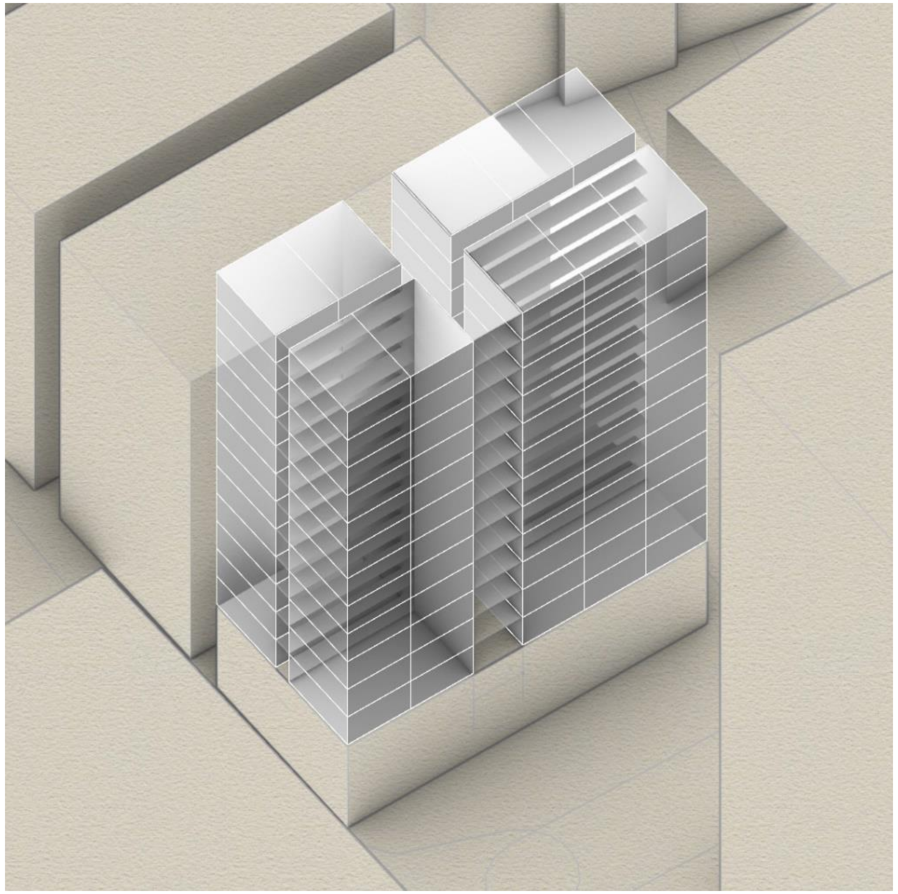
e. Visual inspection – Debounding of plaster

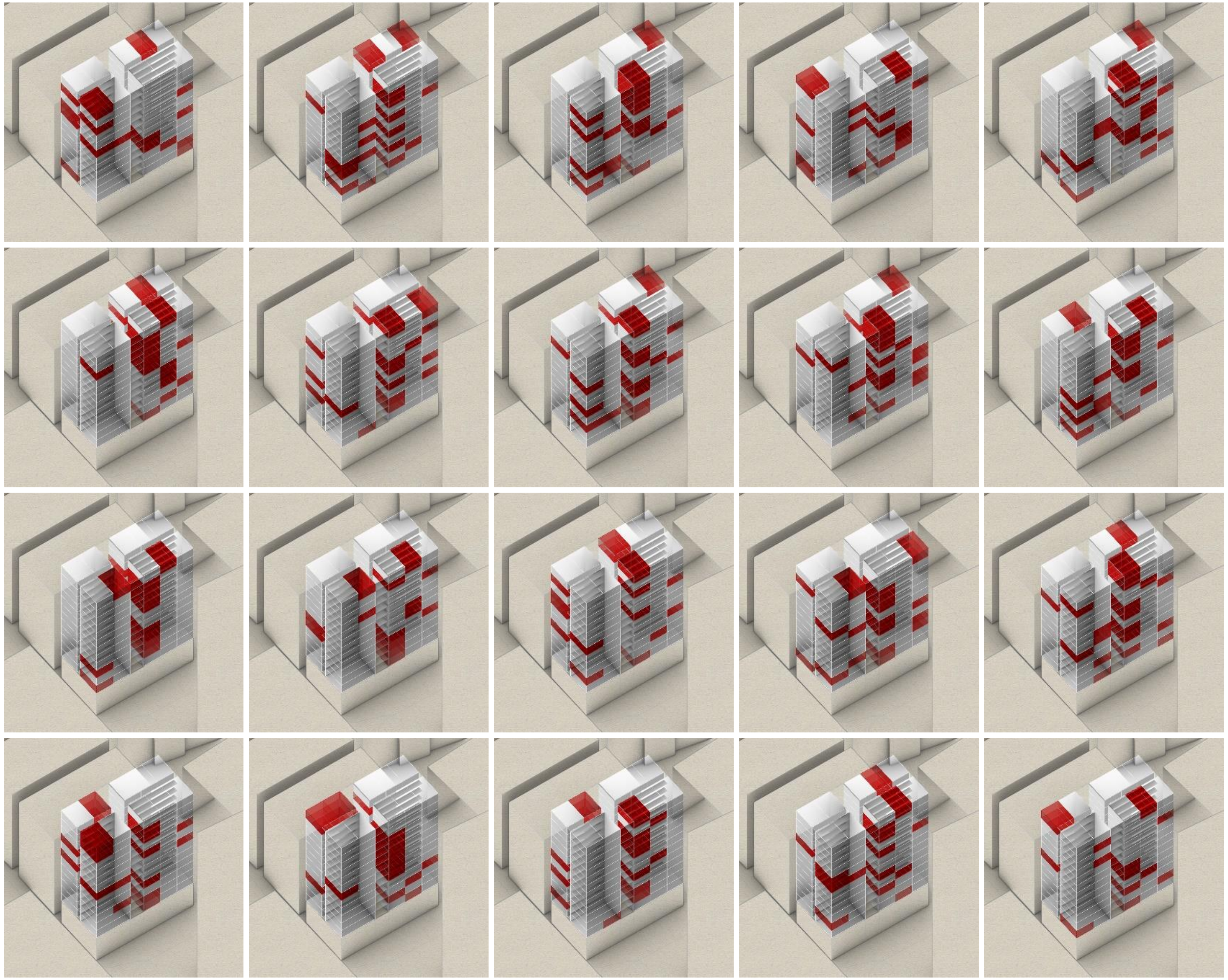
Void Strategy

Structural Limitations

Worst 20%

Iterations **Removed**





Void Strategy

Structural Limitations

Worst 20%

Iterations **Removed**

Natural Ventilation

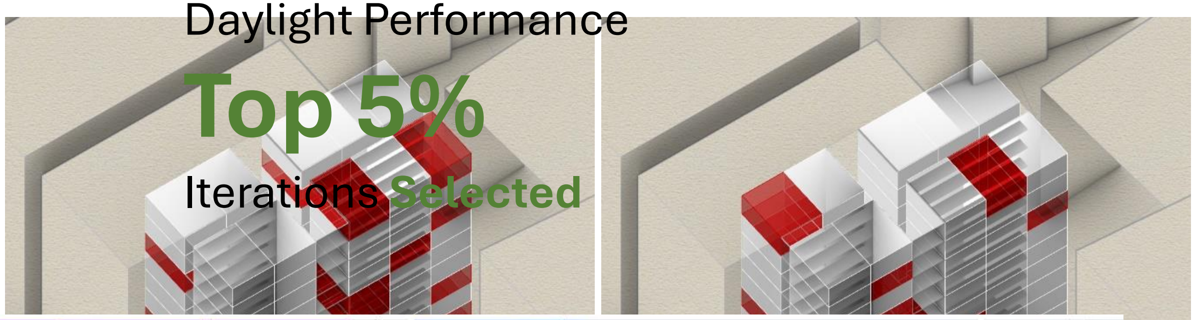
Best 20%

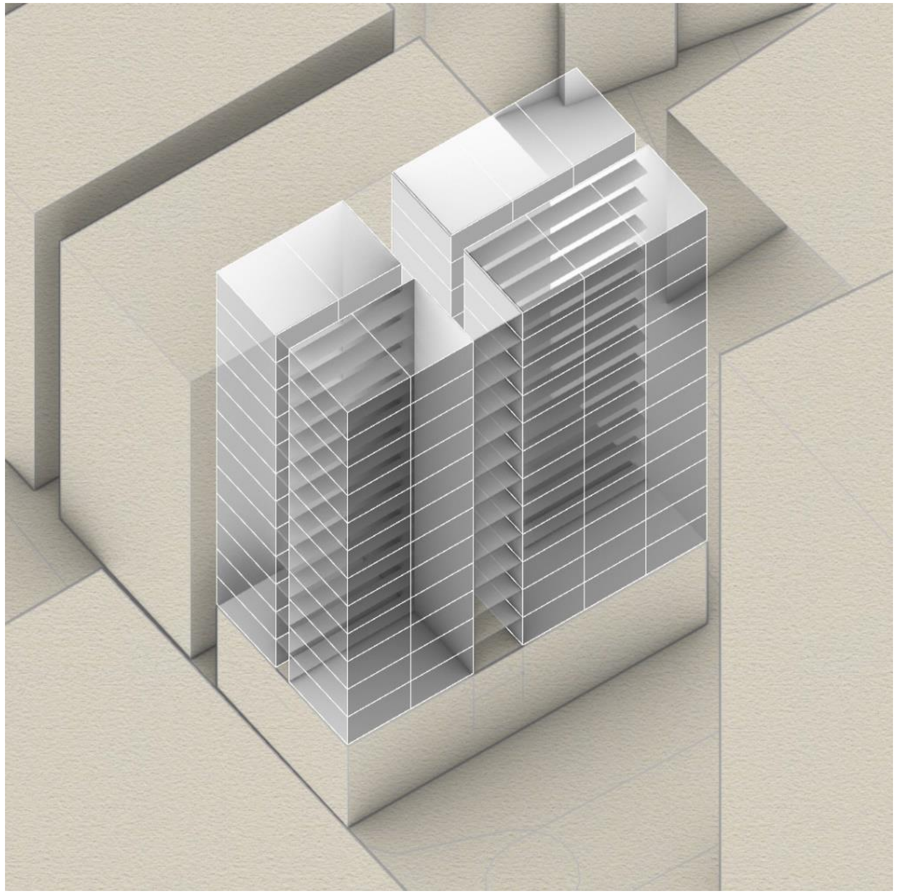
Iterations **Selected**

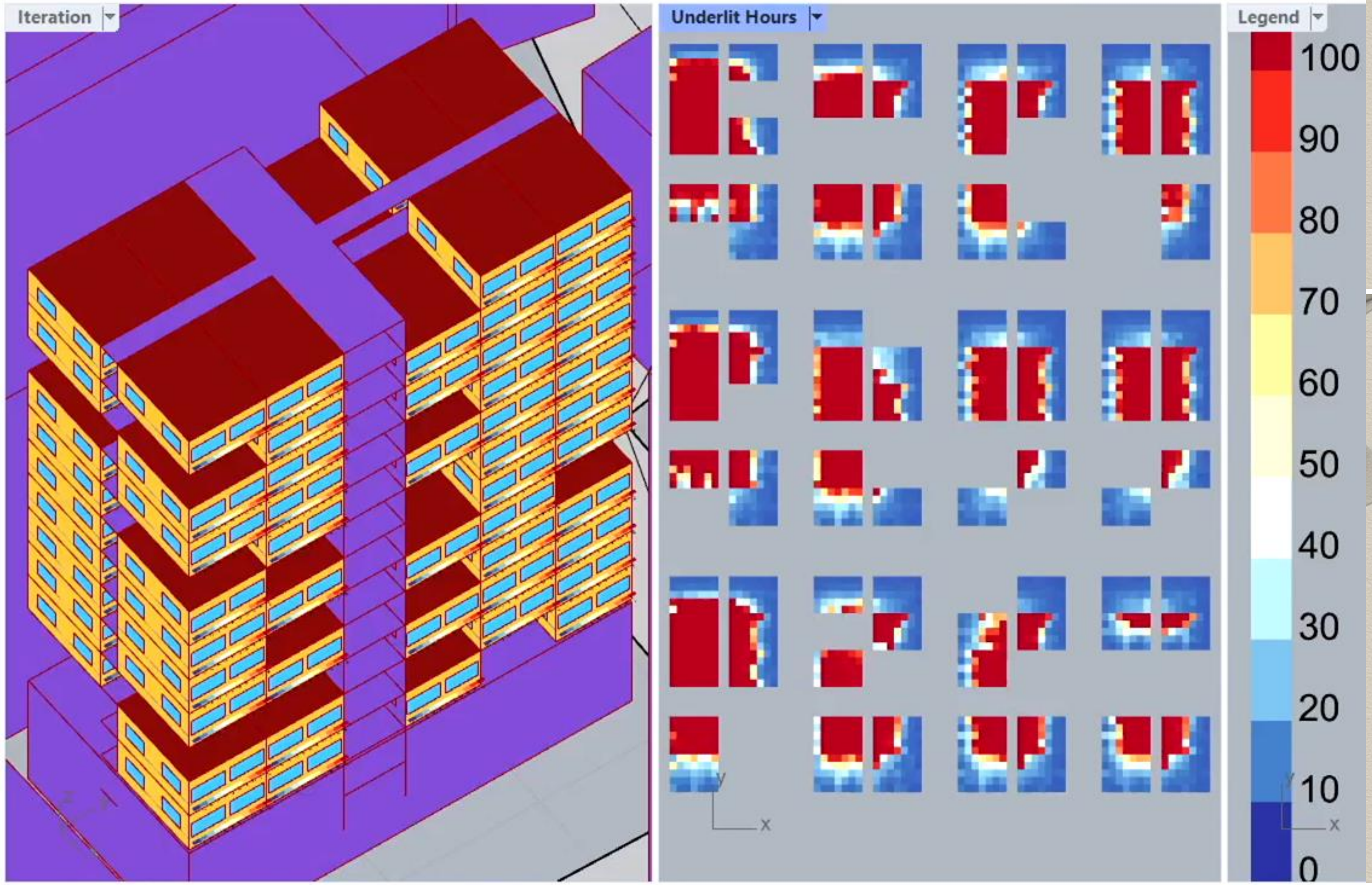
Daylight Performance

Top 5%

Iterations **Selected**







Void Strategy

Structural Limitations

Worst 20%

Iterations **Removed**

Natural Ventilation

Best 20%

Iterations **Selected**

Daylight Performance

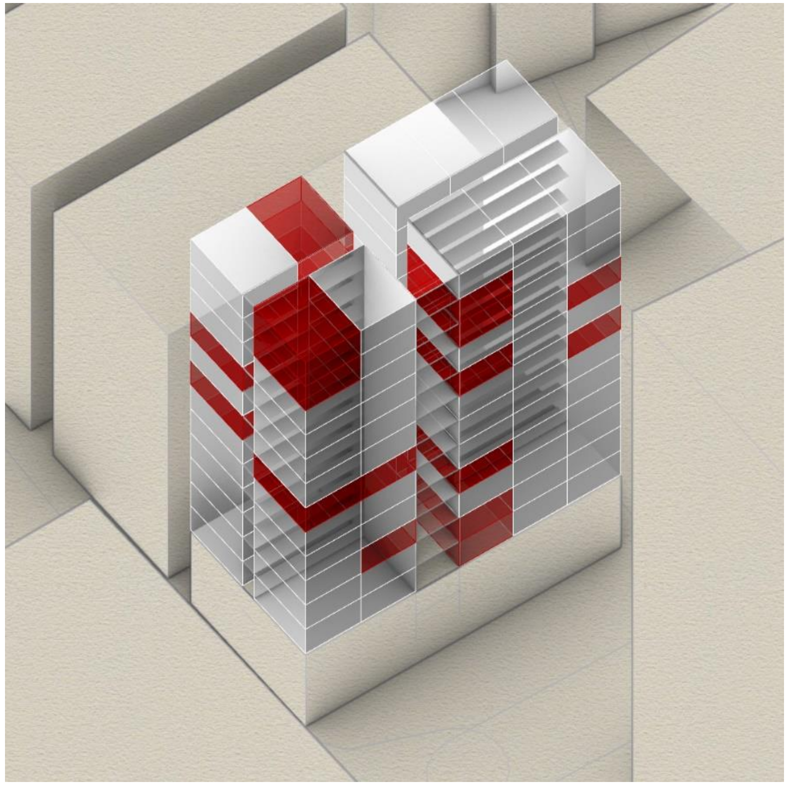
Top 5%

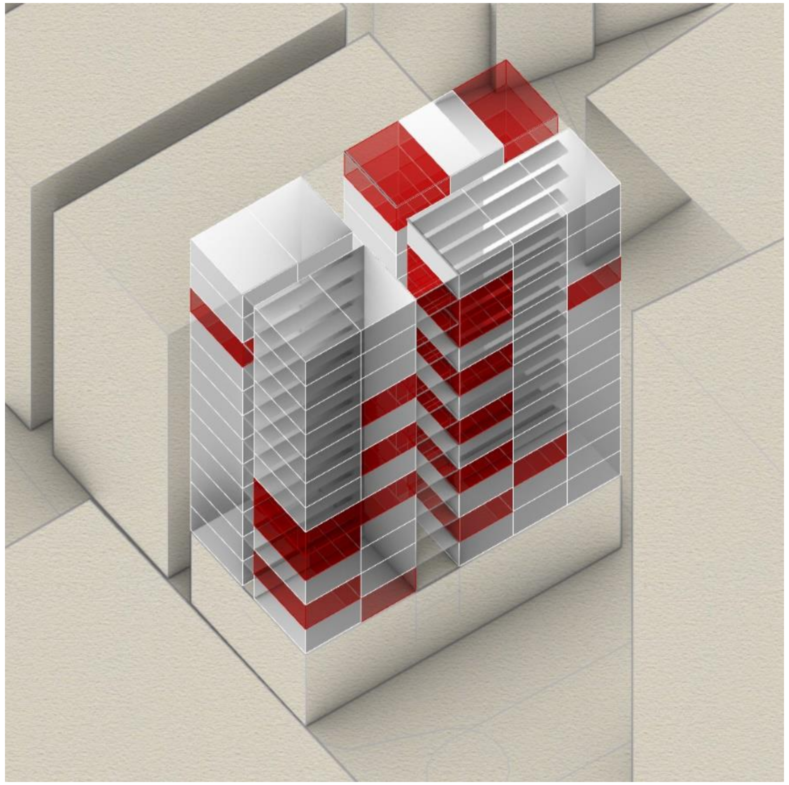
Iterations **Selected**

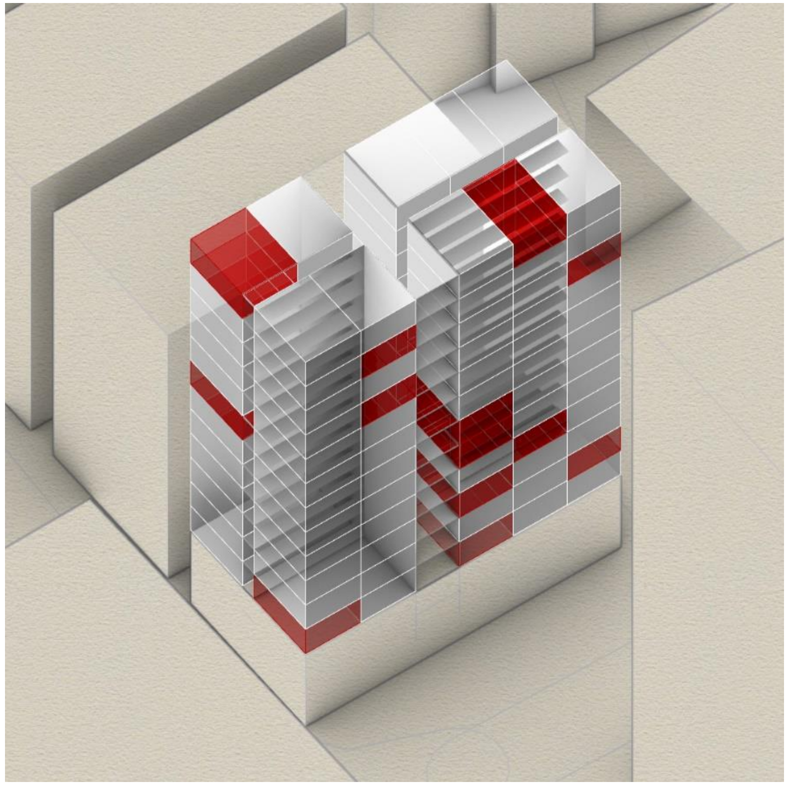
Energy Demand

Best 3

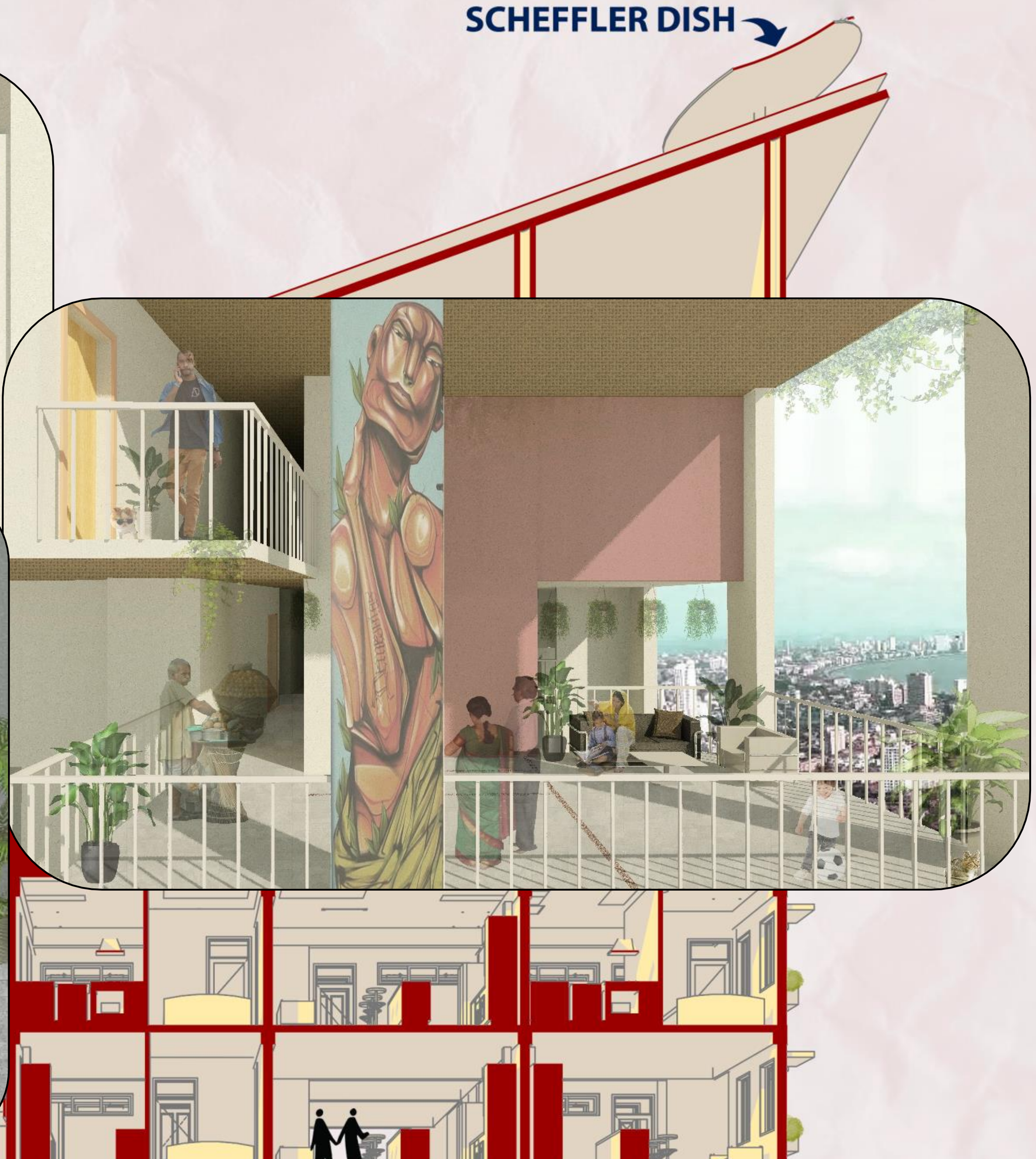
Iterations **Analyzed**







Community Spaces



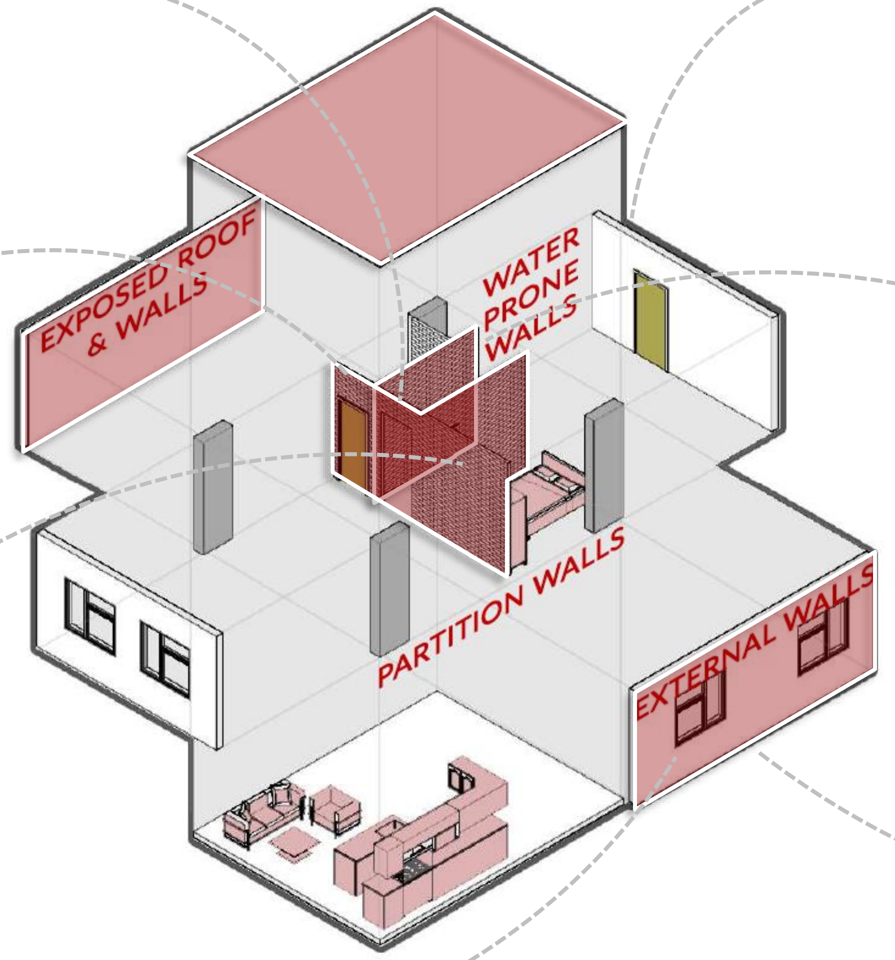
R-Values

Wall
2.22
(K-m²)/W

Roof
2.5
(K-m²)/W

Window
0.38
(K-m²)/W

Foundation
4.5
(K-m²)/W



Climatic zone

0A

(tropical warm-humid)

Cooling setpoint

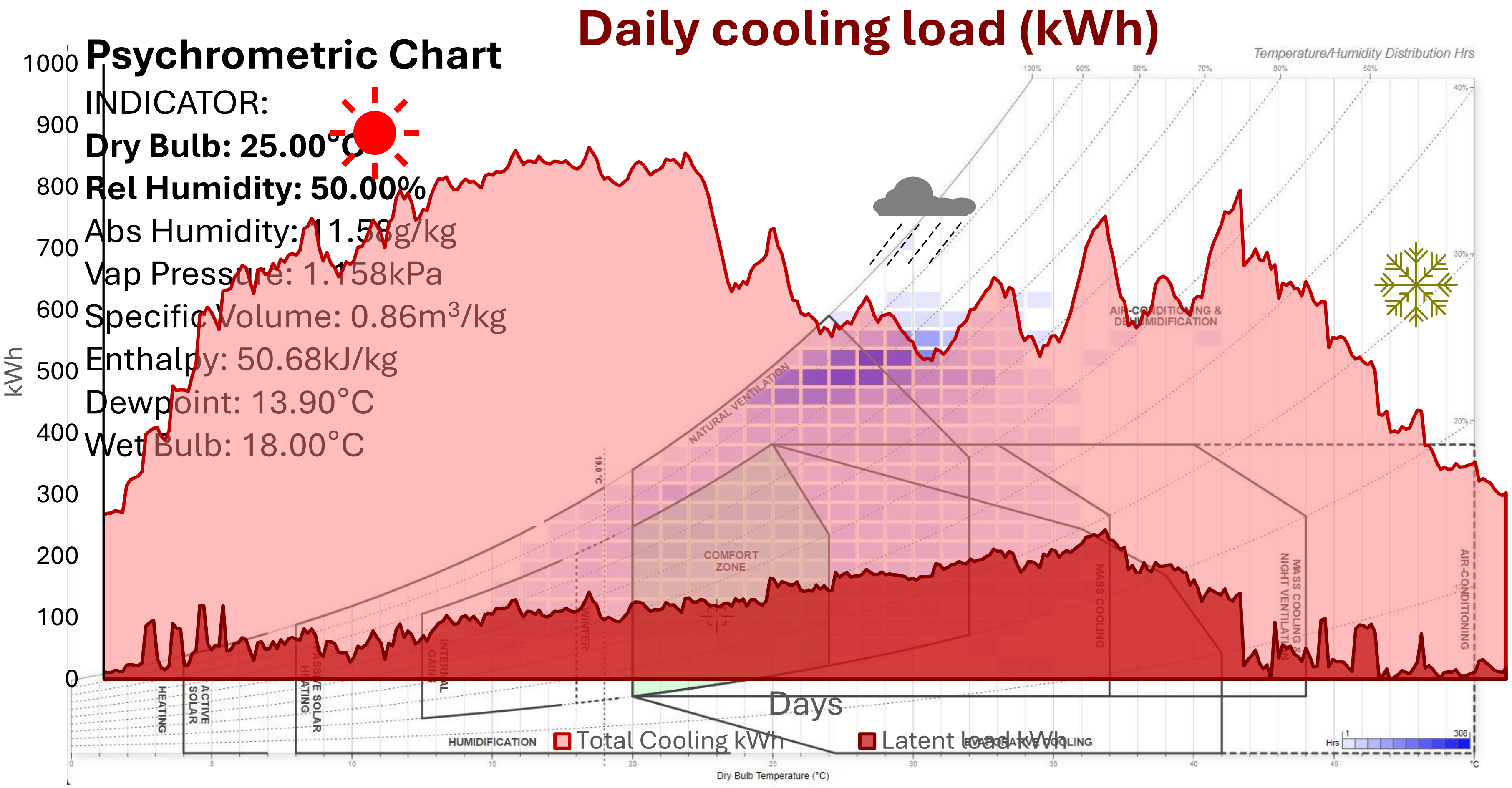
25°C

Relative humidity

50%

Cooling degree days

1611

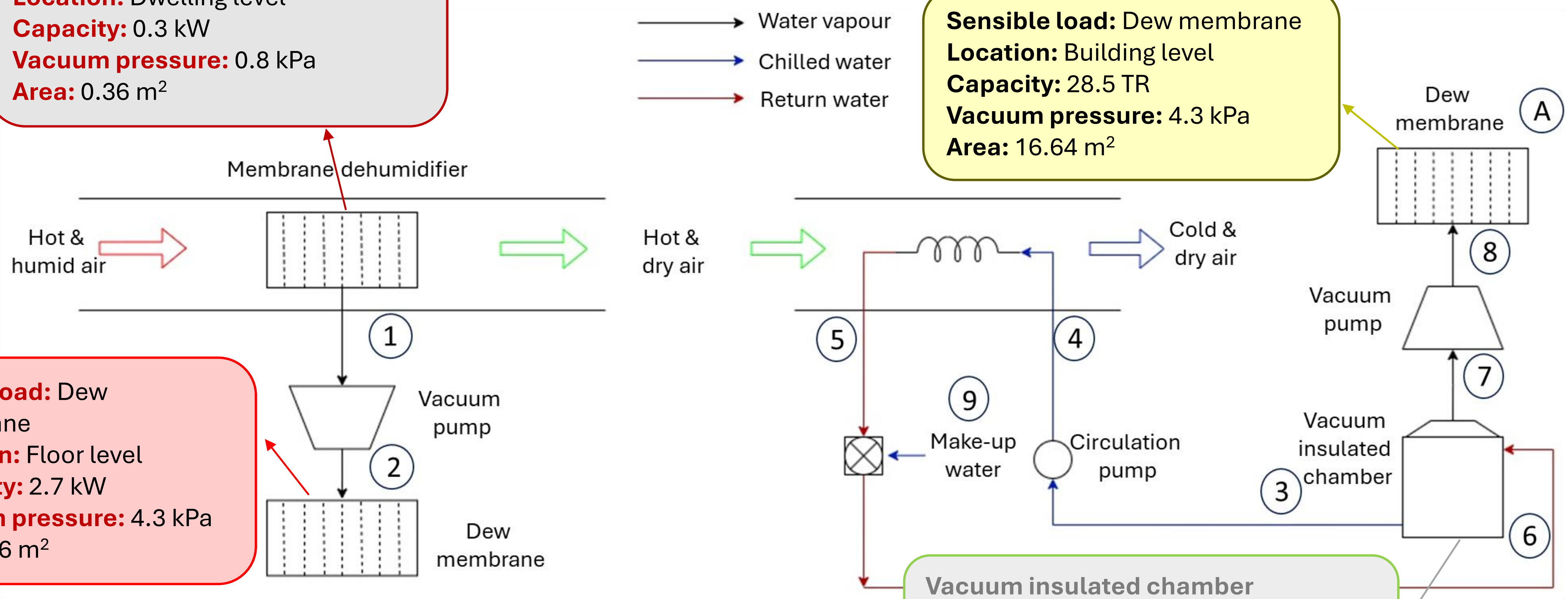


HVAC Details

Latent load: Membrane dehumidifier
Location: Dwelling level
Capacity: 0.3 kW
Vacuum pressure: 0.8 kPa
Area: 0.36 m^2

Sensible load: Dew membrane
Location: Building level
Capacity: 28.5 TR
Vacuum pressure: 4.3 kPa
Area: 16.64 m^2

Latent load: Dew Membrane
Location: Floor level
Capacity: 2.7 kW
Vacuum pressure: 4.3 kPa
Area: 0.6 m^2



Membrane Dehumidification Module

Vacuum insulated chamber
Capacity: 26.6 TR
Chilled water inlet temperature: 25 ℃
Water outlet temperature: 13 ℃

Energy Savings

7.4 > 3.8

High COP

60-85%

Annual Energy Savings

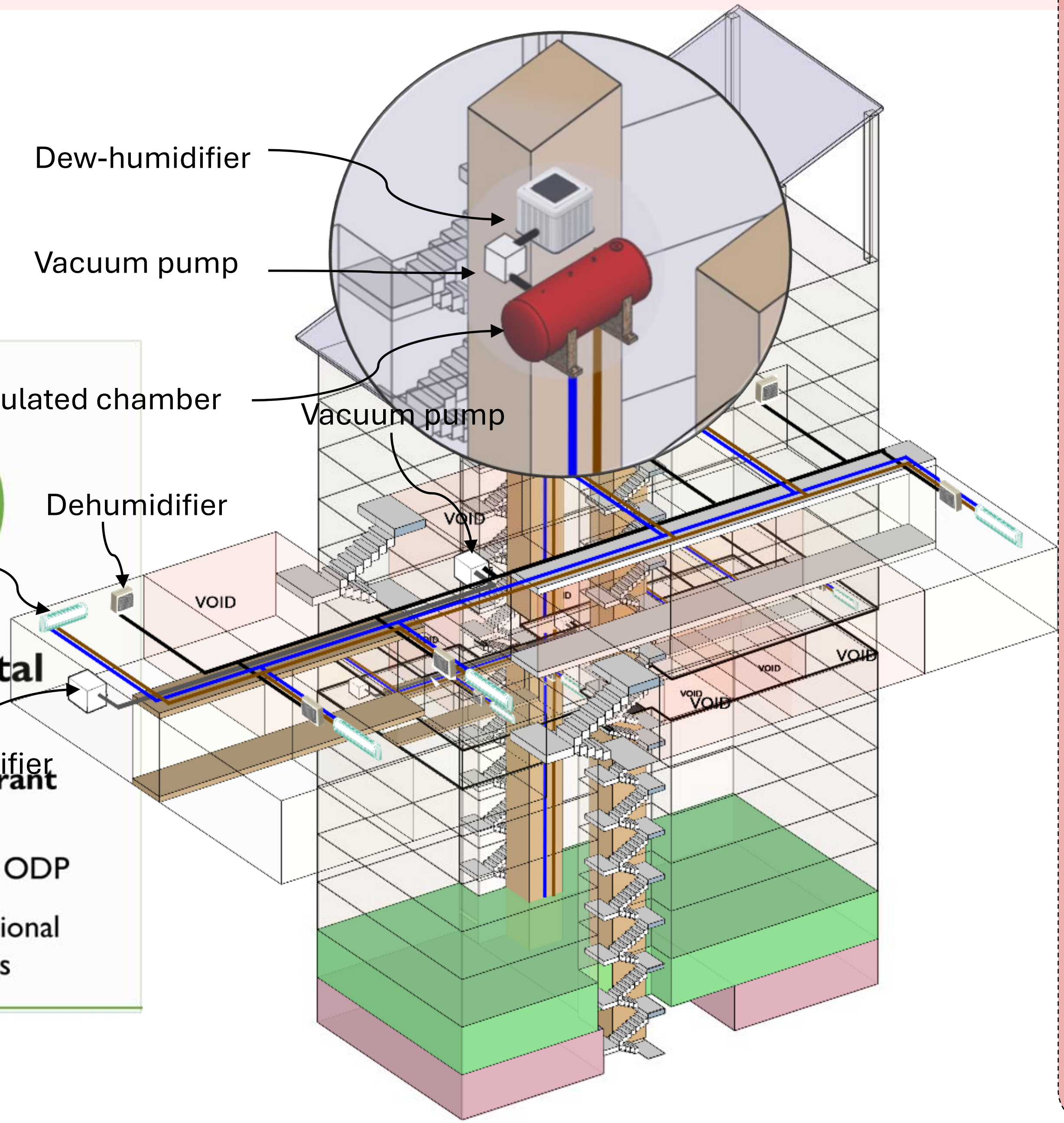
Environmental Impact

Water as Refrigerant

Non-Toxic

Zero GWP & low ODP

43.5% lower operational carbon emissions



Water vapour line

Chilled water supply line

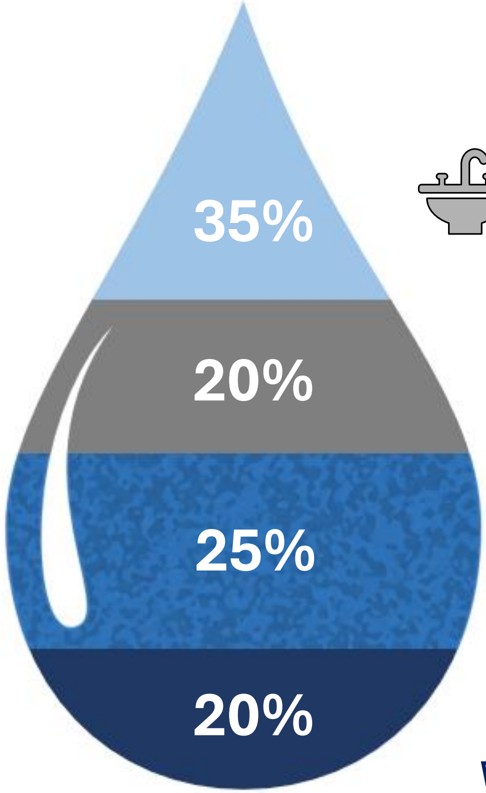
Chilled water return line

Net Zero Water

Daily water demand
60,000
liters per day

Grey Water (70-80%)
35,000
liters per day

Treated Water (50-60%)
15,000
liters per day



Water Efficient Fixture
UIPC 3☆ Rated

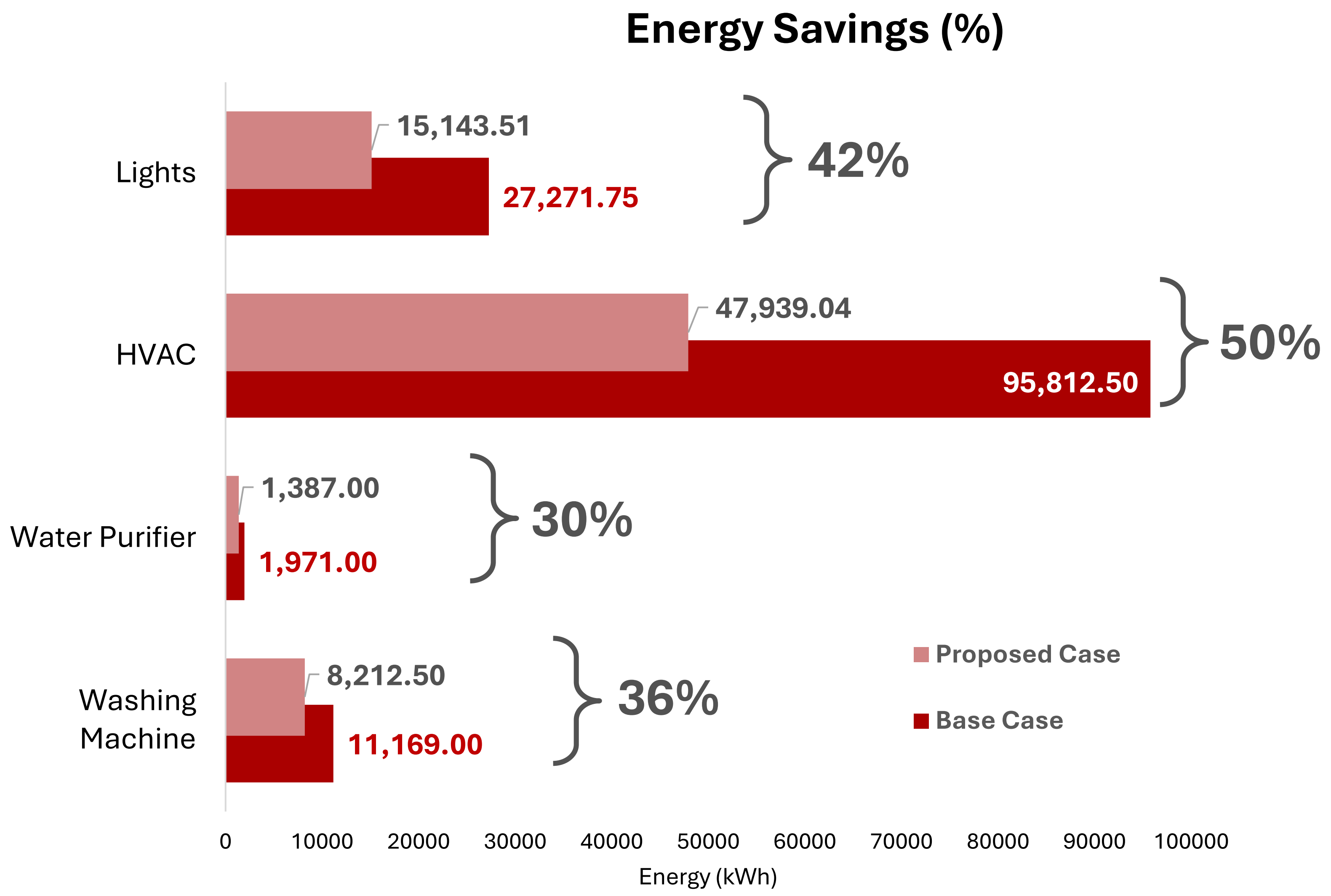
Grey Water Recycling

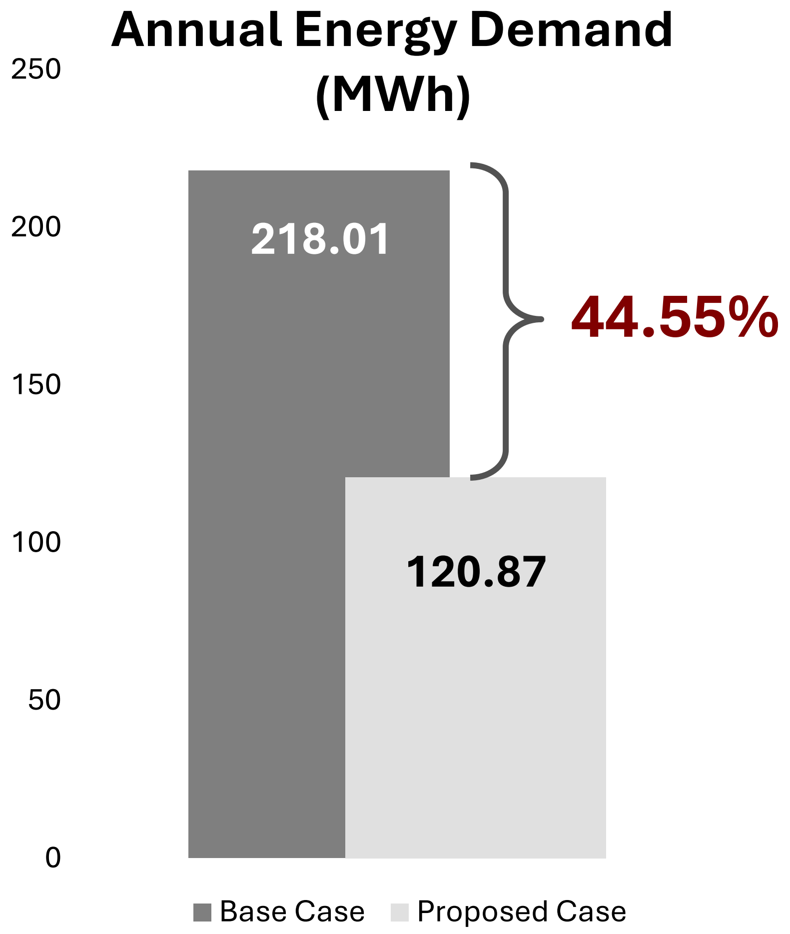
Rain Water Harvesting

Required Freshwater

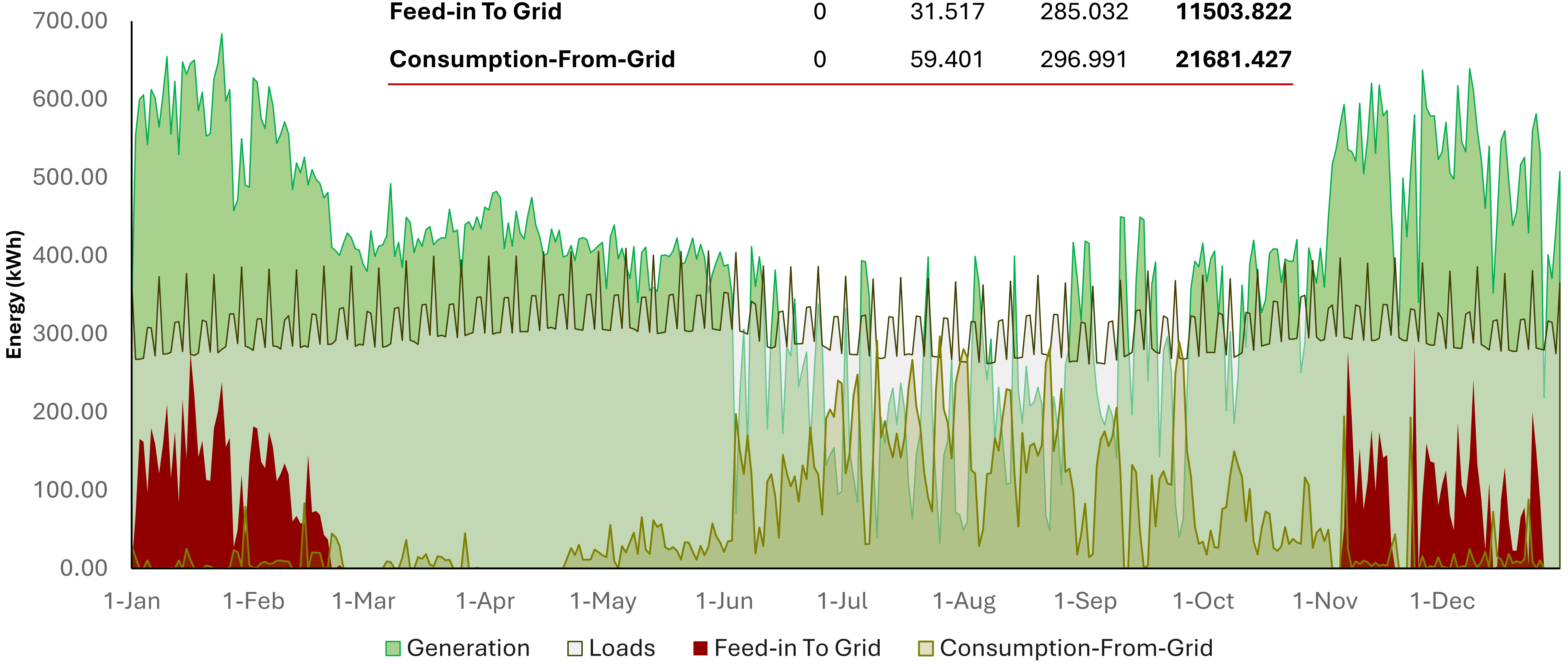
202 ton CO_2e
Emissions Avoided

Energy Demand Reduction

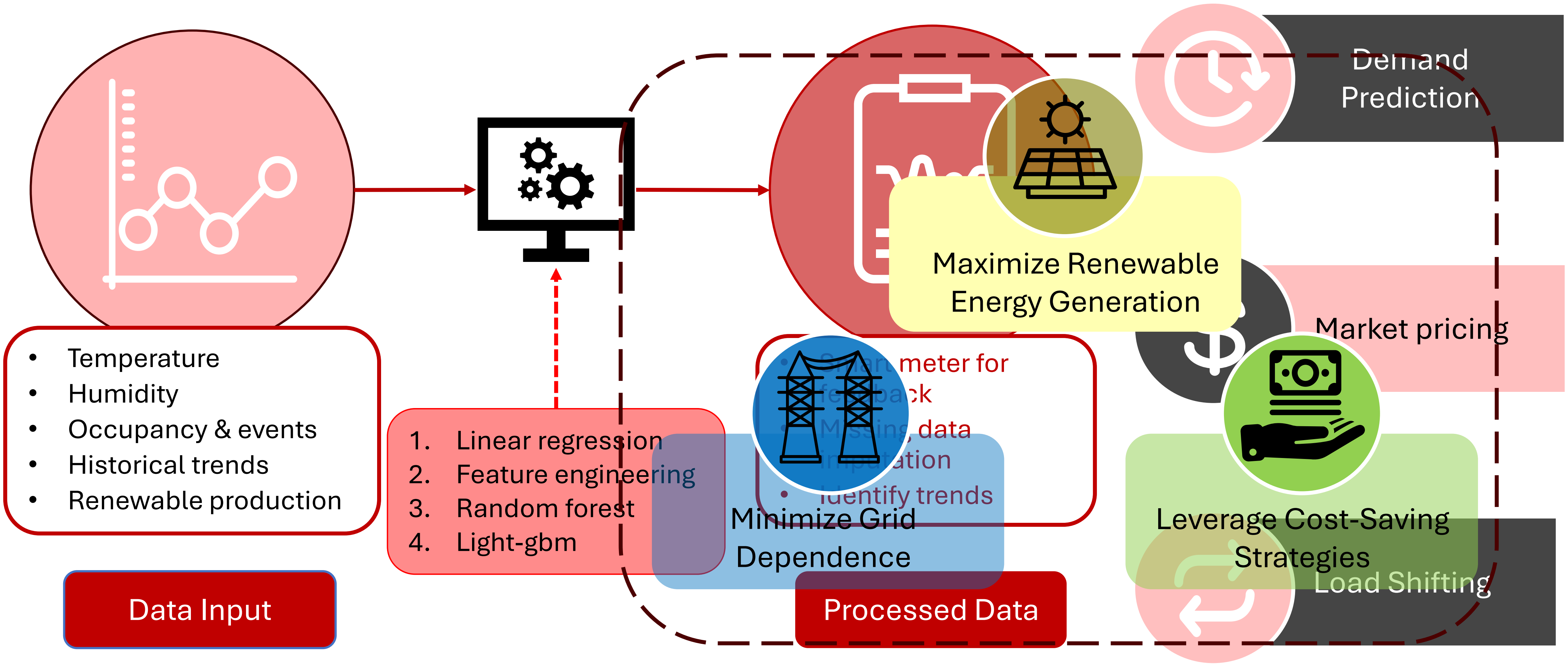




	Min	Average	Max	Total
Loads	261.44	312.14	409.28	**120,866.19**
Generation	32.54	387.50	684.00	**141,439.90**
Feed-in To Grid	0	31.517	285.032	**11503.822**
Consumption-From-Grid	0	59.401	296.991	**21681.427**



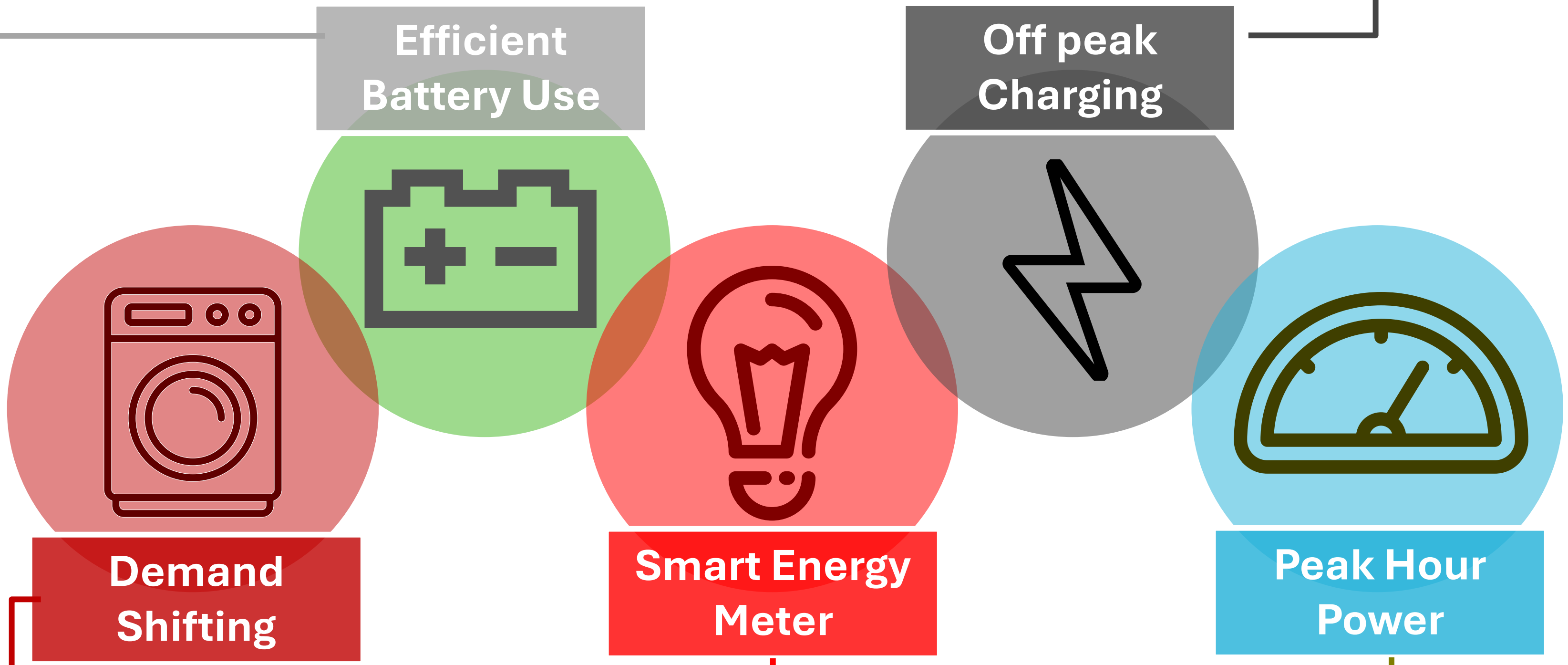
Smart Demand Management



Reducing Grid Dependency

Smart demand management system to minimize cost by effective battery use

Off-peak hours to charge battery for least cost



Shifting the manageable loads to off-peak hours

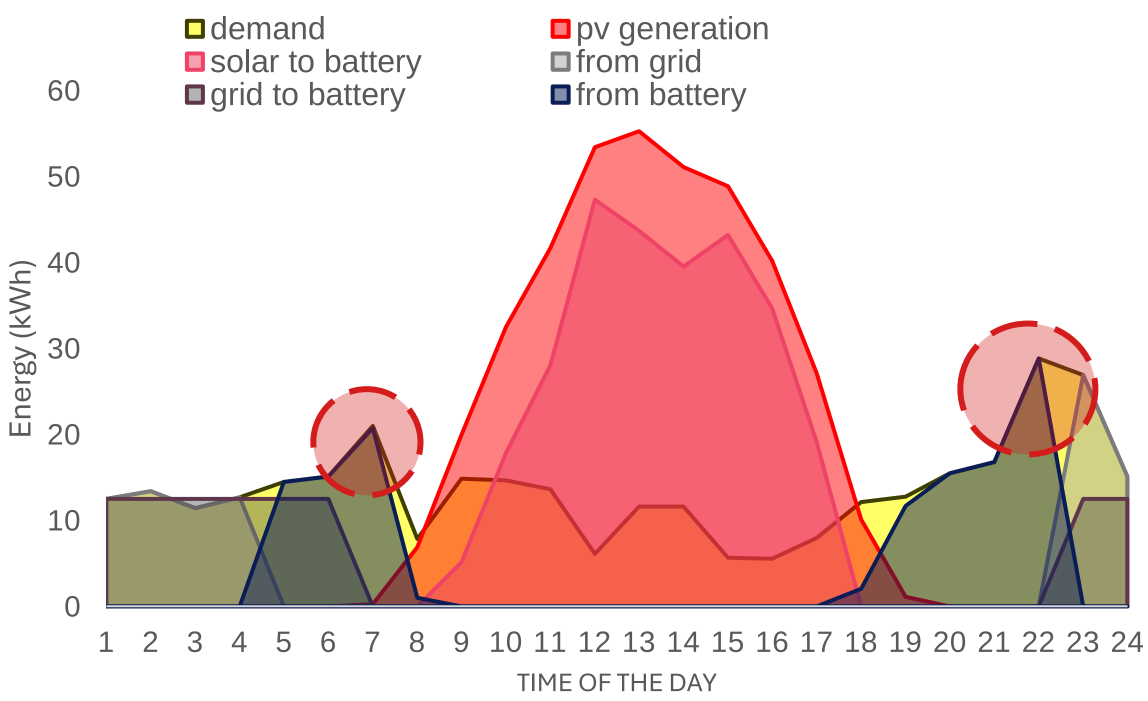
Can be used for real time energy pricing

Reducing dependency on the grid by leveraging PV and battery power

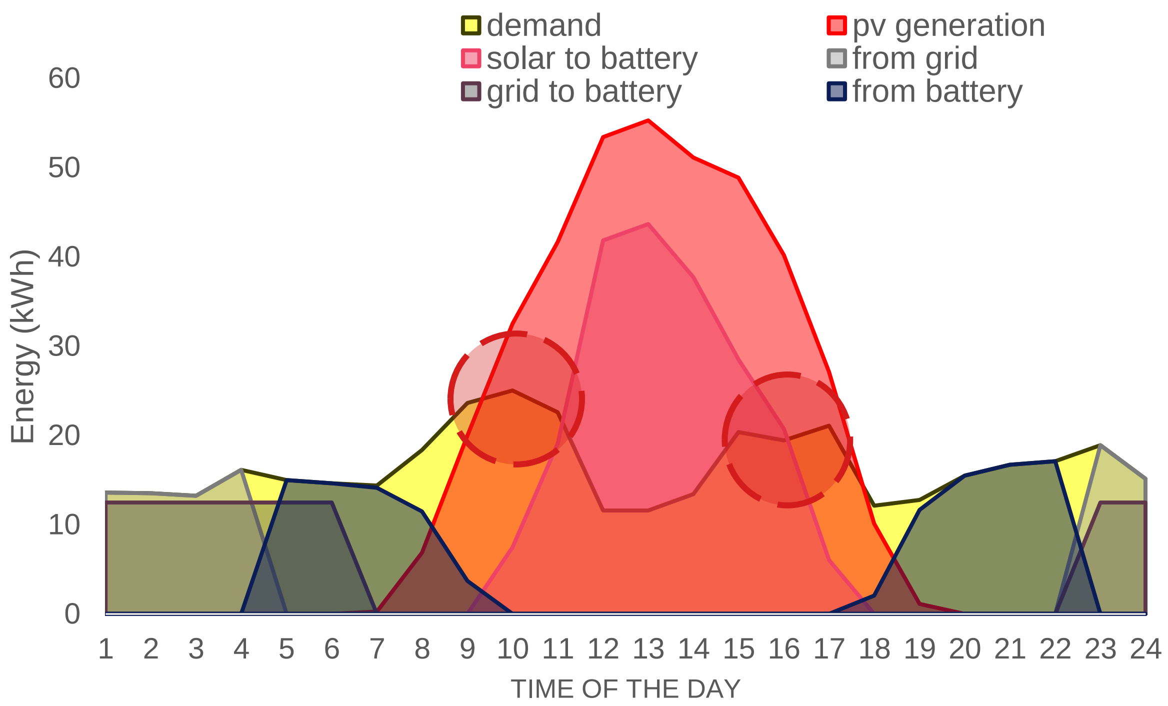
Demand Shift & Response

Time slot	Tariff (cents/kwh)
6 am to 9 am	nil
9 am to 12 pm	9.82
12 pm to 6 pm	nil
6 pm to 10 pm	19.64
10 pm to 6am	-14.73

Building Demand Response **without** Smart Energy Management System



Building Demand Response **with** Smart Energy Management System



Resilience Strategies

Grid Disruption

3 Day Backup for Dwellings

92.88 kWh/day

Essential Loads:
- Lights
- Fans
- Power Sockets

7 Day Backup for Building critical loads

16.372 kWh/day

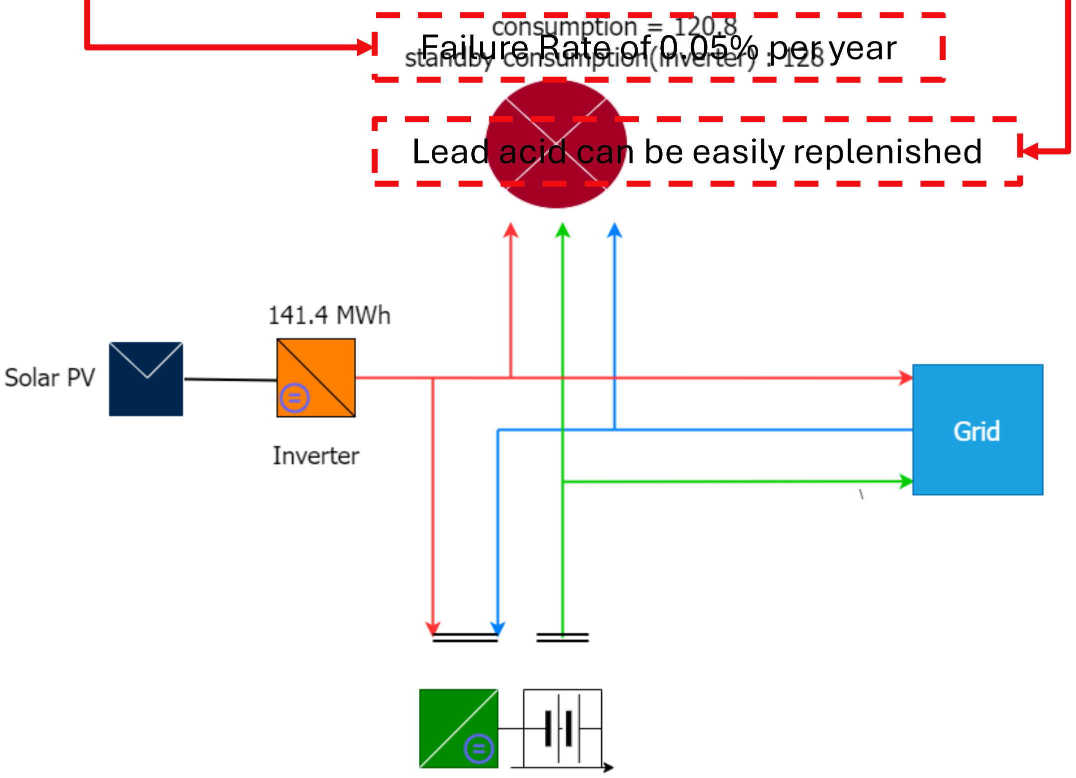
Critical Loads:
- Elevator
- Pump
- Corridor Lights

PV Failure

Battery Failure

Failure Rate of 0.05% per year

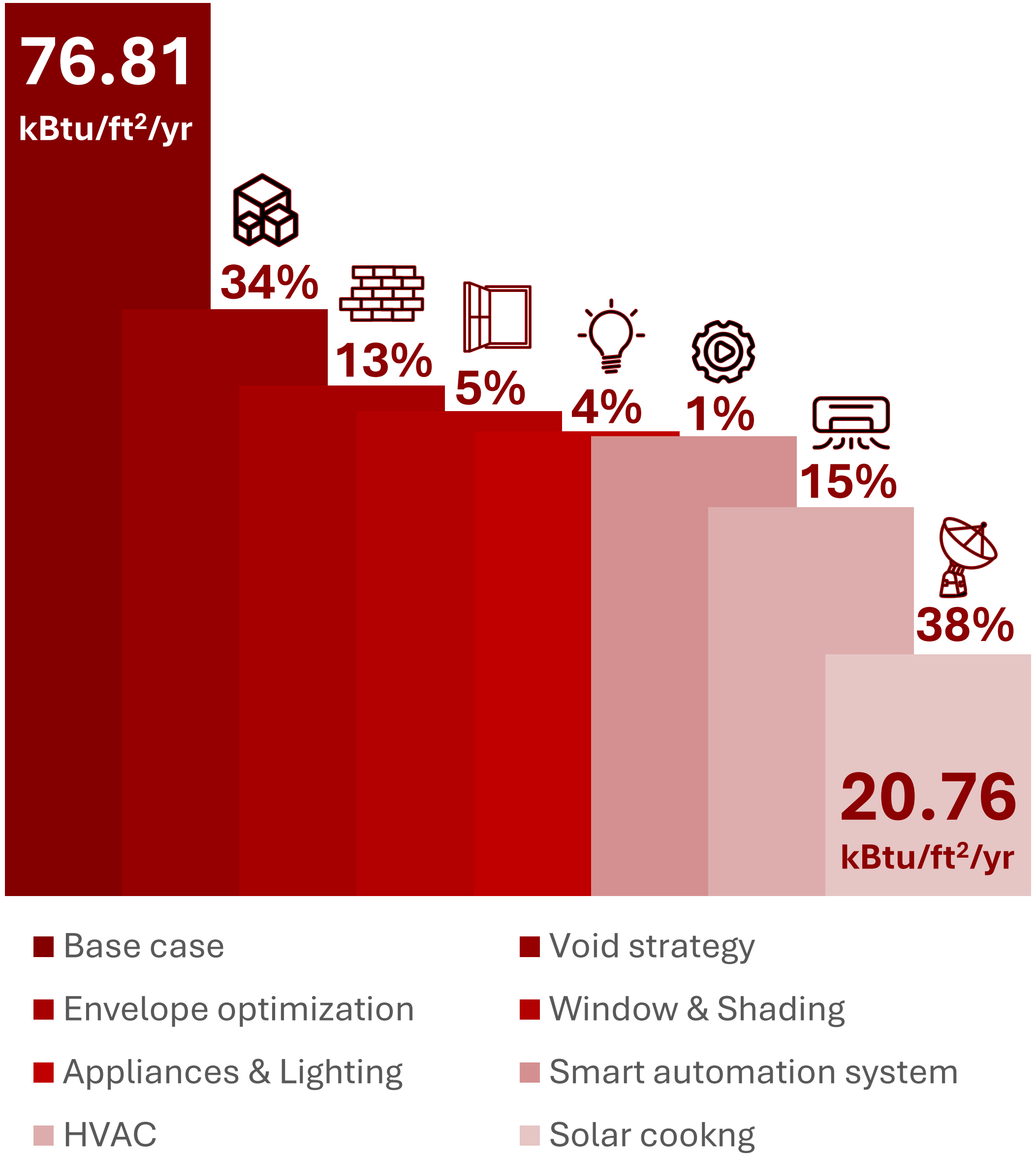
Lead acid can be easily replenished



battery charge at beginning: 725kWh
battery charge (total) = 92,872 kWh

Energy Use Intensity

Source EUI Reduction with Design Decisions



Without Renewables

20.76

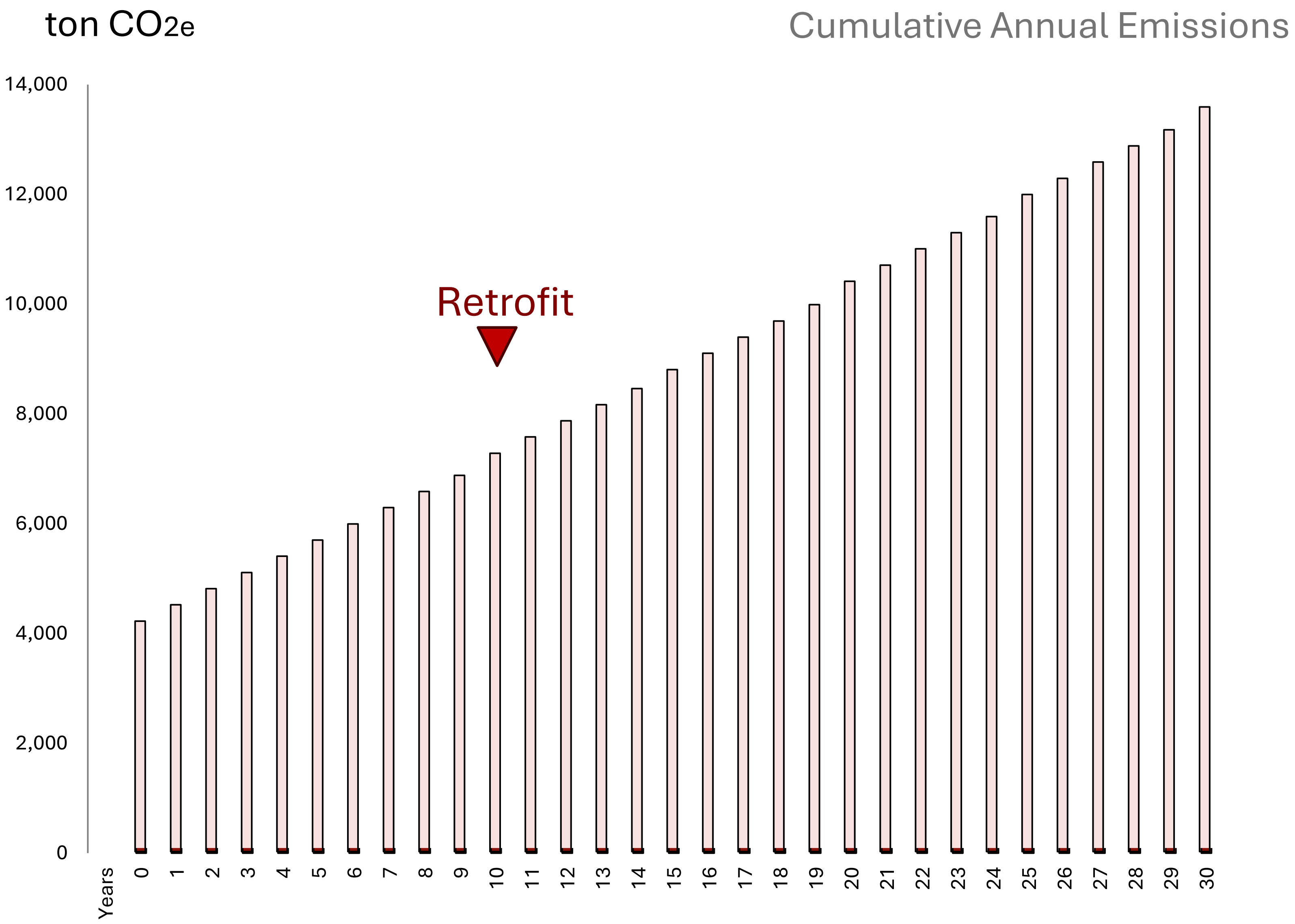
kBtu/ft²/yr

With Renewables

-3.92

kBtu/ft²/yr

Cradle-to-Grave Emissions

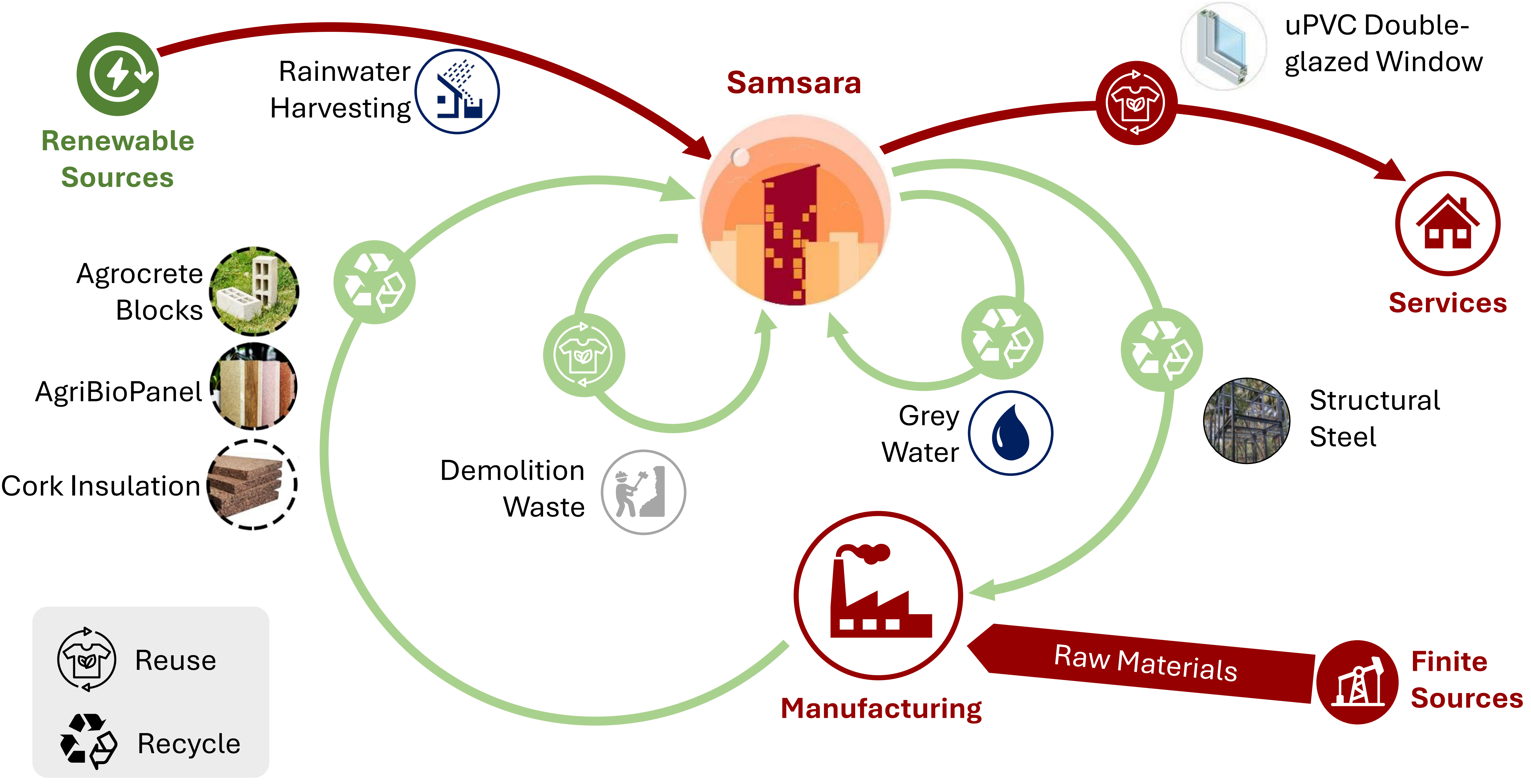


Total Carbon Emissions Avoided

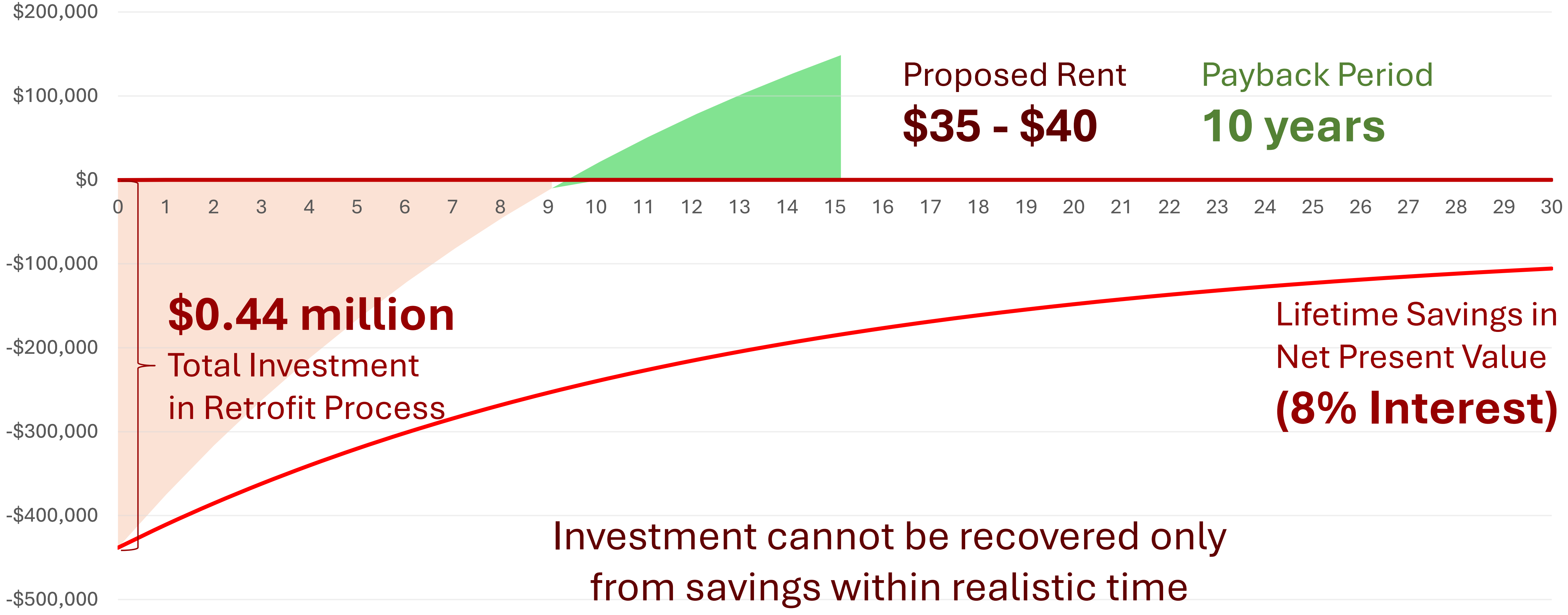
6,819 ton CO_2e

Post-retrofit Life Cycle Emissions (40 years)

Circularity



Payback Period



Payback with Rent

Payback with Savings

Payback Period

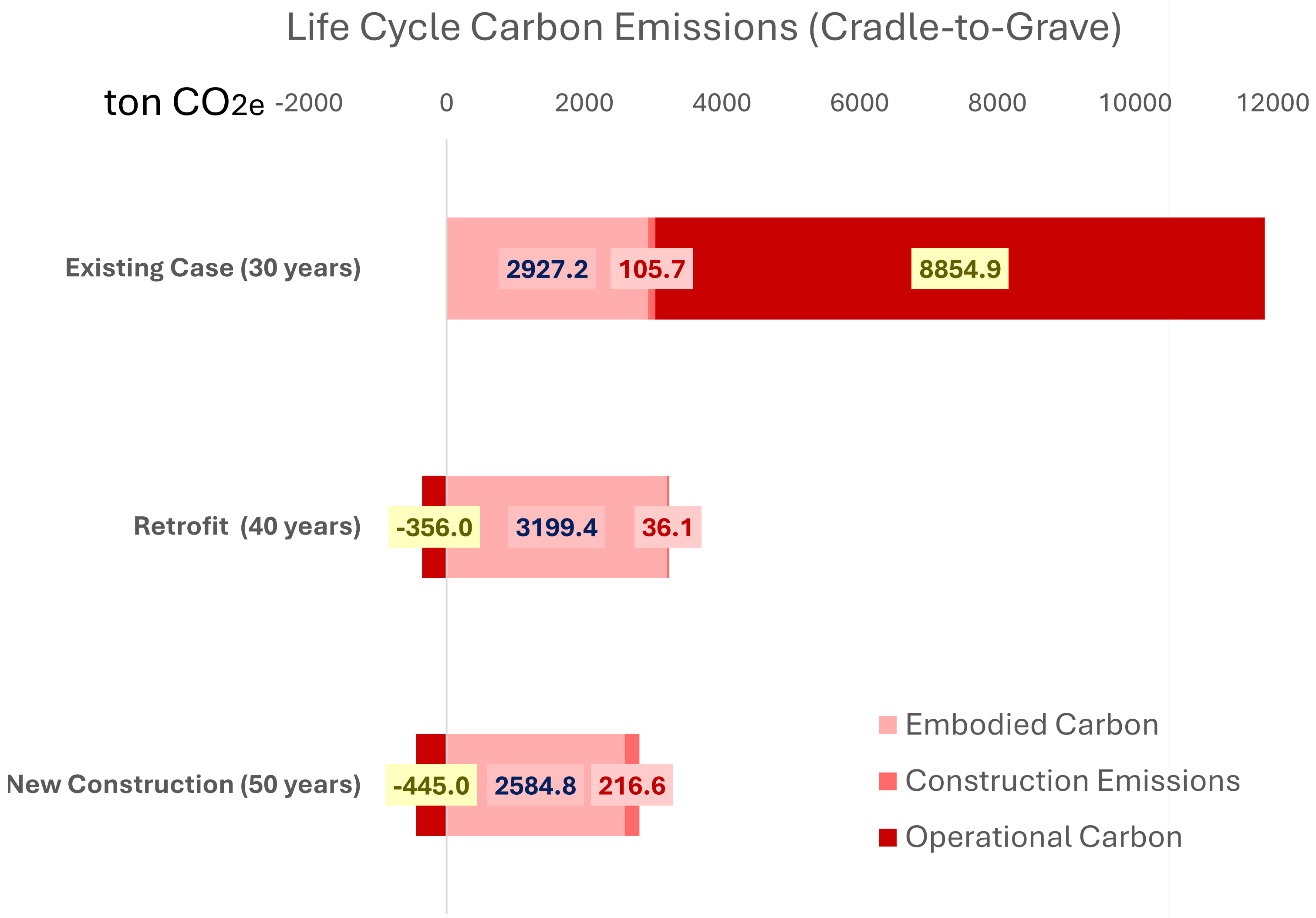
Construction cost of retrofit	Total Investment in Solar Cooking	Investment in HVAC Systems	Complete payback of retrofitting considering revenues	Investment in PV Systems	Demolition and Waste Processing
$17.6/ft^2$ ($17.6/ft²)	$9,980	$35,273		$91,880	
Total investment for retrofitting	Communal Kitchen Payback	Central HVAC Payback		On-site Energy Payback	End of Life
$438,206	3 Years	9 Years	10 Years	13 Years	40 Years

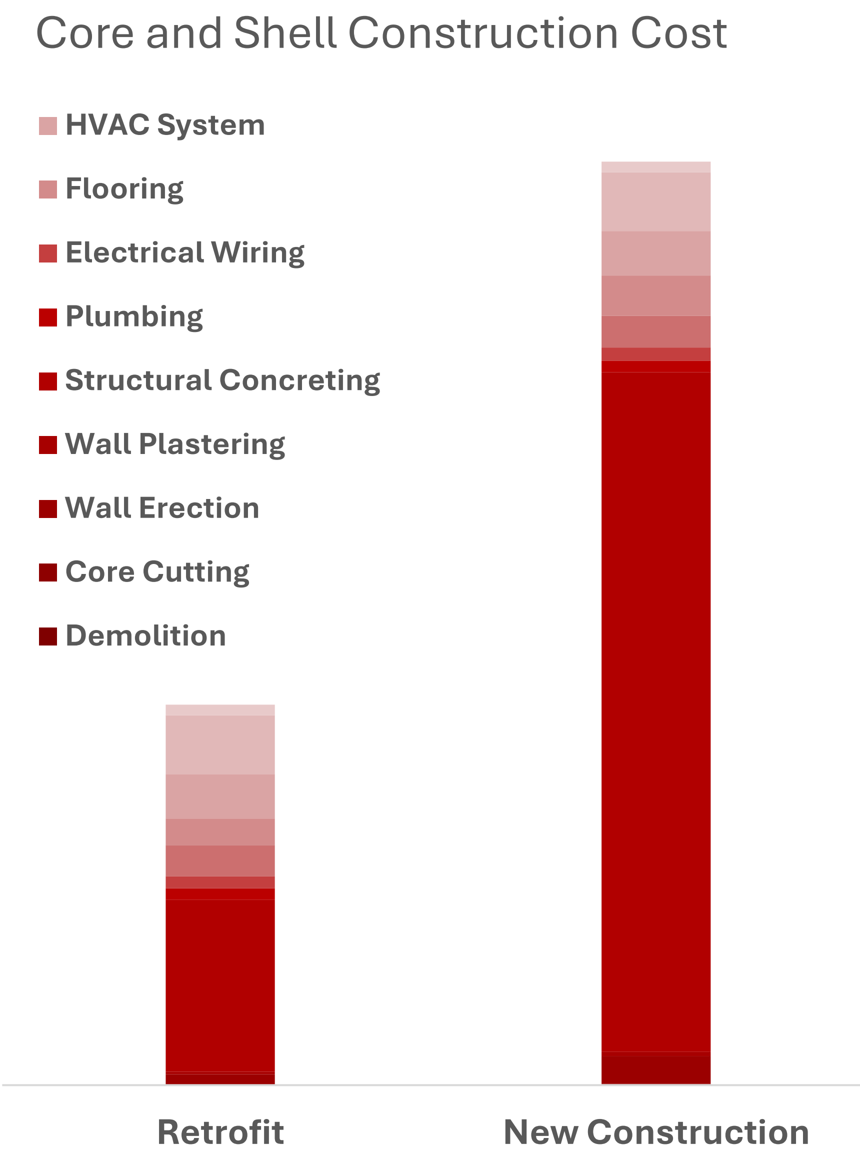
1,539 ton CO_2e
avoided by Solar Cooking

1,281 ton CO_2e
avoided by HVAC Retrofit

6,147 ton CO_2e
avoided by On-site Generation

Retrofit vs New Construction





8% less CO_2 emissions

67% more expensive

Retrofit	New Construction
$438,206	$1,272,496

Design Impact

Community | Health | Efficiency






Cooking Fuel	Lighting	Open Spaces	Thermal Comfort

Slums / **SRH**

cost of utilities

$540/yr

quality of life

Poor / **Worse**

Retrofit / **SRH**

cost of utilities

$540/yr

quality of life

Better / **Worse**

Design Impact

Summary

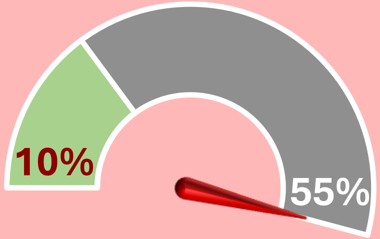
Passive Performance

Ventilation
1 to 4 ACH

Daylight Autonomy
10 to 45% Hours

Envelope
28% less load

Affordability



Monthly Income to Mortgage Ratio

Project Summary

Location:	**Mumbai, India**
Climate Zone:	**0A (Coastal Warm-Humid)**
Lot Size:	**5,509 ft^2 (512 m^2)**
Dwelling Size:	**360 ft^2 (33.5 m^2)**
Building Size:	**66,700 ft^2,15 stories**
Occupancy:	**450 people (148 ft^2/person)**

Energy Performance

Generation 143 MWh

Consumption 120 MWh

Net +ve Energy Building

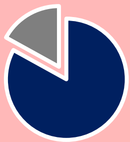
Net Carbon Offset

79.5% On-site PV Generation

19.9% Solar-powered Cooking

Net +ve Carbon Retrofit

Water Savings



80%

IGBC Net-Zero Water Building

Source EUI (kBtu/ft^2/yr)

Without Renewables:	**20.76**
With Renewables:	**-3.92**

HVAC Systems

Membrane based Heat Pump System:

Membrane Dehumidifier: **1.5 TR**

Membrane Cooling: **28.5 TR**

Refrigerant: **Chilled Water**

Construction Timeline

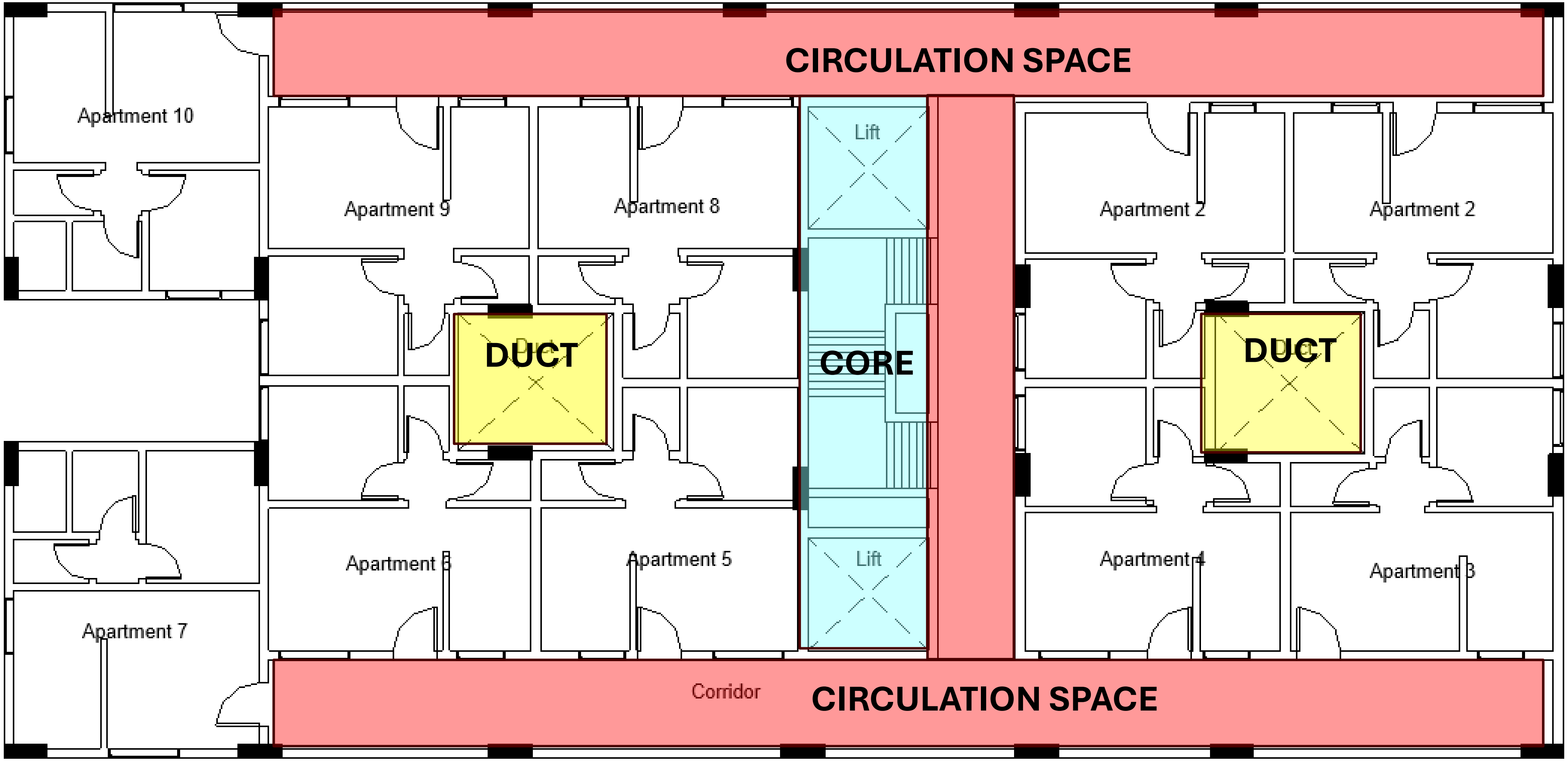
Structural Additions & Repairs	Constructing New Dwelling Units	Shifting Tenants within the Building	Demolition of Poor-performing Units	Creating Community Spaces

- 3 months: Structural Additions & Repairs → Constructing New Dwelling Units
- 6 months: Constructing New Dwelling Units → Shifting Tenants within the Building
- 1 months: Shifting Tenants within the Building → Demolition of Poor-performing Units
- 2 months: Demolition of Poor-performing Units → Creating Community Spaces

Thank you!

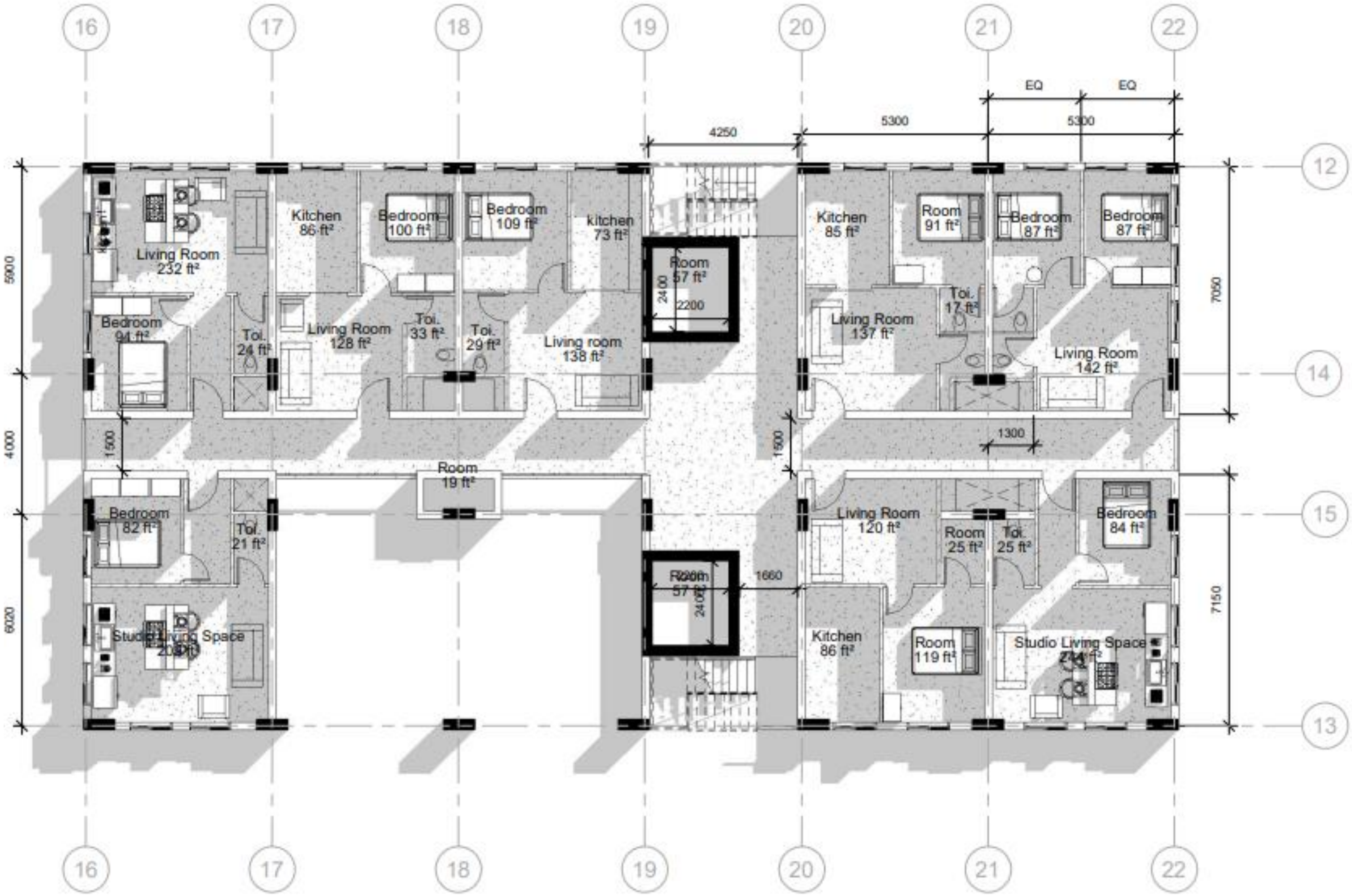
Questions?

Existing Layout



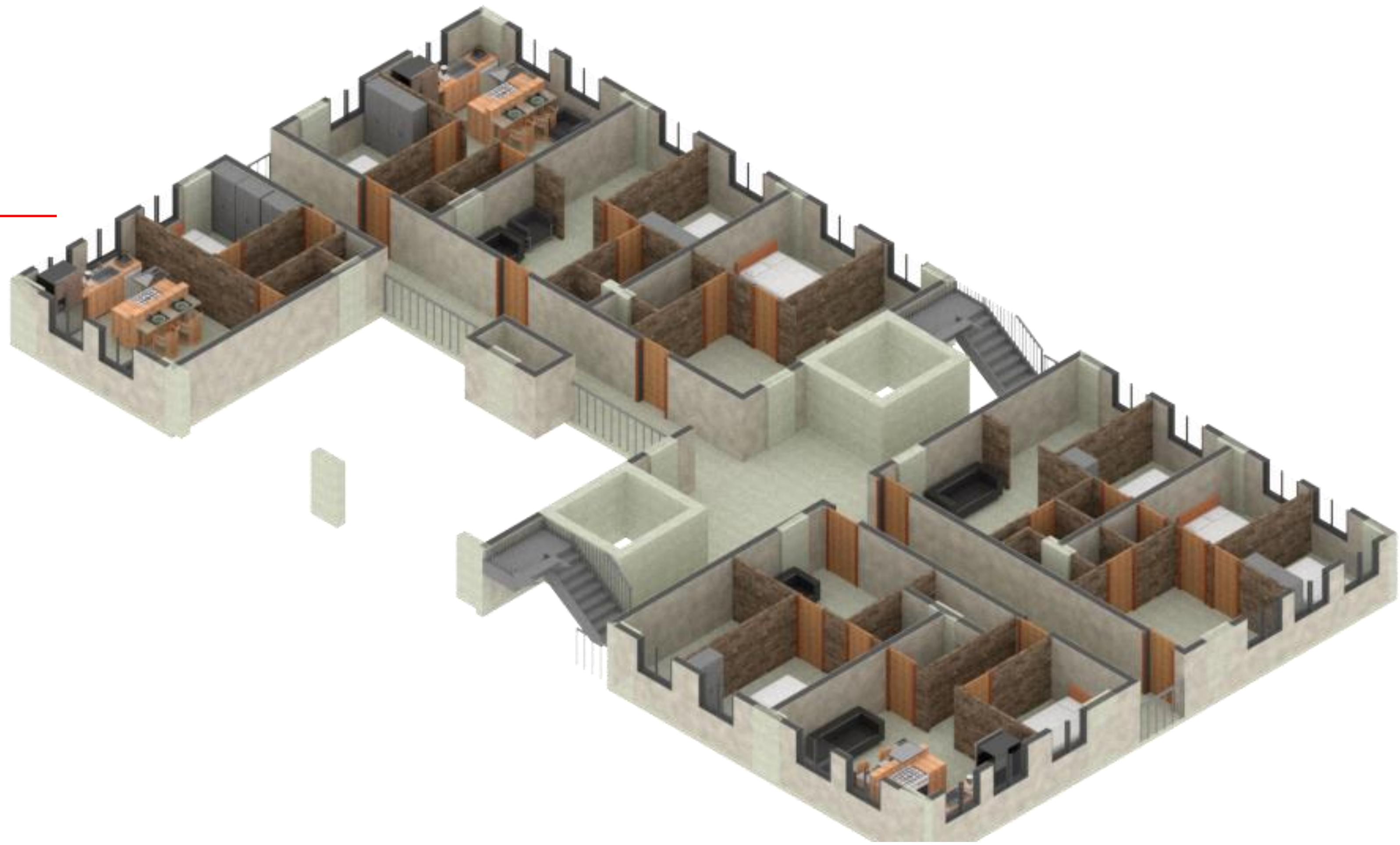
Circulation space = **26.6 %**

Typical Floor Plan

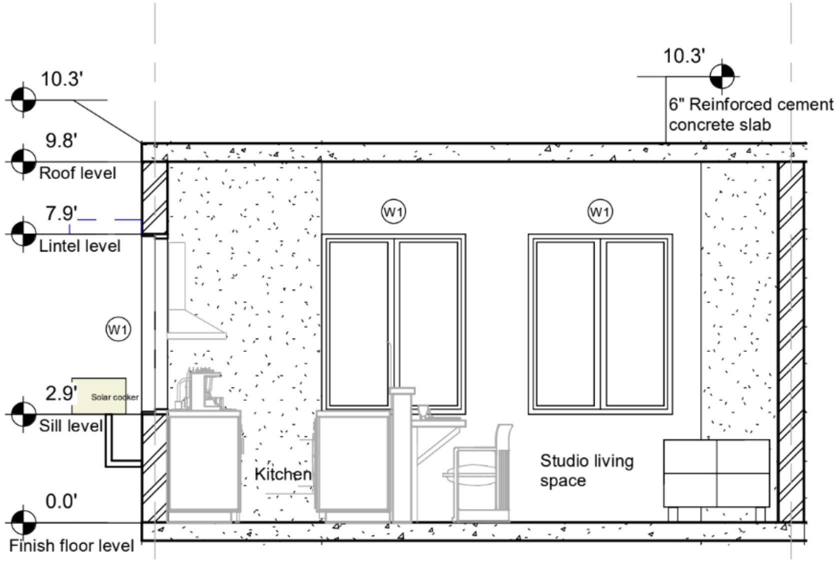


Free Plan Concept

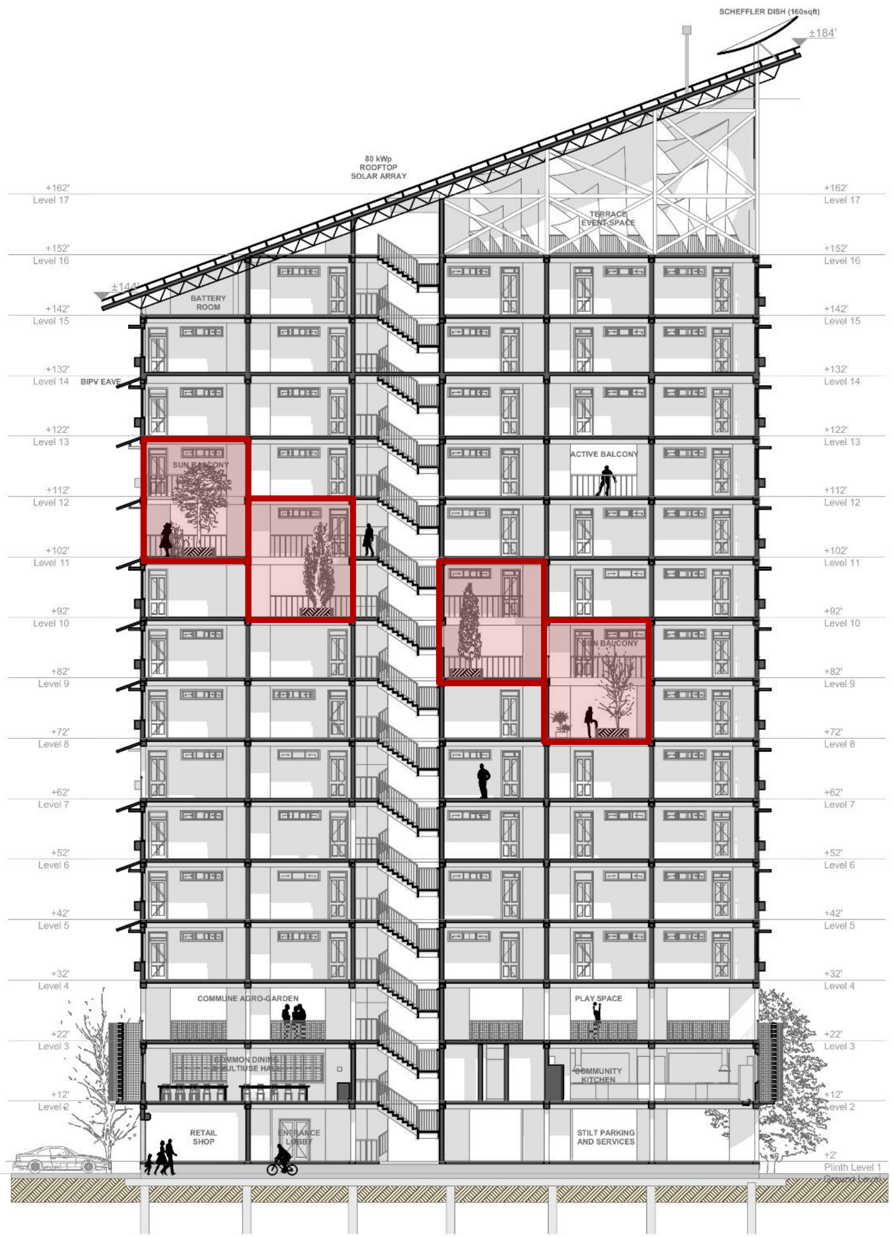
Description (for a given floor)	Before retrofit	After retrofit
Doors	30	30
Windows	20	32
External walls	124 m	96 m
Internal walls	148 m	162 m



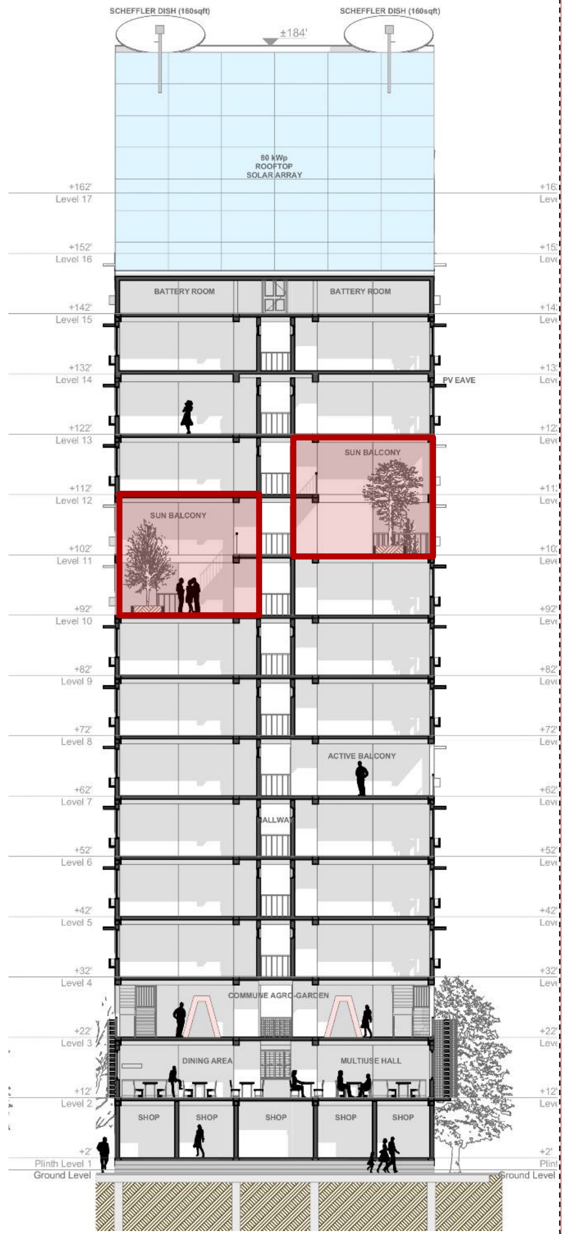
Free Plan Concept



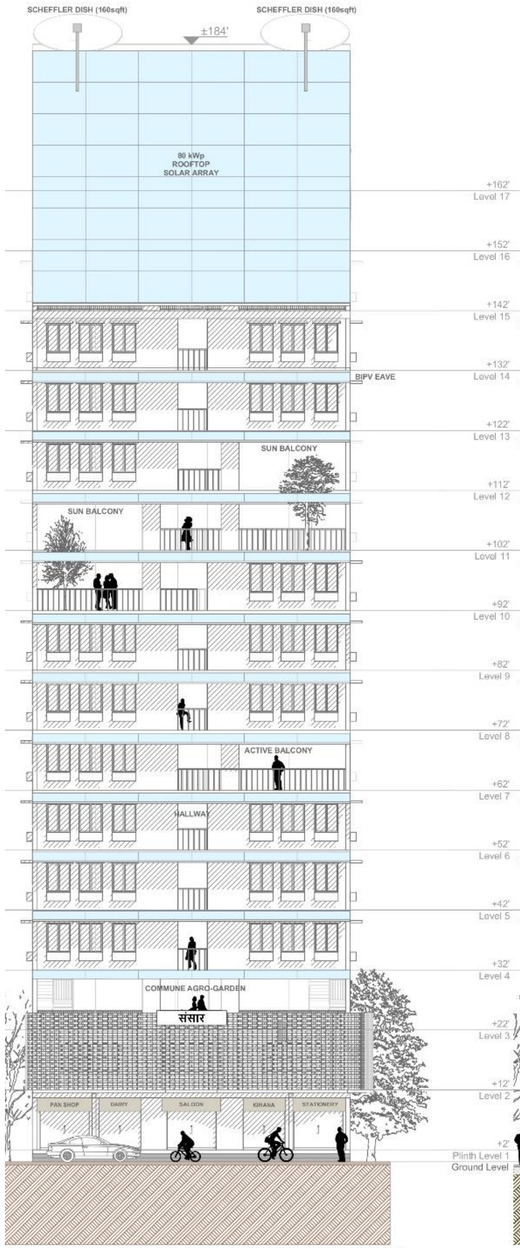
Key plan



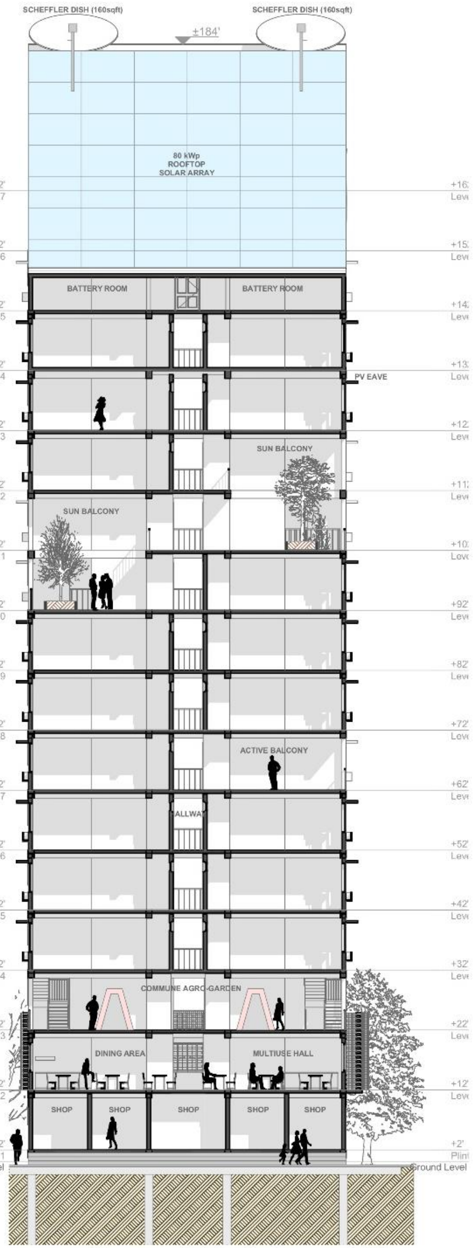
Section 1



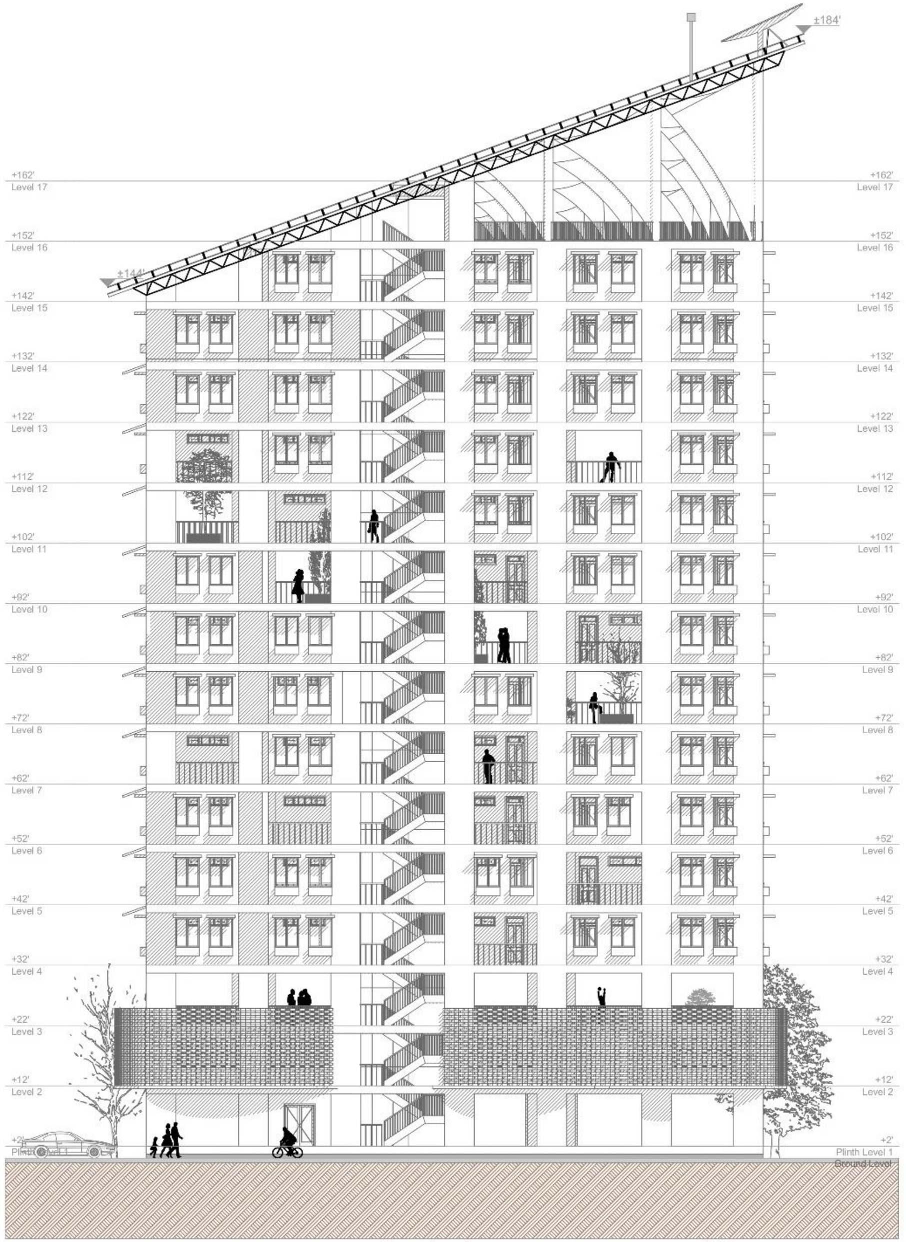
Section 2



South Elevation 1:200

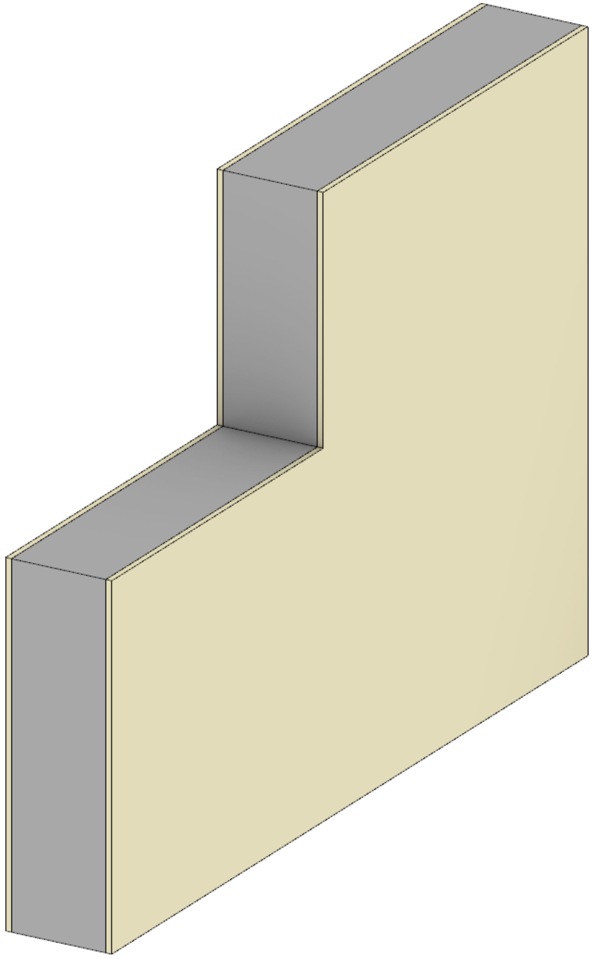


S2 Building Section 1:200

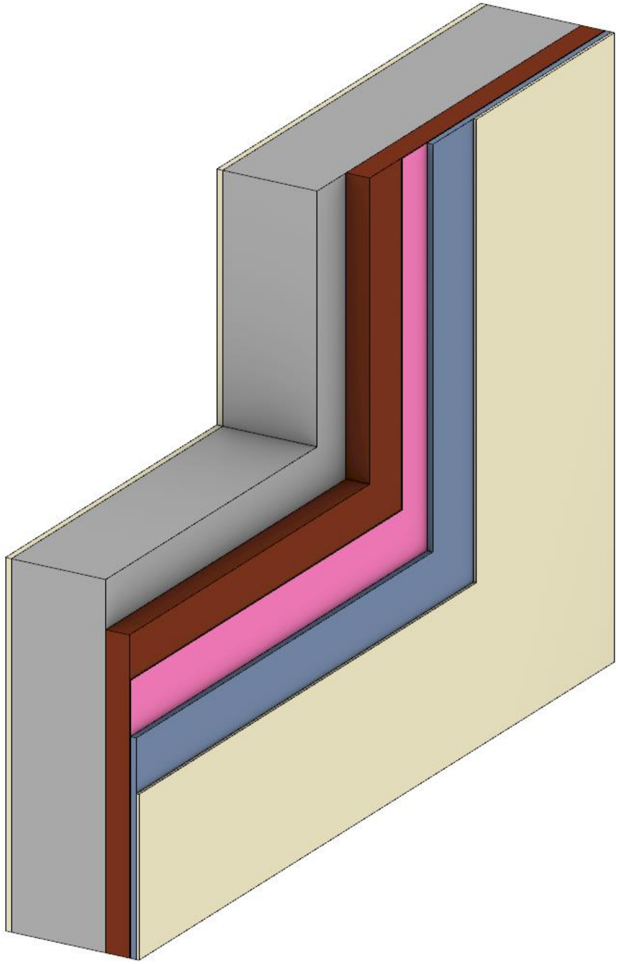


East Elevation 1:200

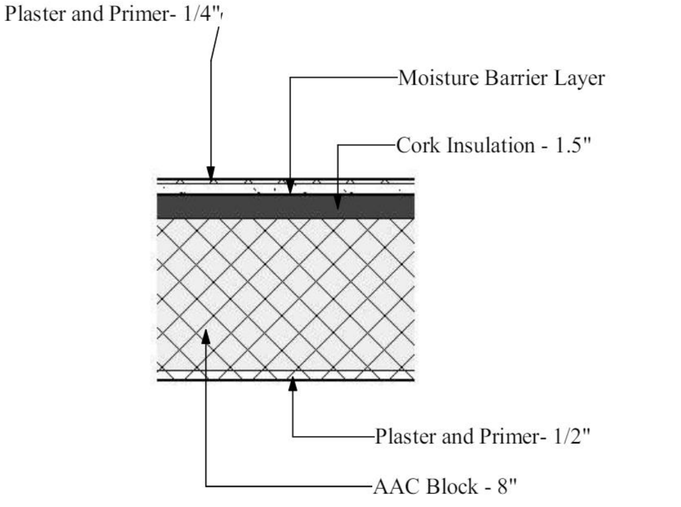
Envelope Details



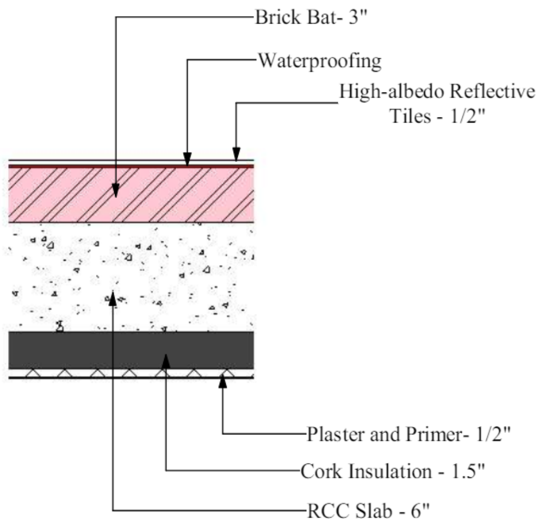
Existing Assembly



Retrofit Assembly

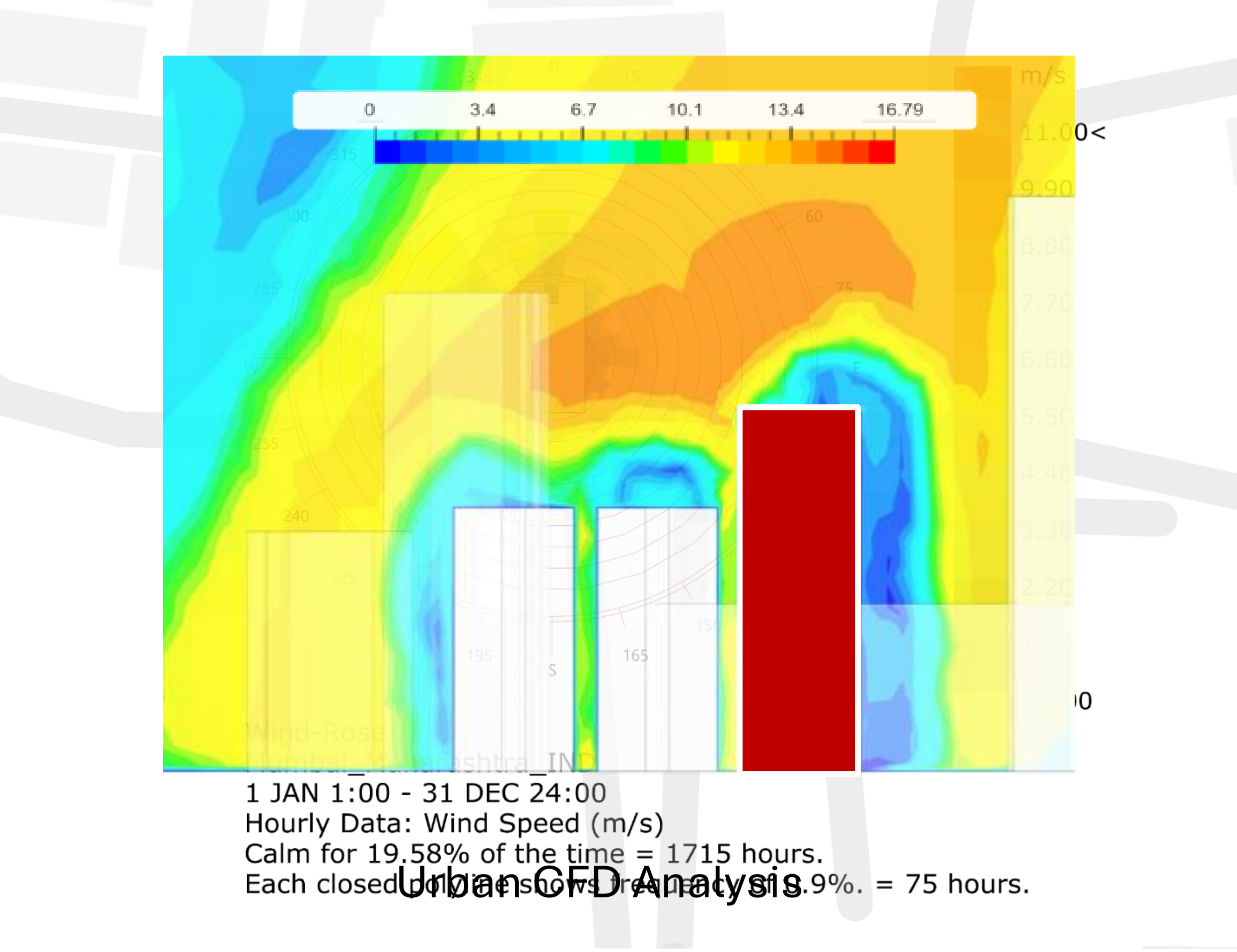


Retrofit Assembly- External wall



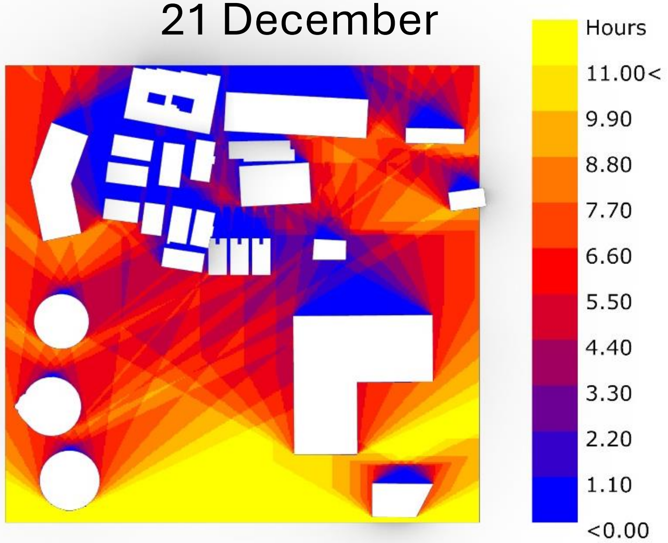
Retrofit Assembly- Roof slab

Climatic Conditions

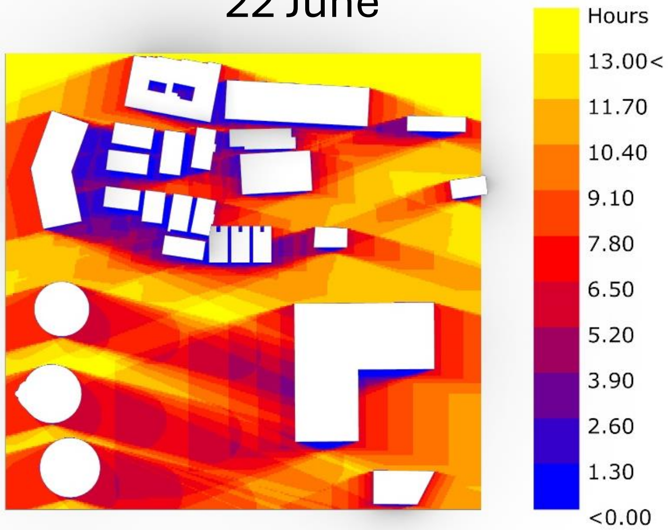


Urban CFD Analysis

21 December



22 June



Sunlight Hours

Building Code Considerations

Min Water Demand

Water Supply System Sizing

Wastewater & Sewage

- CPEEHO, UPCI, Mumbai DCR

Fire Escapes

System Specifications

Water Tanks & Sprinklers

- NBC, Mumbai DCR

Spatial Dimensions

Min Habitable Area

Structural Specifications

- NBC, IS 456, 10262

Min Lighting Requirements

Min Appliance Ratings

- ECBC, BEE

Air Changes per Hour (ACH)

Recommended Air Flow Rate

Min Window Areas

- NBC, CSIR, ECBC

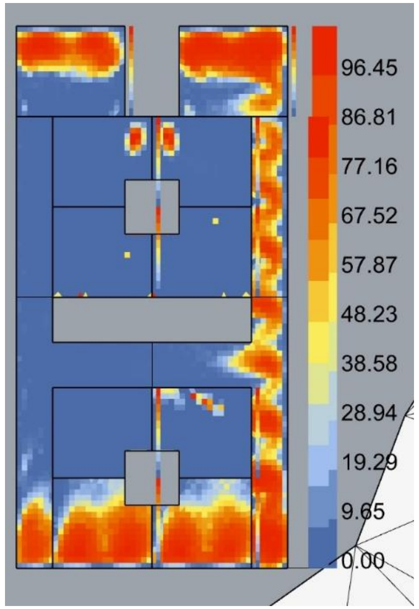
Wall-Window Ratio

Infiltration Rate

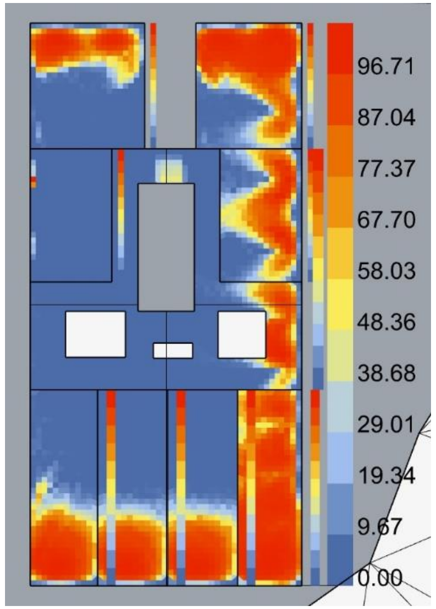
U-values & SHGC

- LEED, ECBC, ENS

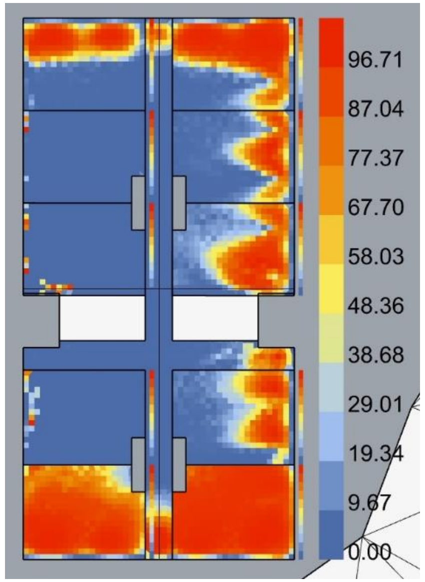
Floor Plan Iterations



Existing Layout



Iterative Extent



Final Proposal

- Base Case = 60% area of all DUs are underlit (<300 lux)
- Iterations reduce underlit areas to only 28%
- Final Proposal:
  - 10 DUs per floor
  - Avg underlit area < 20%
  - 60% walls retained

N

Life Cycle Framework

System Boundary

Technical	Geographical	Temporal
Cradle-to-Grave Analysis	Material procurement: Local Sources	GWP over a Lifespan of **40** years

Our focus is primarily on:

- Second-life Materials
- Circularity
- Social Life Cycle Assessment

Limitations of Study

Impact Coverage

Life Cycle Carbon
40 Years of GWP

Methodological

Data Sensitivity
Unavailability of Data

Assumption

Labor Intensive Construction
(7% of materials phase)

Market Potential

Replicability

- Light house projects
- Consuming local resources

Scalability

- Affordable housing schemes
- Modular construction

Limitations

- Skilled labor
- Space constrained