# Decision support for the design of a building form coupling daylight and natural ventilation consideration in a dense urban context

Authors:

Fatemeh Yazdandoust, Master of Science in Architecture, Iowa State University, USA

Ulrike Passe, Professor of Architecture, College of Design, and Director of Center for Building Energy Research, Iowa State University, USA

# Literature review

The literature review is structured around three main topics discussing the current state of the art.

Topic I
Passive strategies to apply DL & NV

Topic II
Application of DL & NV cases

Topic III
Coupled application of DL & NV cases

# Daylight strategies on urban and building scale

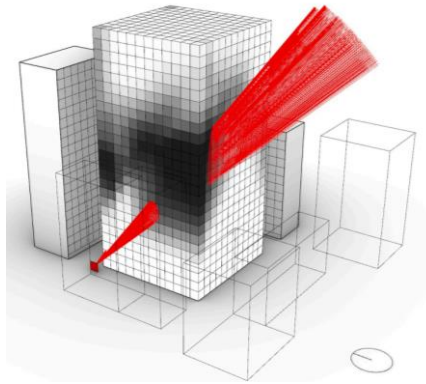


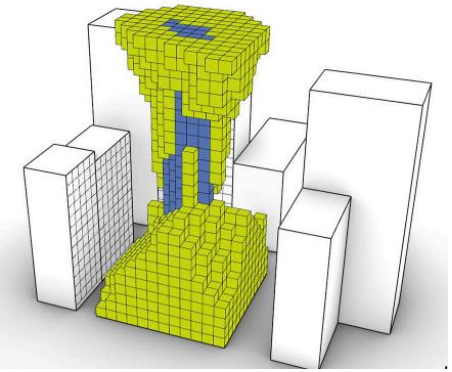
URBAN SCALE

1916 — NYC Solar Zoning

1978 — Solar Envelope

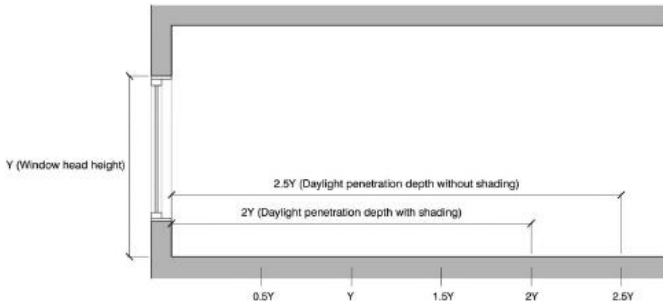
2021 — Reverse Solar Envelope



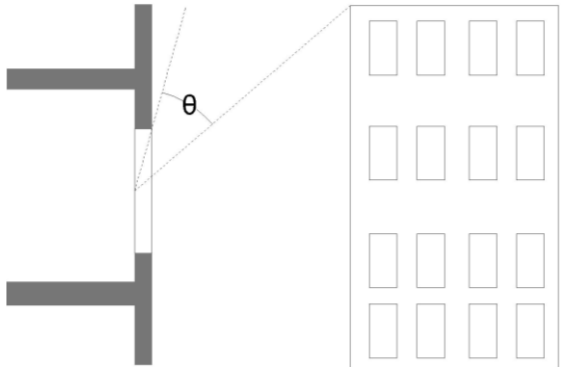


BUILDING SCALE

Window-Head-Height Rule

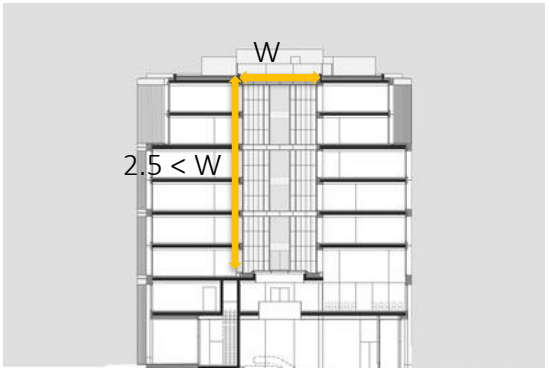



Daylight feasibility test




WWR> (0.88 DF/ $V_t$ )*( 90˚/ θ)

Atrium



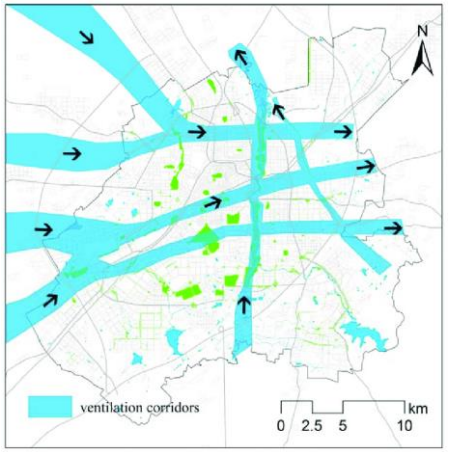
# Natural ventilation strategies on urban and building scale



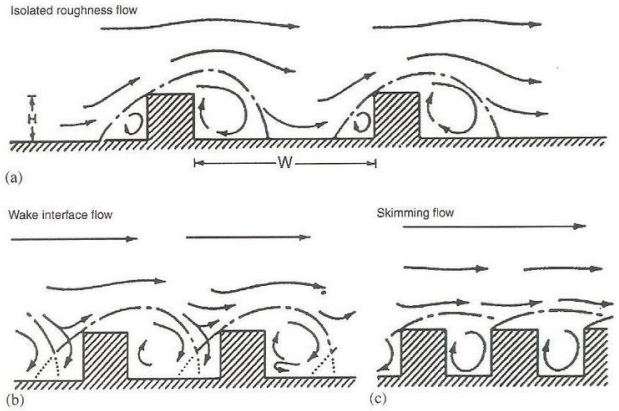
Spatial ratio of open spaces to built-up areas is crucial in determining wind patterns, velocity, and pressure (Passe et al., 2015).

URBAN SCALE

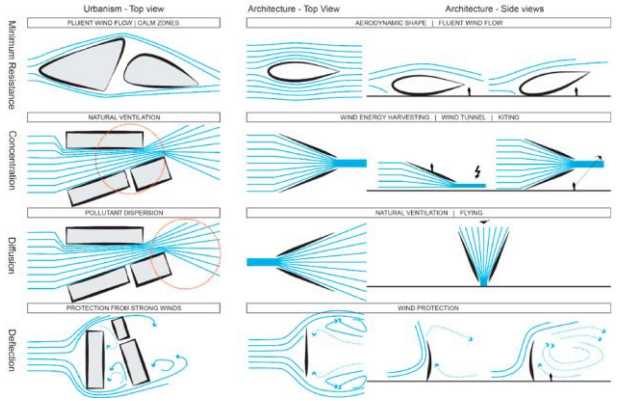
Urban ventilation corridors




Street canyon
Urban Aspect Ratio (UAR)

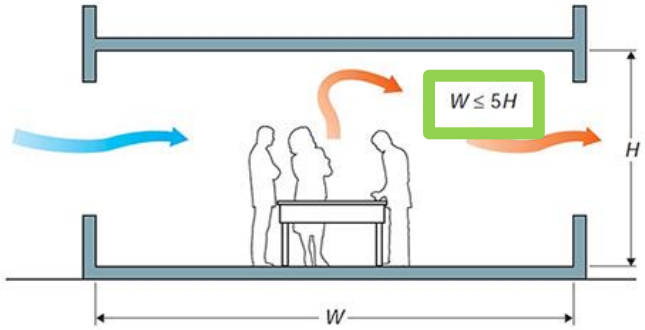



Open space around the building



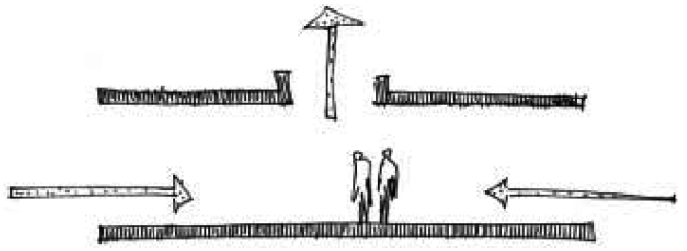

BUILDING SCALE

Cross ventilation

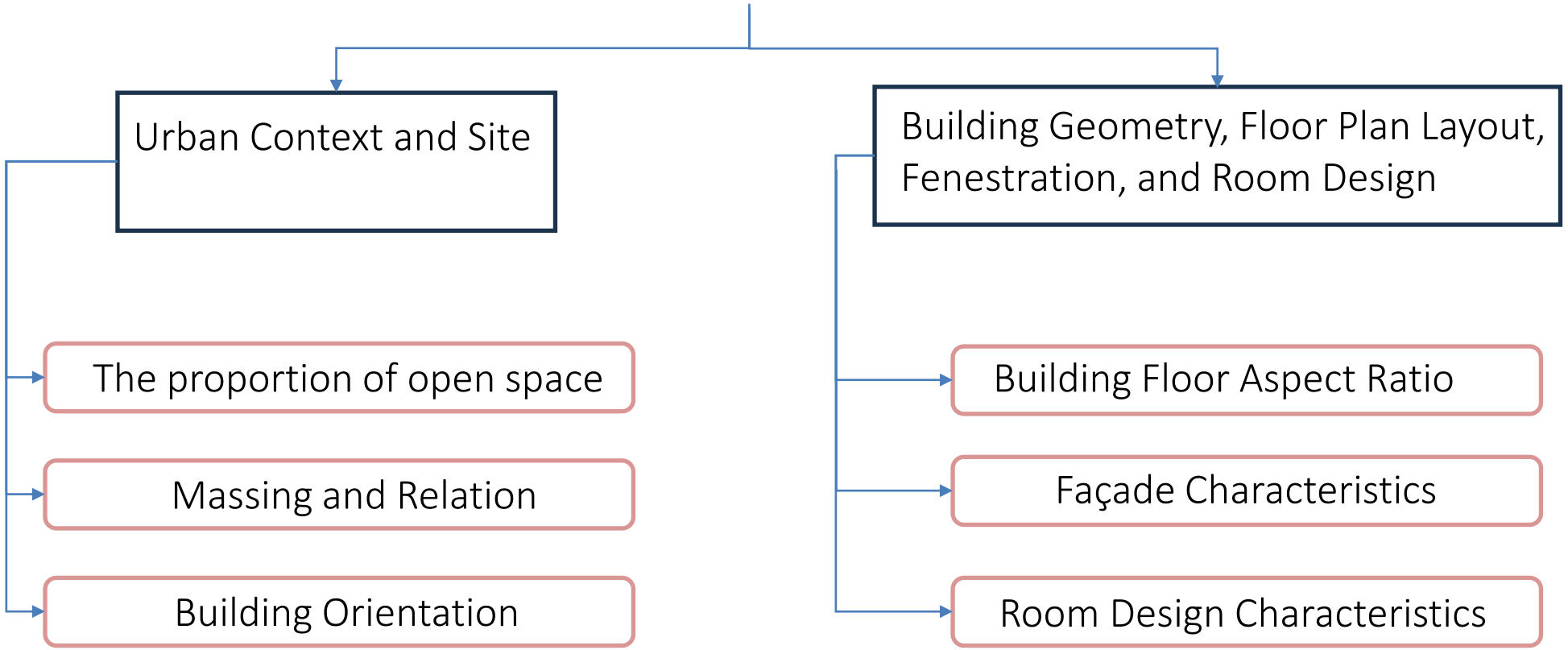



Perpendicular to the prevailing wind direction

Stack ventilation

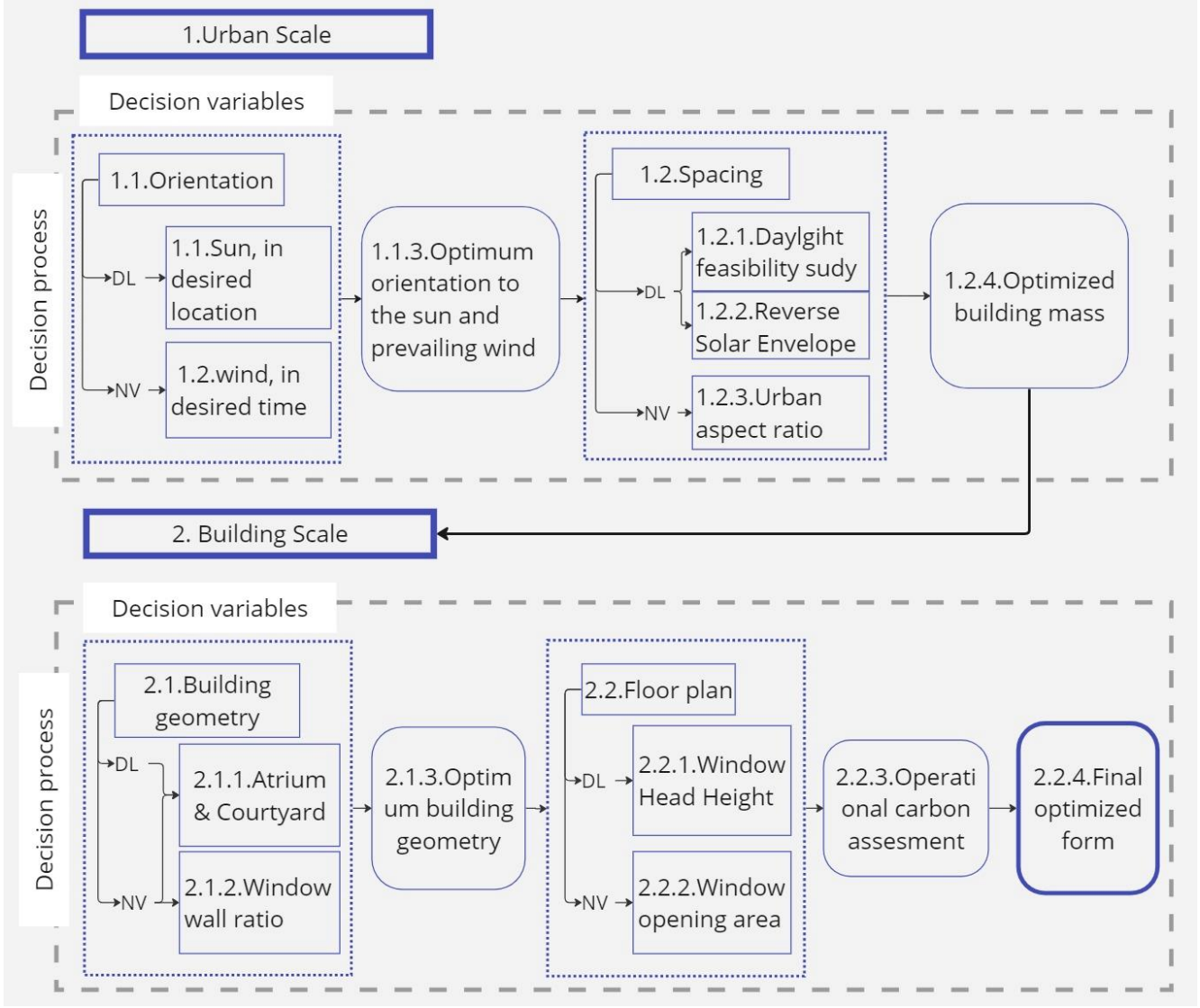


## Summarizing the Daylight and Natural Ventilation Strategies



# Proposed framework

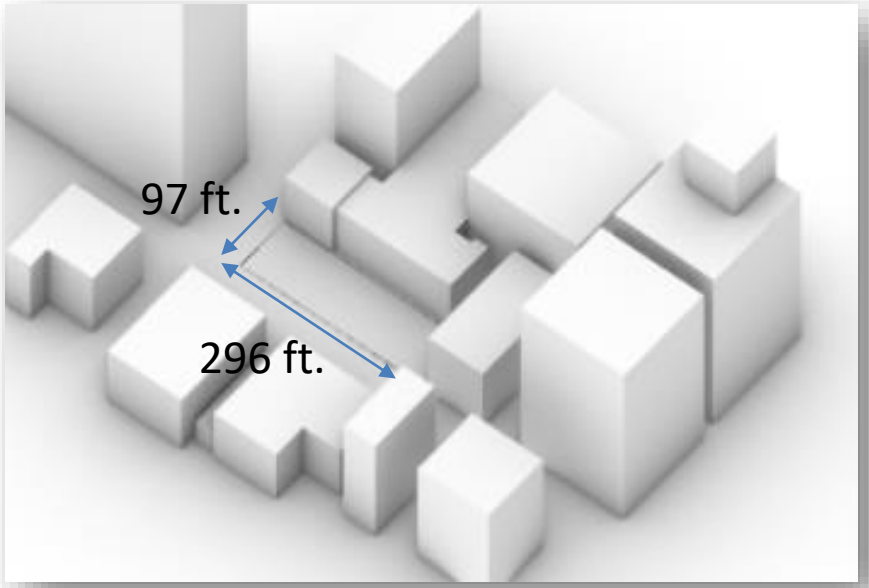




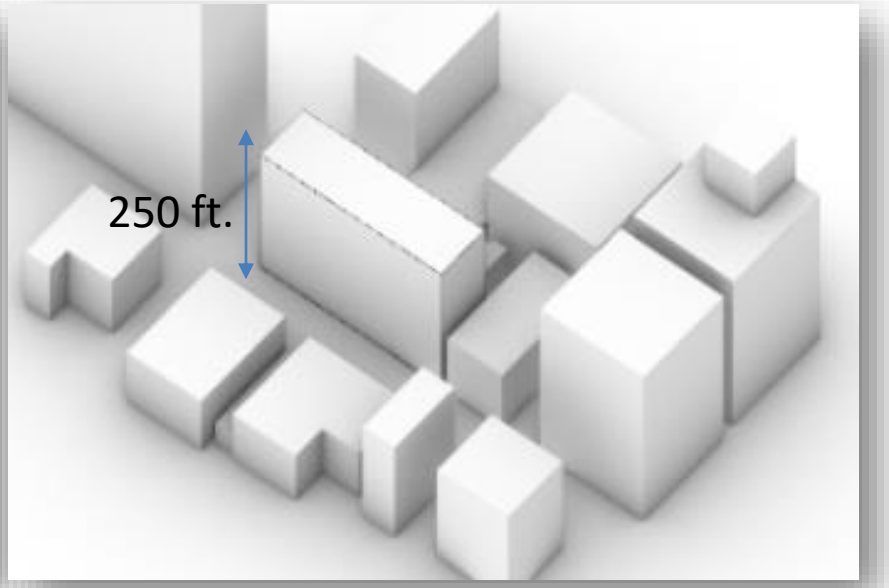

The form-finding framework for the coupled application of daylight and natural ventilation

# Site: Chicago, IL, USA




It is a vacant rectangular lot with a width of 97 ft. and a length of 296 ft., surrounded by mid-rise and high-rise, primarily office buildings with an average height of 100 ft.




A building bulk with a height of 250 ft and a 97 by 296 ft footprint is used to start the form-finding process.

1.1.Orientation ← 1.Urban Scale → 1.2.Spacing

DL
1.1.Sun, in desired location

NV
1.2.wind, in desired time

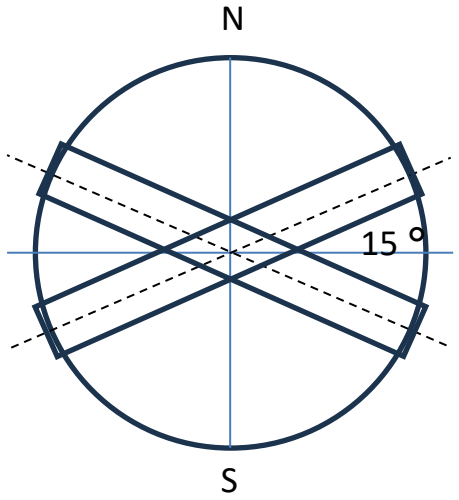
1.1.3.Optimum orientation to the sun and prevailing wind

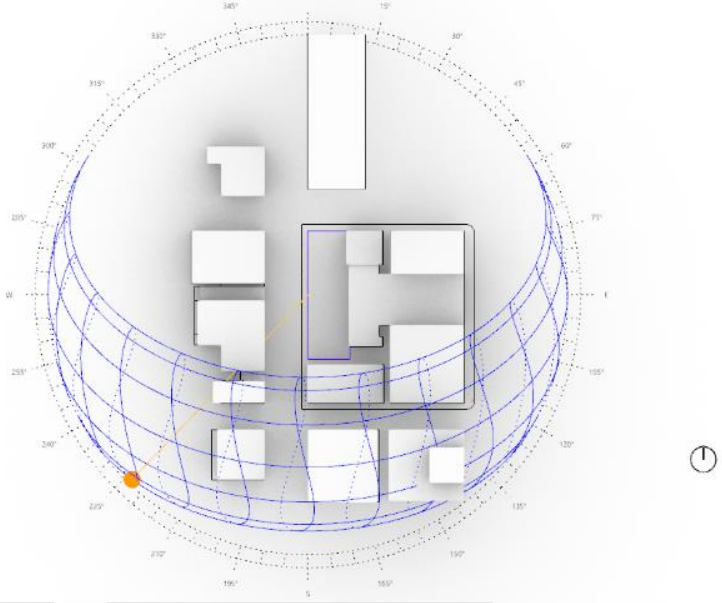
DL
1.2.1.Daylight feasibility study

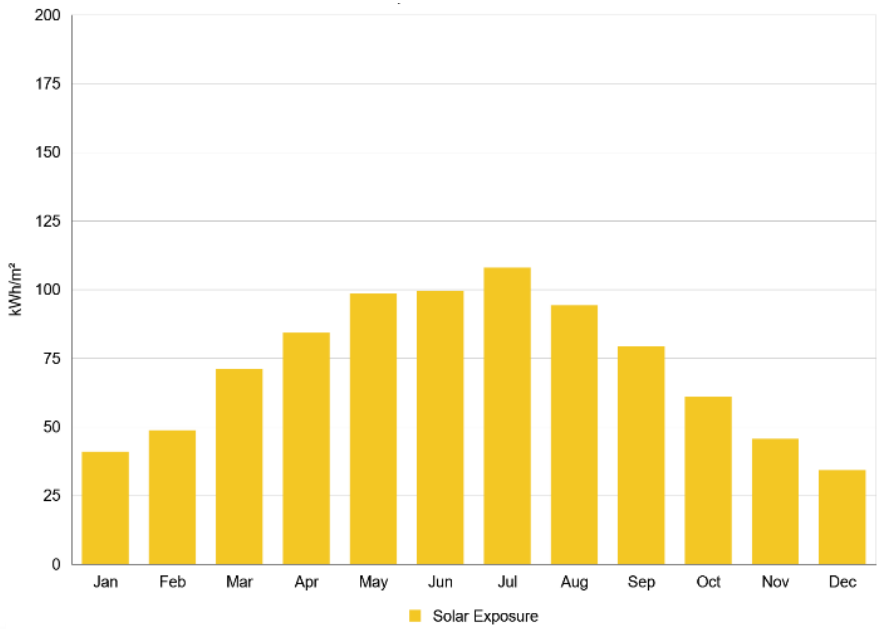
DL
1.2.2.Reverse Solar Envelope

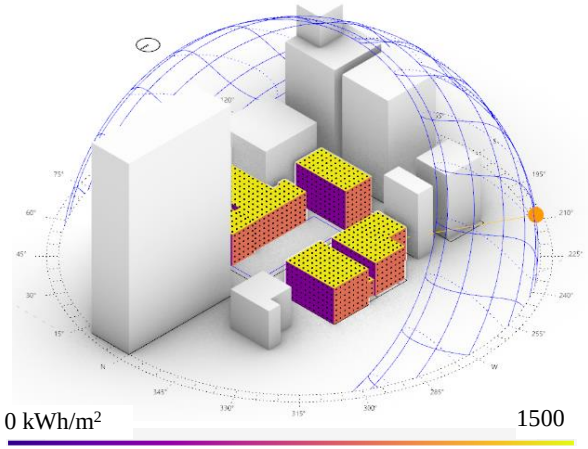
NV
1.2.3.Urban aspect ratio

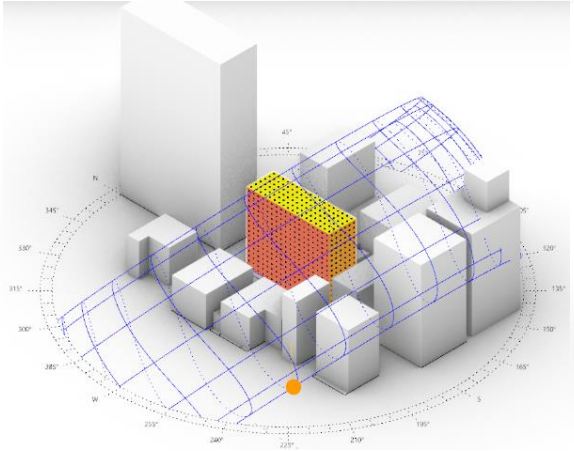
1.2.4.Optimized building mass

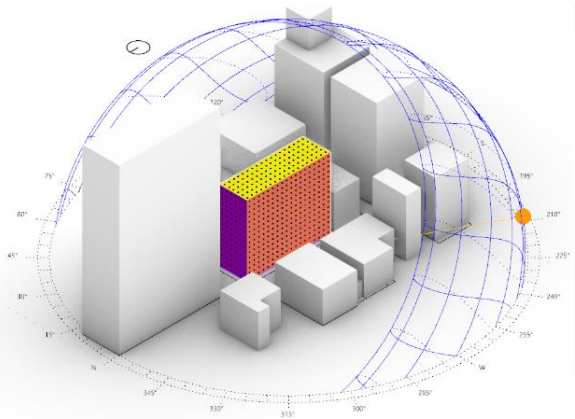


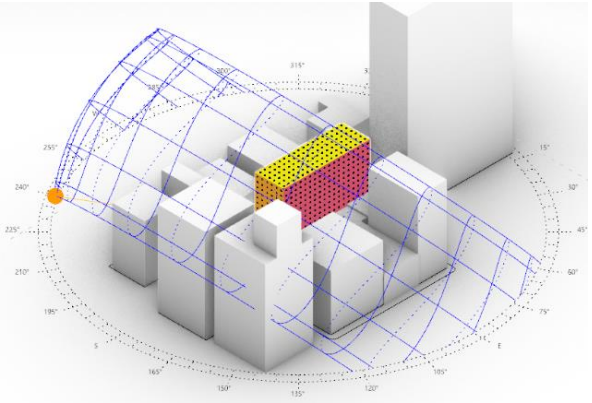







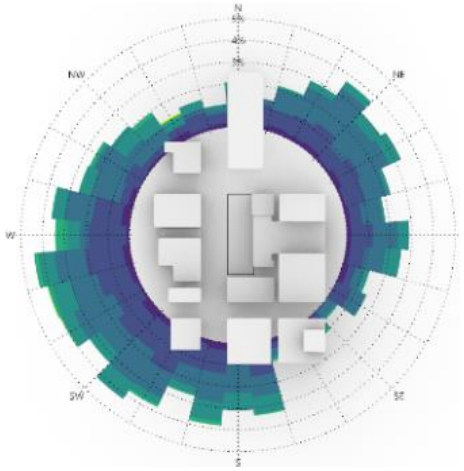


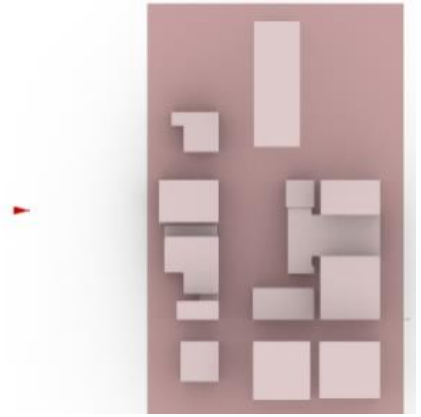
1.1.Orientation ← 1.Urban Scale → 1.2.Spacing

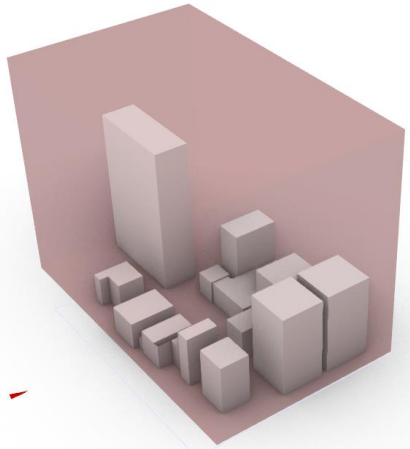
DL | NV | | DL | DL | NV

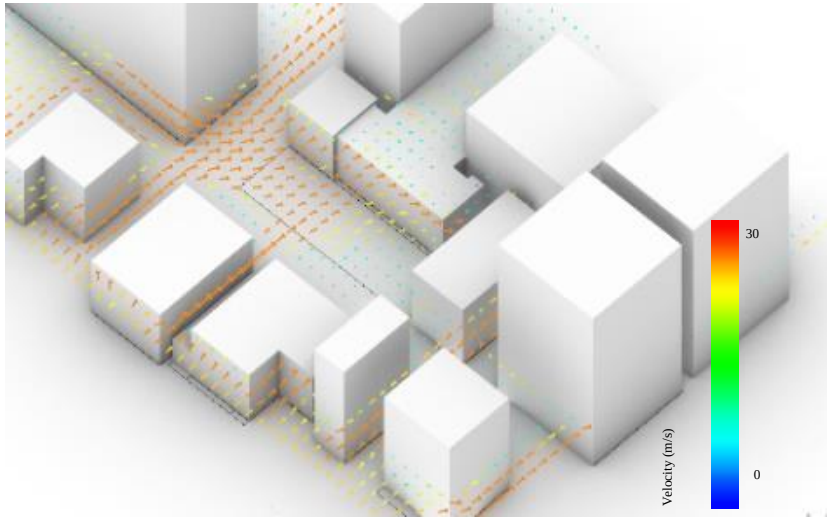
1.1.Sun, in desired location → 1.2.wind, in desired time → 1.1.3.Optimum orientation to the sun and prevailing wind → 1.2.1.Daylight feasibility study → 1.2.2.Reverse Solar Envelope → 1.2.3.Urban aspect ratio → 1.2.4.Optimized building mass

Oct 21-March 21



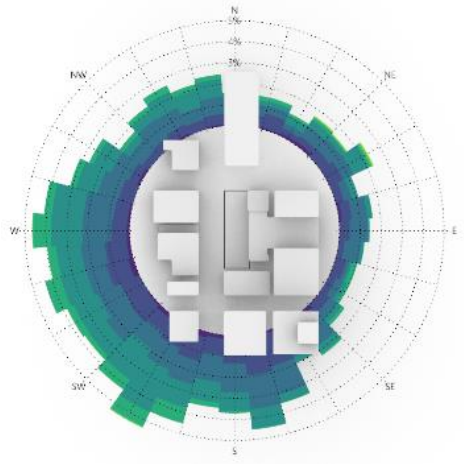


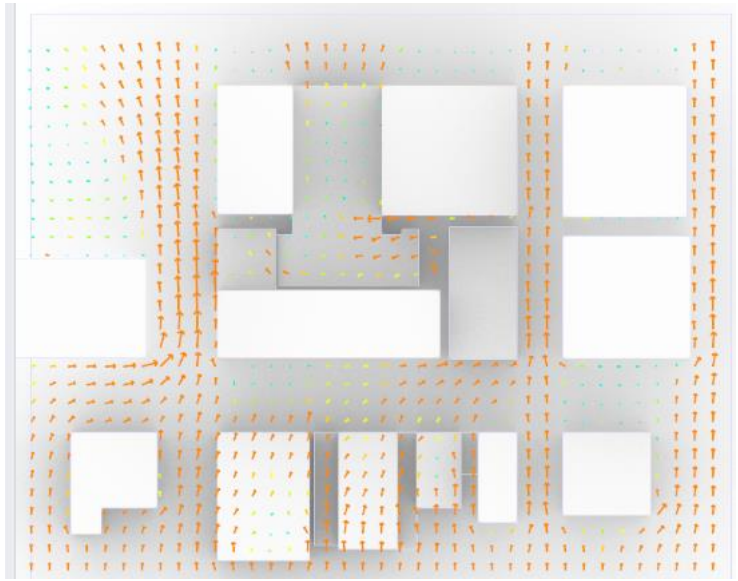


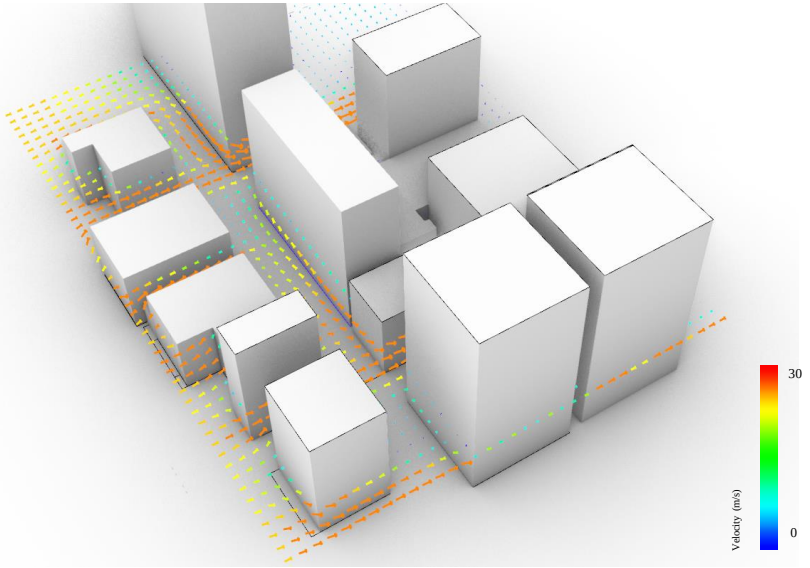



simulation domain and wind direction

Jun 21-Aug 21







1.1.Orientation

1.Urban Scale

1.2.Spacing

DL

1.1.Sun, in desired location

NV

1.2.wind, in desired time

1.1.3.Optimum orientation to the sun and prevailing wind

DL

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DL

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NV

1.2.3.Urban aspect ratio

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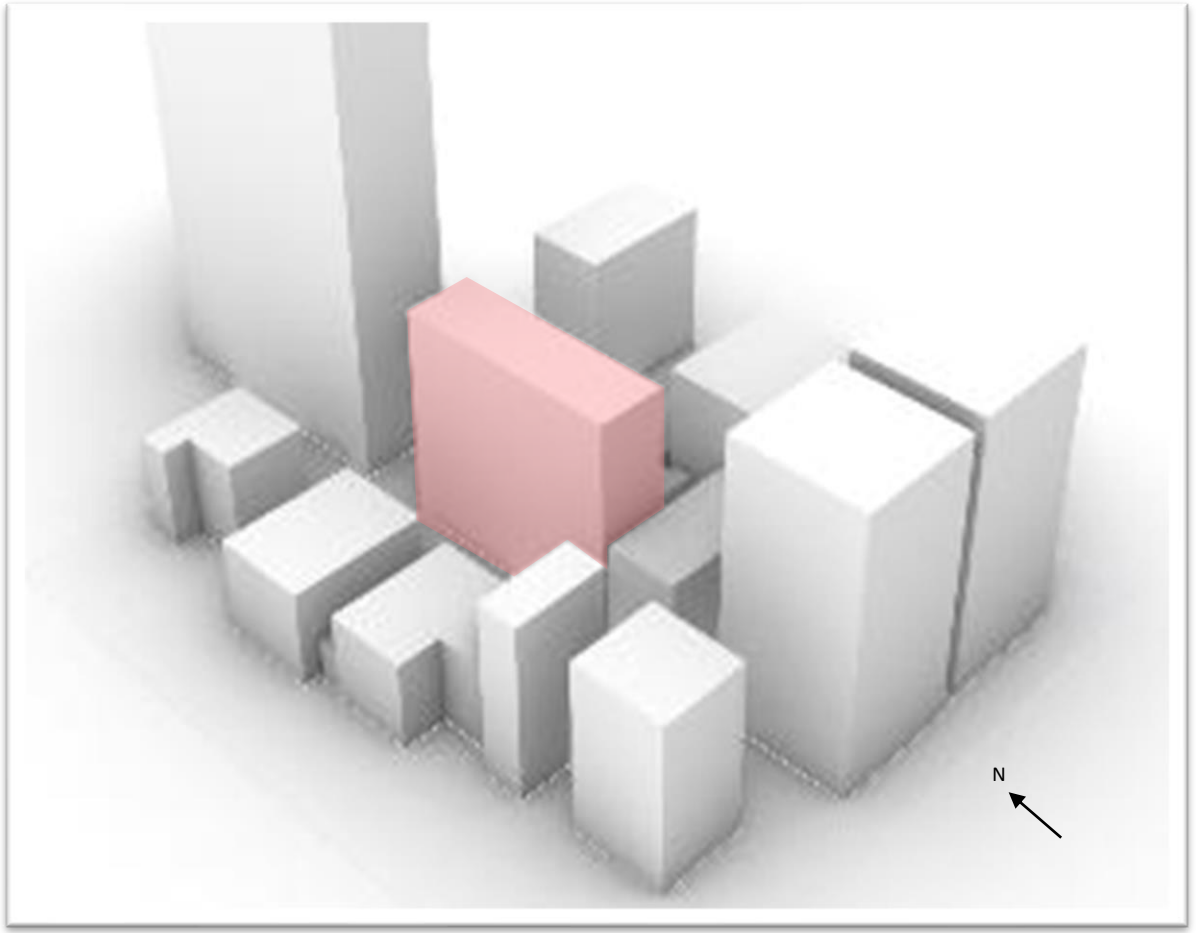
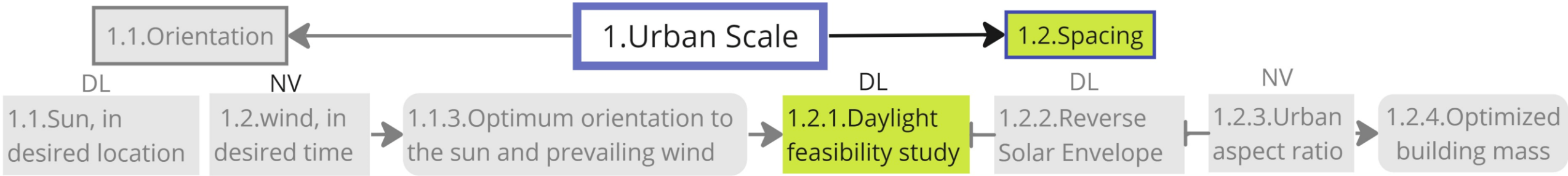
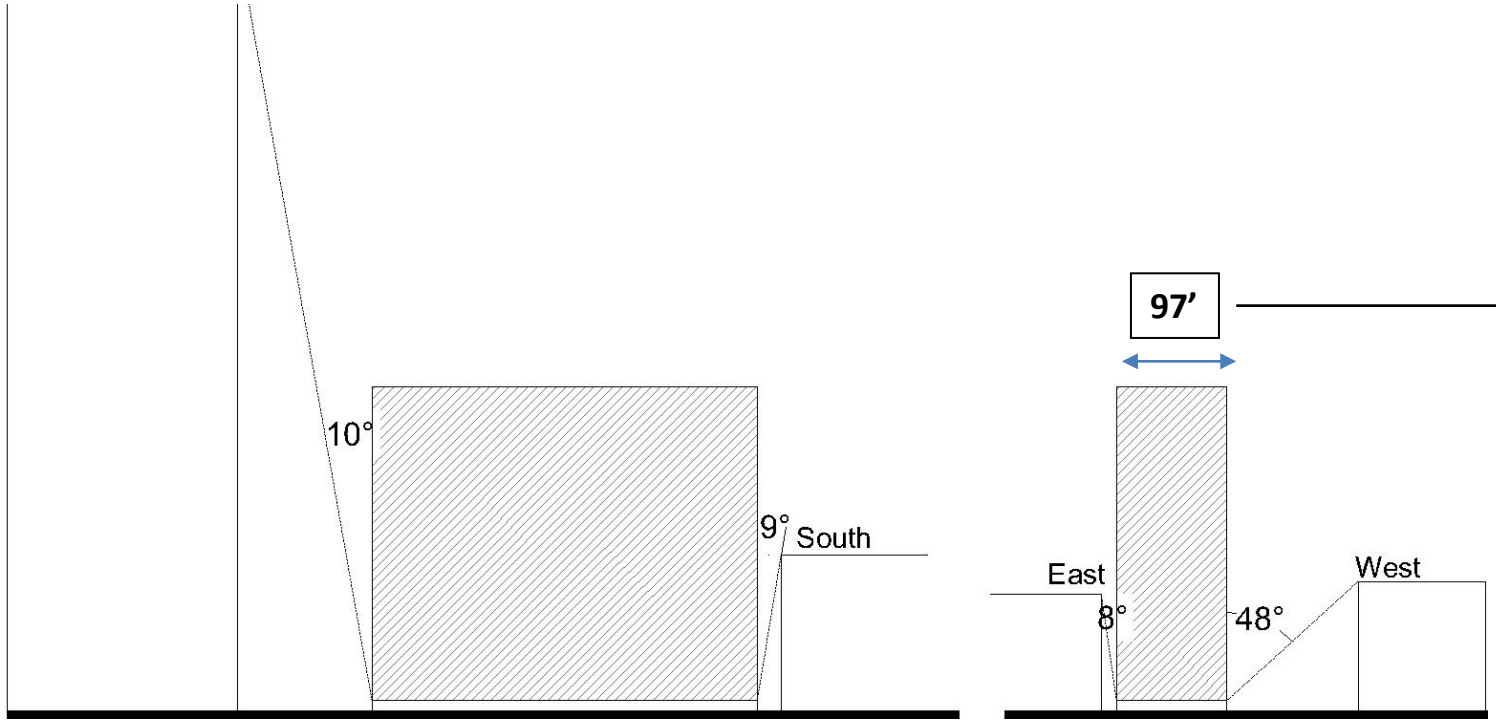



Optimum building orientation for daylight and natural ventilation

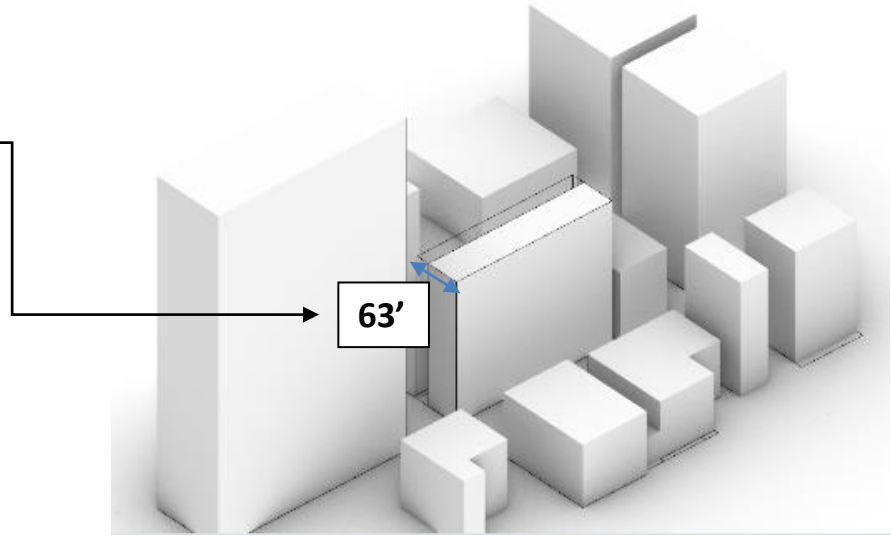



θ * WWR > 2000

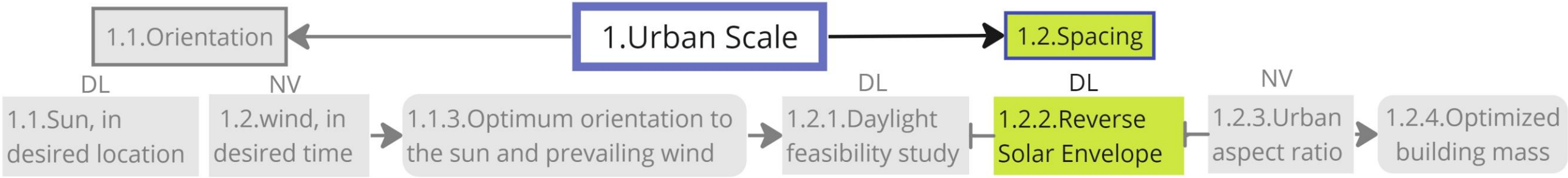
If WWR= 80 % then θ = **25** Degree

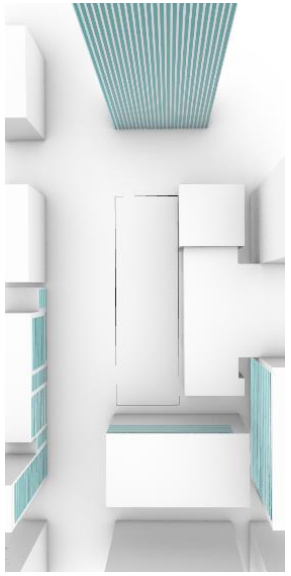


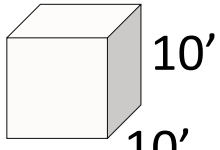

Sky view angle of the building in four directions.



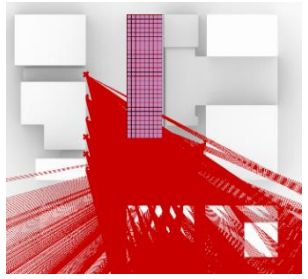

Building bulk to provide daylight access on the east side.



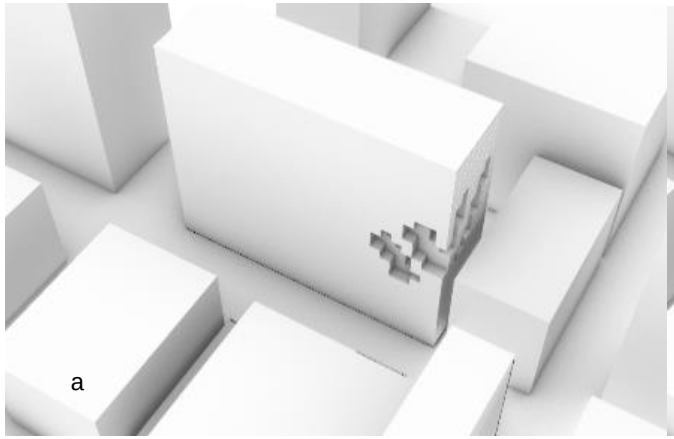





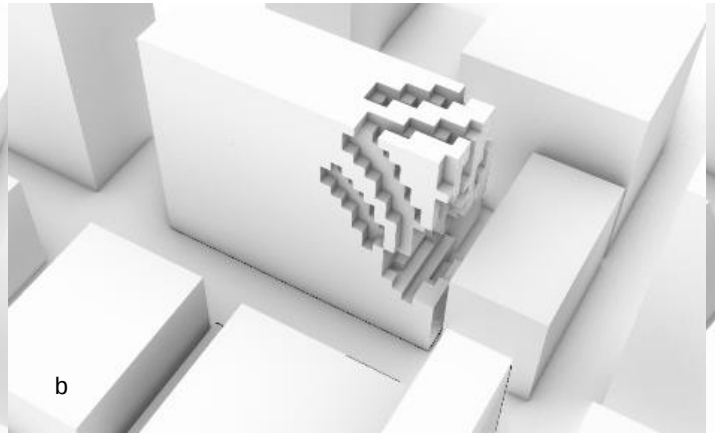

Cell size



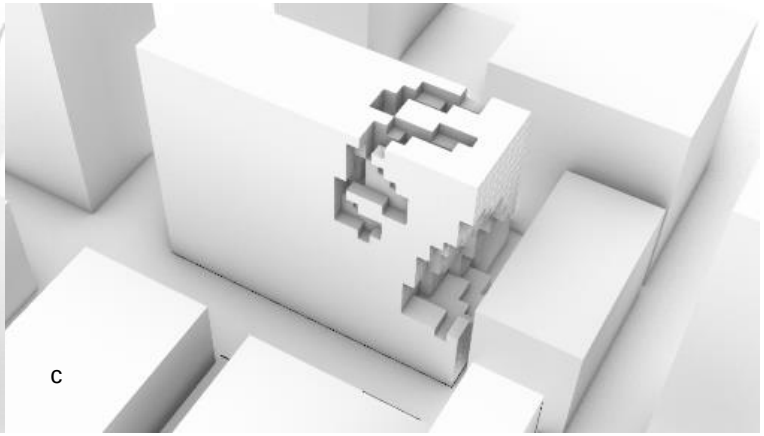
Surrounding building windows



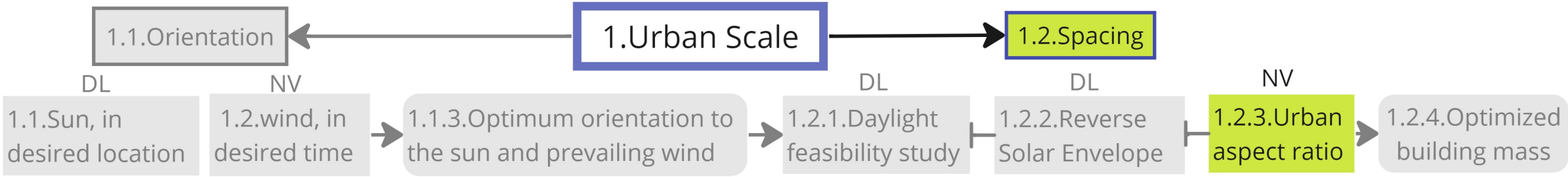

Winter



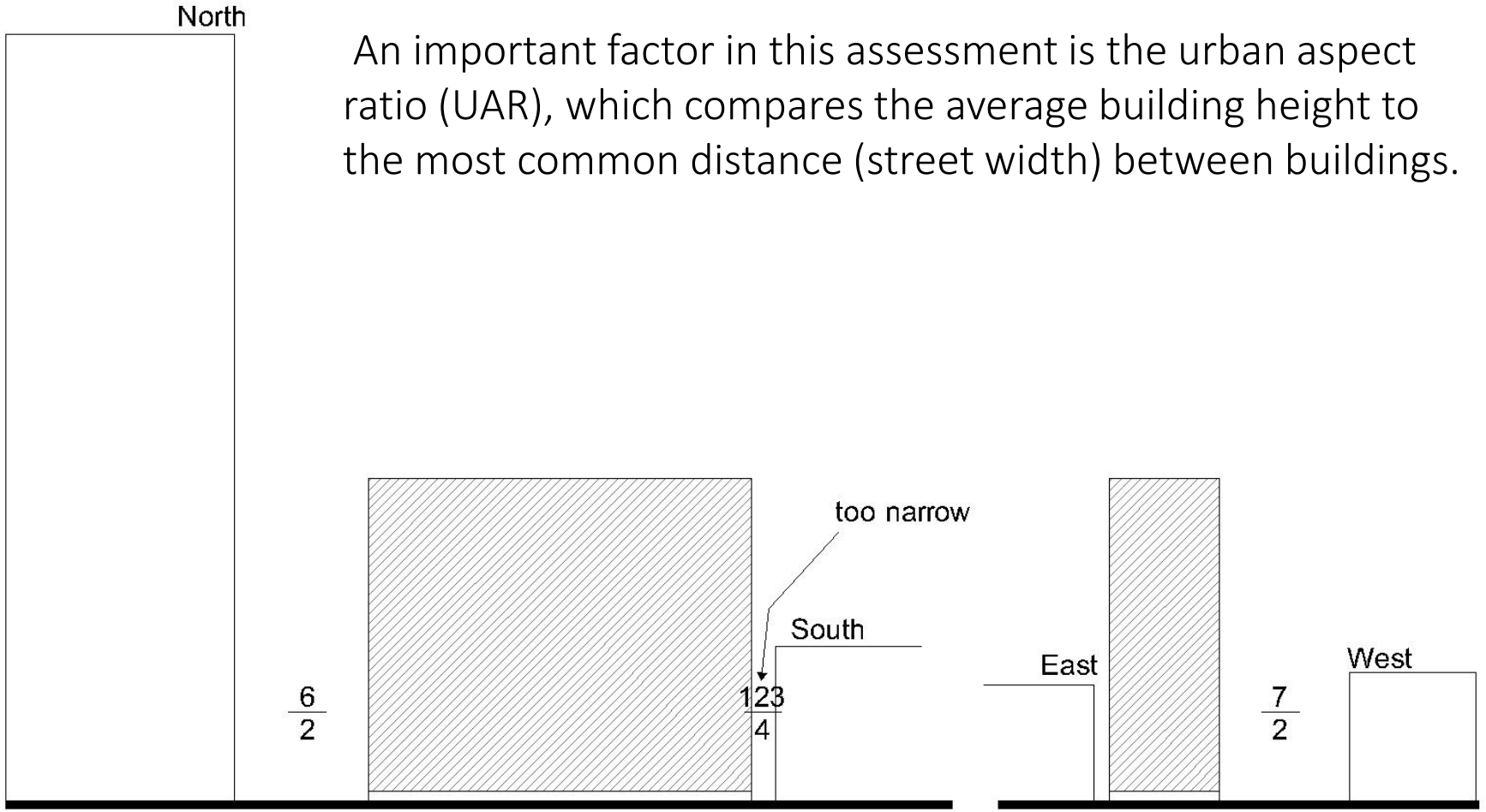

Spring/Fall



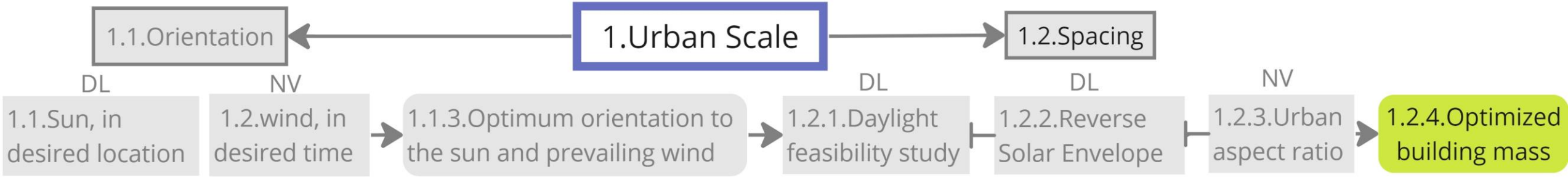

Summer

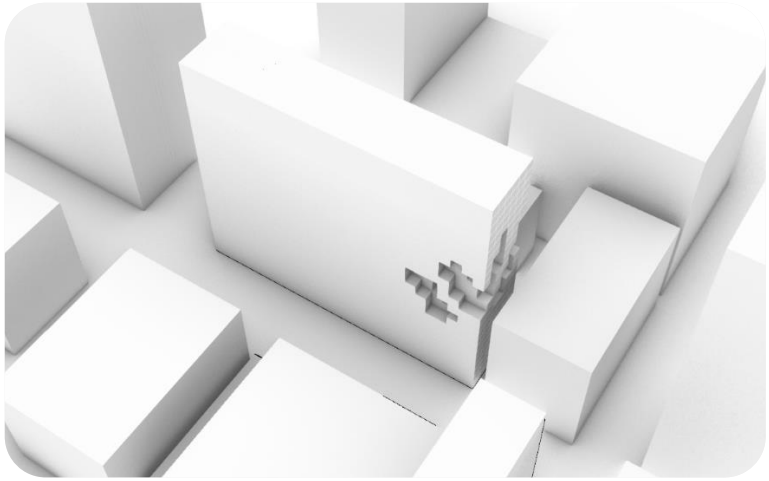



An important factor in this assessment is the urban aspect ratio (UAR), which compares the average building height to the most common distance (street width) between buildings.

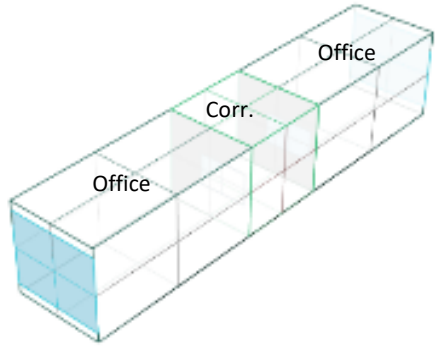



UAR of the building in three directions.

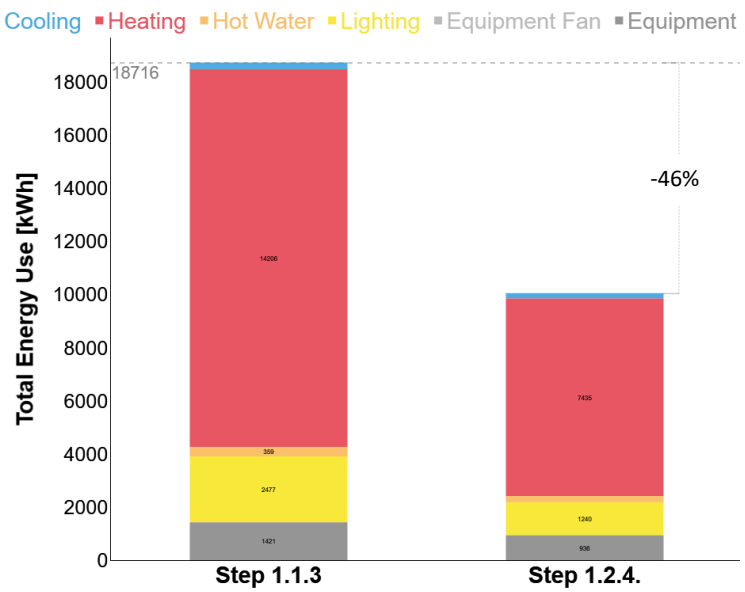


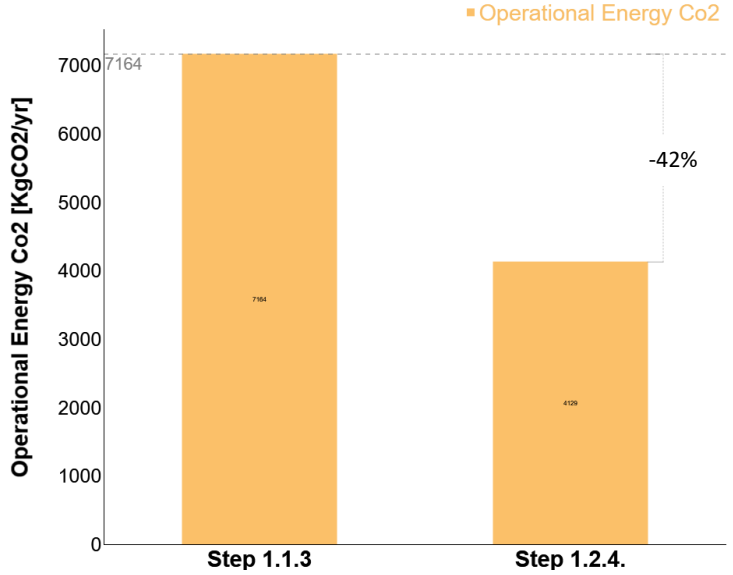



Optimal building mass on an urban scale.




The module for the Climate Studio simulation



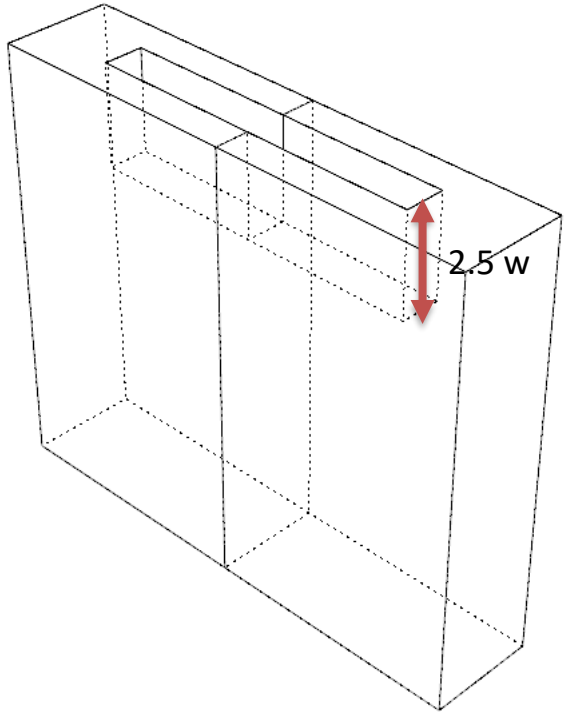

The comparison of energy use and operational carbon of steps 1.1.3 and 1.2.4.

2.1.Building geometry ← 2. Building Scale → 2.2.Floor plan

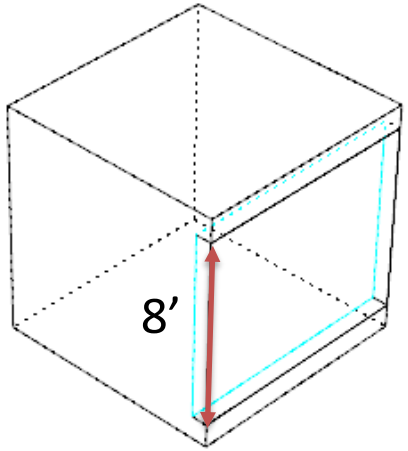
DLNV 2.1.1.Atrium & Courtyard

DLNV 2.1.2.Window wall ratio → 2.1.3.Optimum building geometry → DL NV 2.2.1.Window Head Height – DL NV 2.2.2.Window opening area + 2.2.3.Operational carbon assesment → 2.2.4.Final optimized form

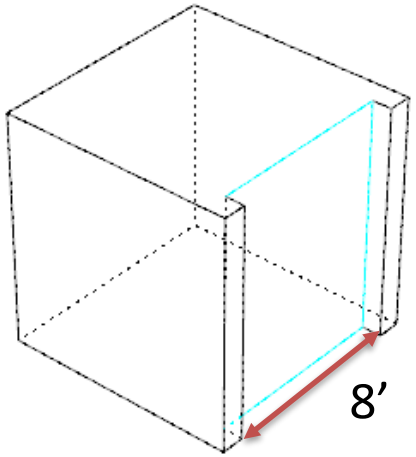
Atrium rule of thumb: Height = 2.5 width




Window wall ratio = 80 %




A




B

2.1.Building geometry

2. Building Scale

2.2.Floor plan

DLNV

2.1.1.Atrium & Courtyard

DLNV

2.1.2.Window wall ratio

2.1.3.Optimum building geometry

DL NV

2.2.1.Window Head Height

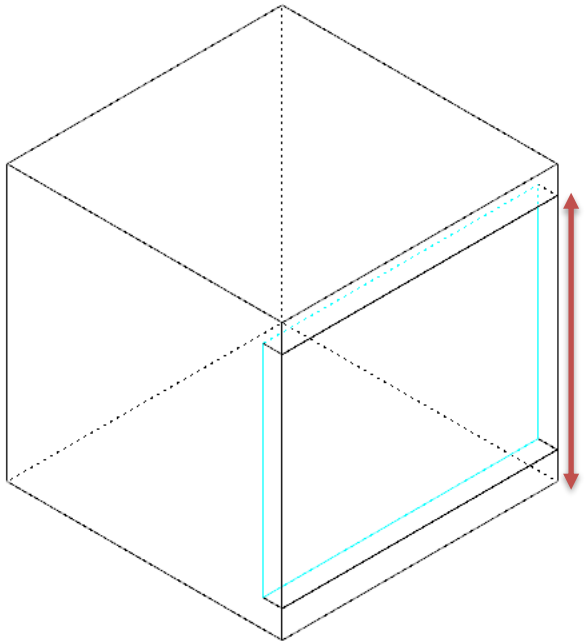
DL NV

2.2.2.Window opening area

2.2.3.Operational carbon assesment

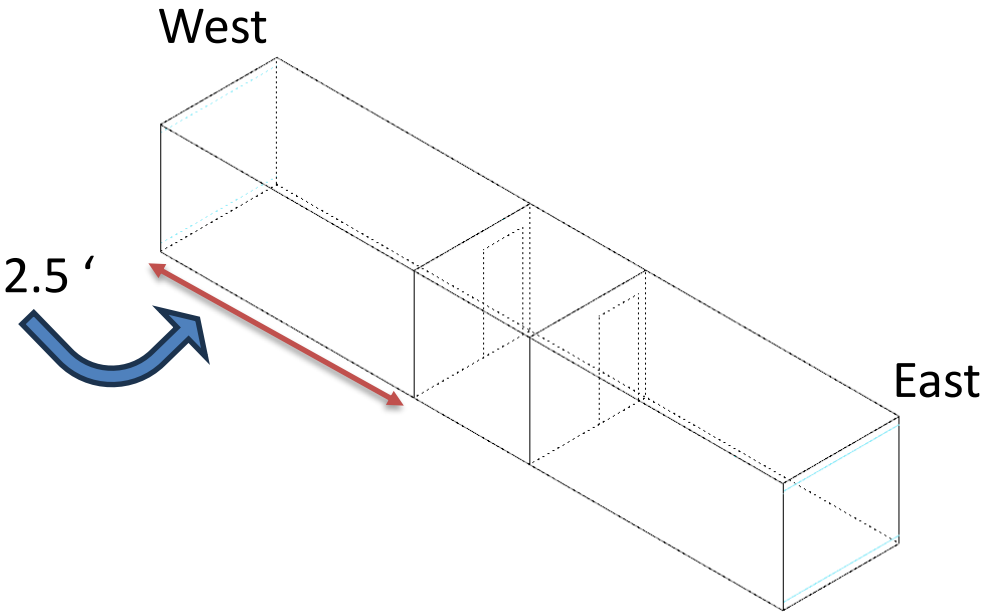
2.2.4.Final optimized form

WHH rule: light penetration depth



A

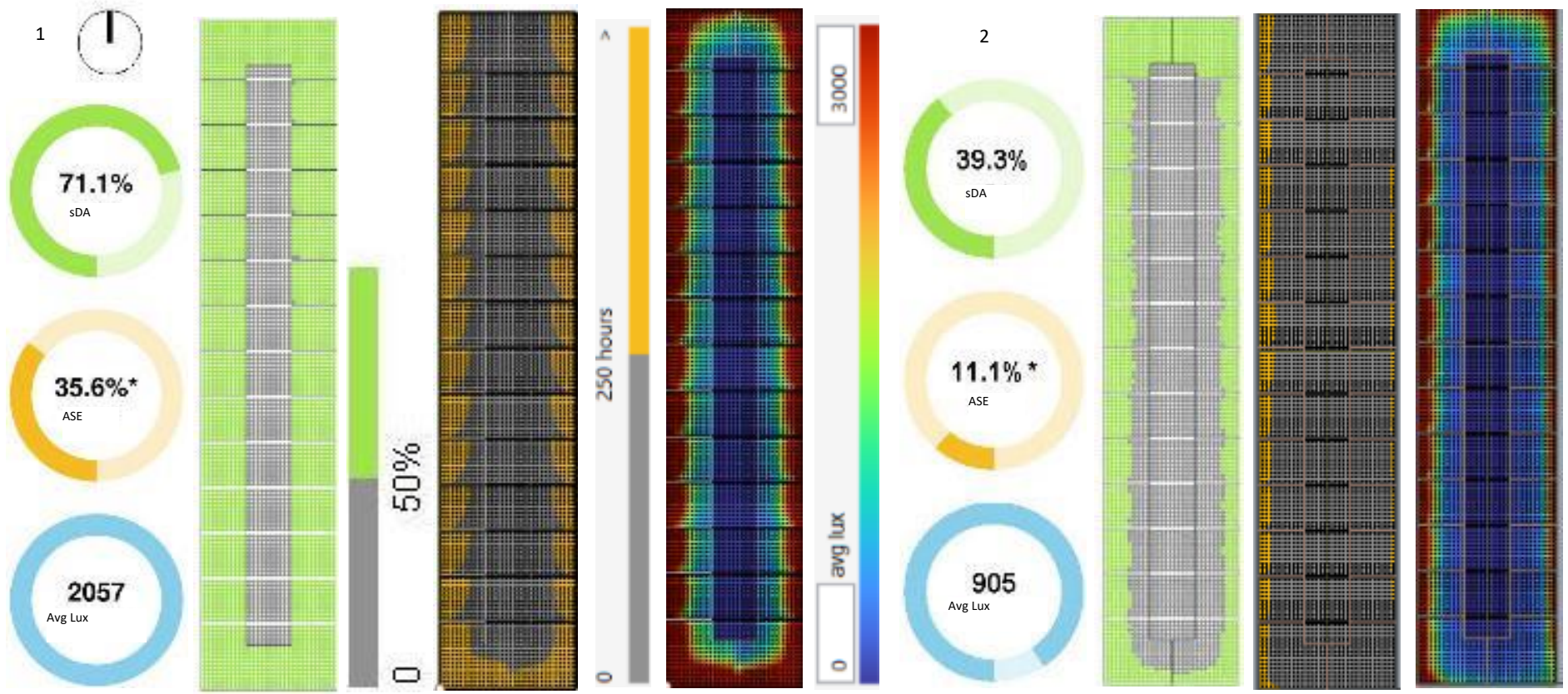
WHH= 9’ ➡ Floor depth = 22.5 ‘



2.1.Building geometry ← 2. Building Scale → 2.2.Floor plan

DLNV 2.1.1.Atrium & Courtyard

DLNV 2.1.2.Window wall ratio → 2.1.3.Optimum building geometry → DL NV 2.2.1.Window Head Height + DL NV 2.2.2.Window opening area + 2.2.3.Operational carbon assesment → 2.2.4.Final optimized form




Daylight availability, Annual Sun Exposure. Illuminance simulation for the (1) fifth floor and (2) 20th floor, and the space layout.

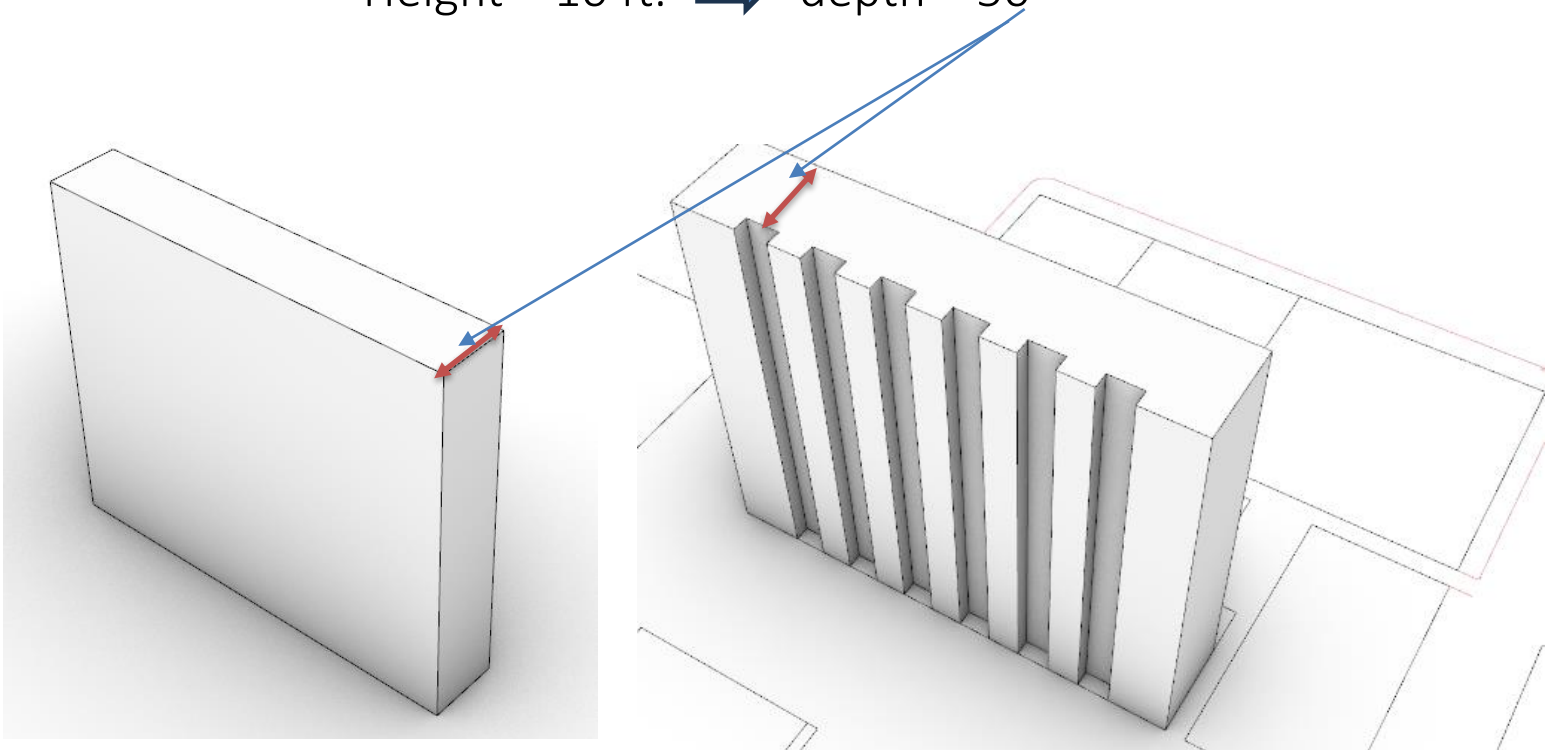
2.1.Building geometry ← 2. Building Scale → 2.2.Floor plan

DLNV 2.1.1.Atrium & Courtyard

DLNV 2.1.2.Window wall ratio → 2.1.3.Optimum building geometry → DL NV 2.2.1.Window Head Height – DL NV 2.2.2.Window opening area + 2.2.3.Operational carbon assesment → 2.2.4.Final optimized form

Cross ventilation: depth =< 5 Height

Height = 10 ft. ➡ depth = 50



Window opening area 10 to 30 % of the room volume

If 30 % of the room volume

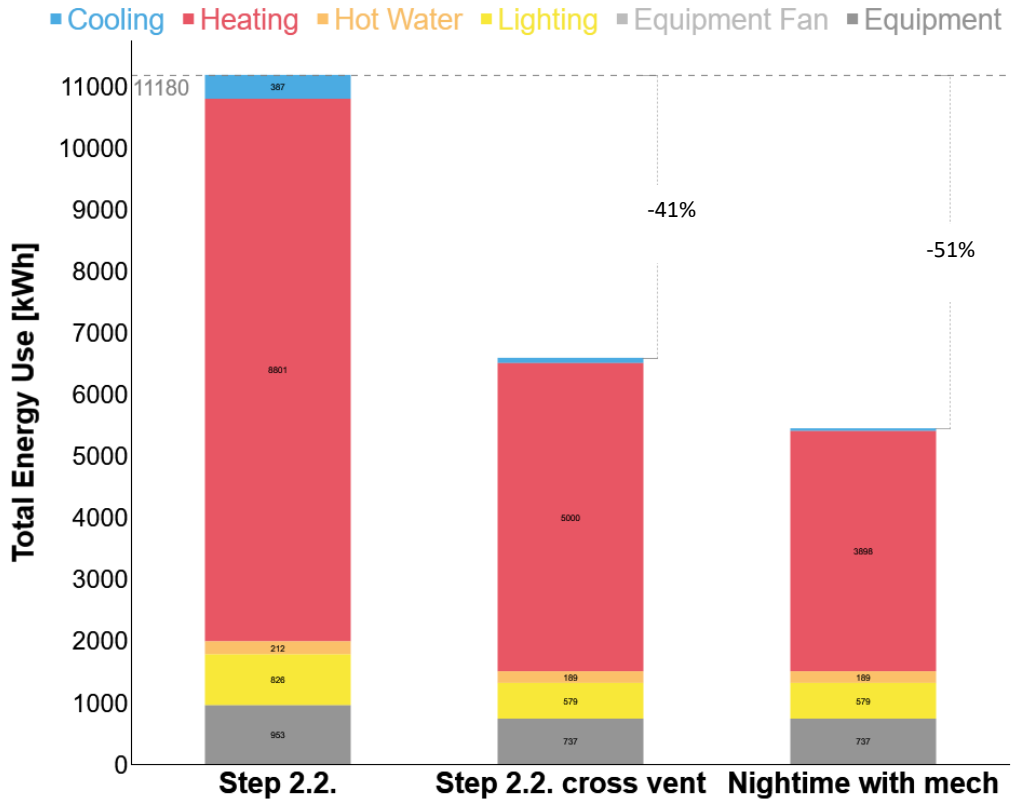
➡ WOA= 60 %

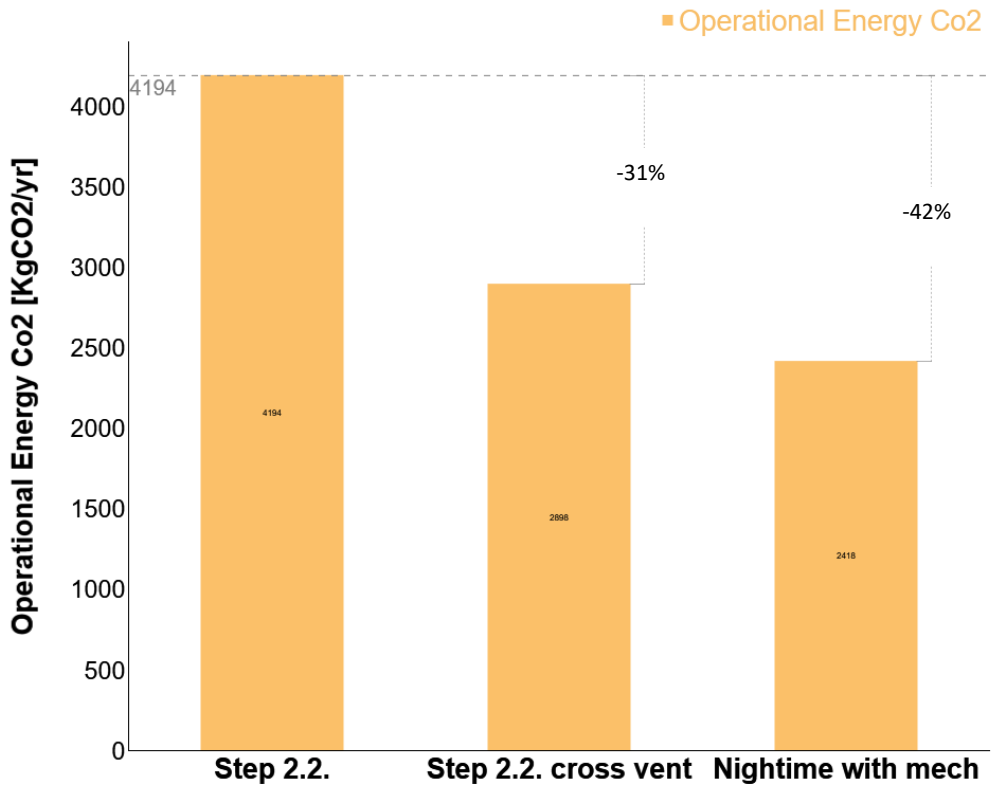
Reducing the width to meet the requirement for cross ventilation.

2.1.Building geometry ← 2. Building Scale → 2.2.Floor plan

DLNV 2.1.1.Atrium & Courtyard

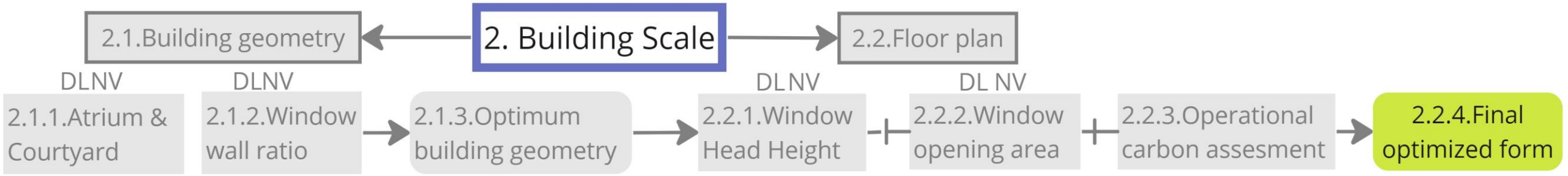
DLNV 2.1.2.Window wall ratio → 2.1.3.Optimum building geometry → DL NV 2.2.1.Window Head Height − DL NV 2.2.2.Window opening area + 2.2.3.Operational carbon assesment → 2.2.4.Final optimized form

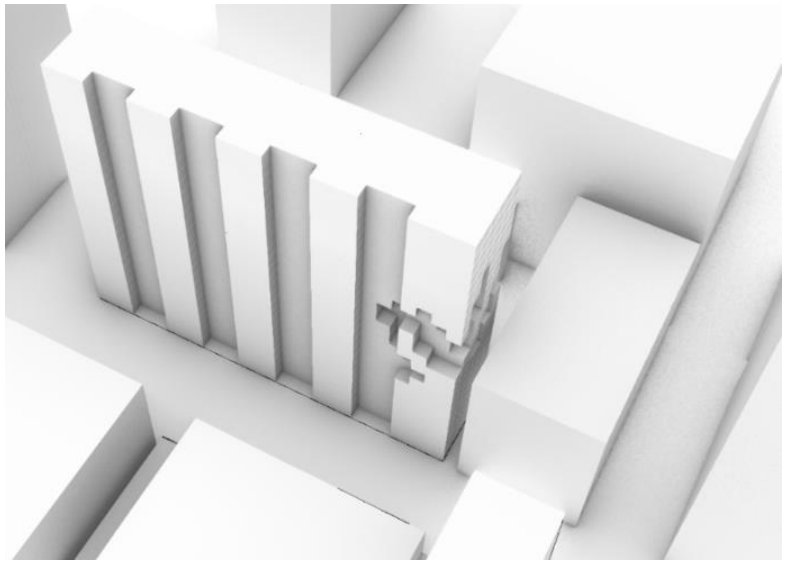


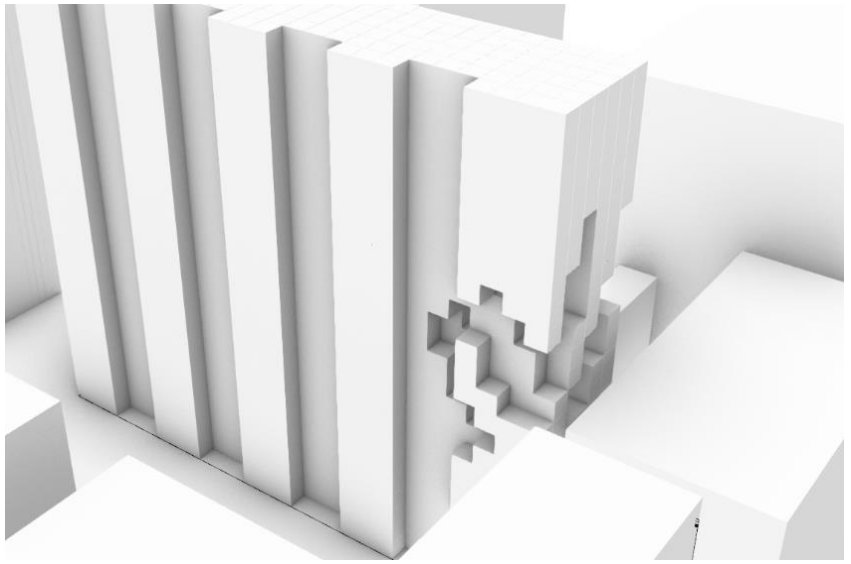



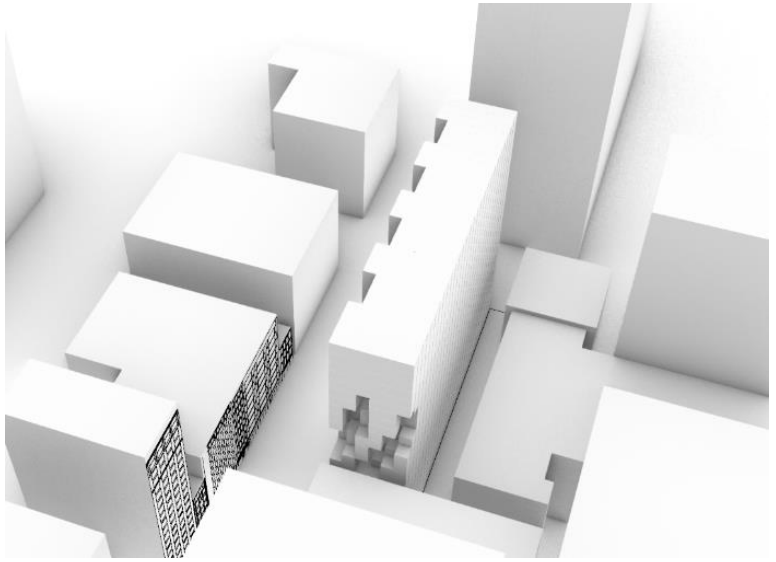

Comparison of simulation results of energy use and operational carbon

In conclusion, combining nighttime ventilation, optimizing natural ventilation, and maximizing daylighting shows significant potential for reducing building energy consumption and operational carbon emissions.



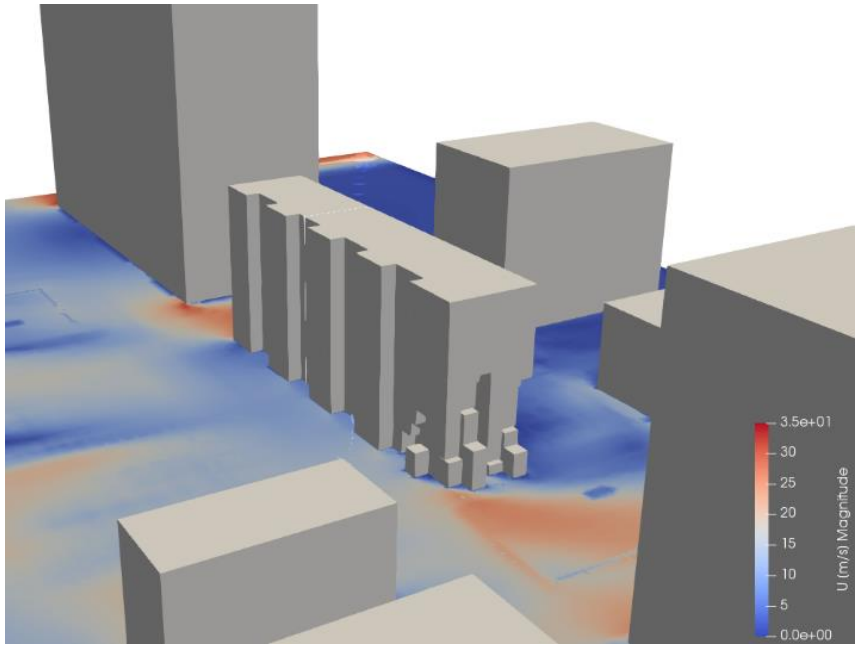



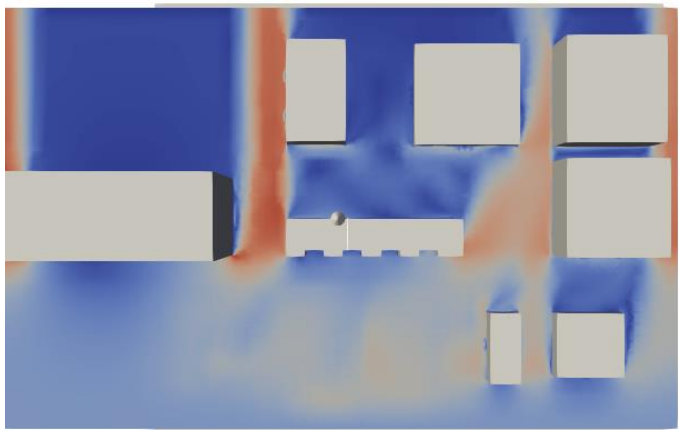


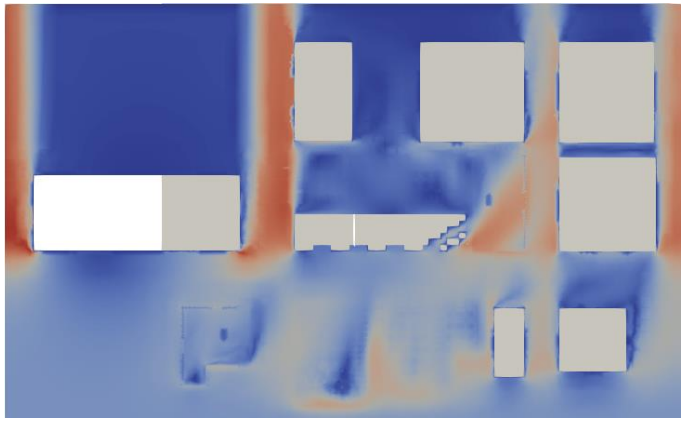


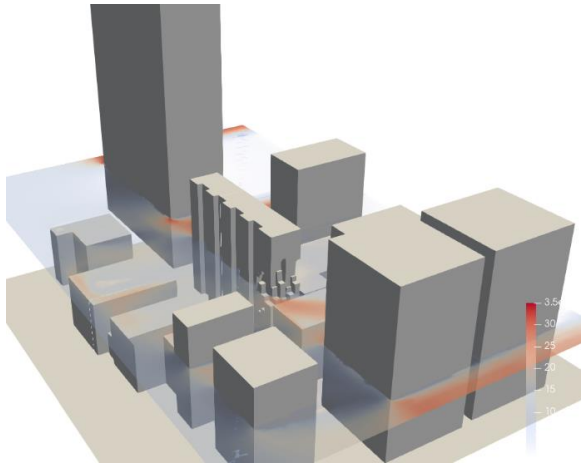
Final form threshold with access to daylight and natural ventilation

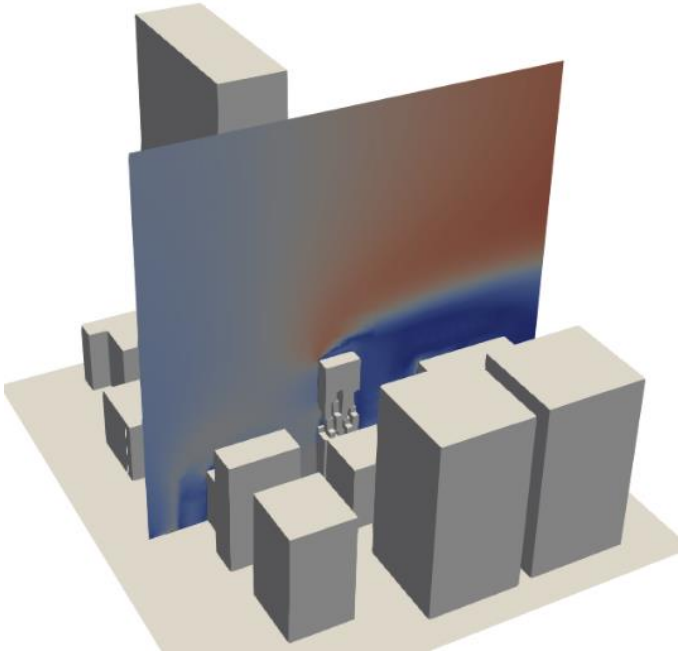
# Simulation result of the final form for natural ventilation

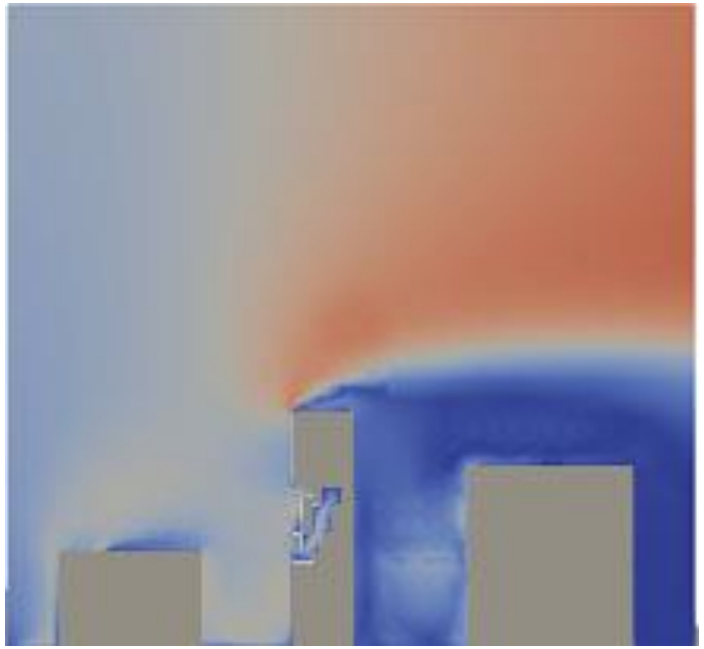










# Thank you!

Ulrike passe: upasse@iastate.edu
Fatemeh Yazdandoust: fatemehyazdandoust@gmail.com