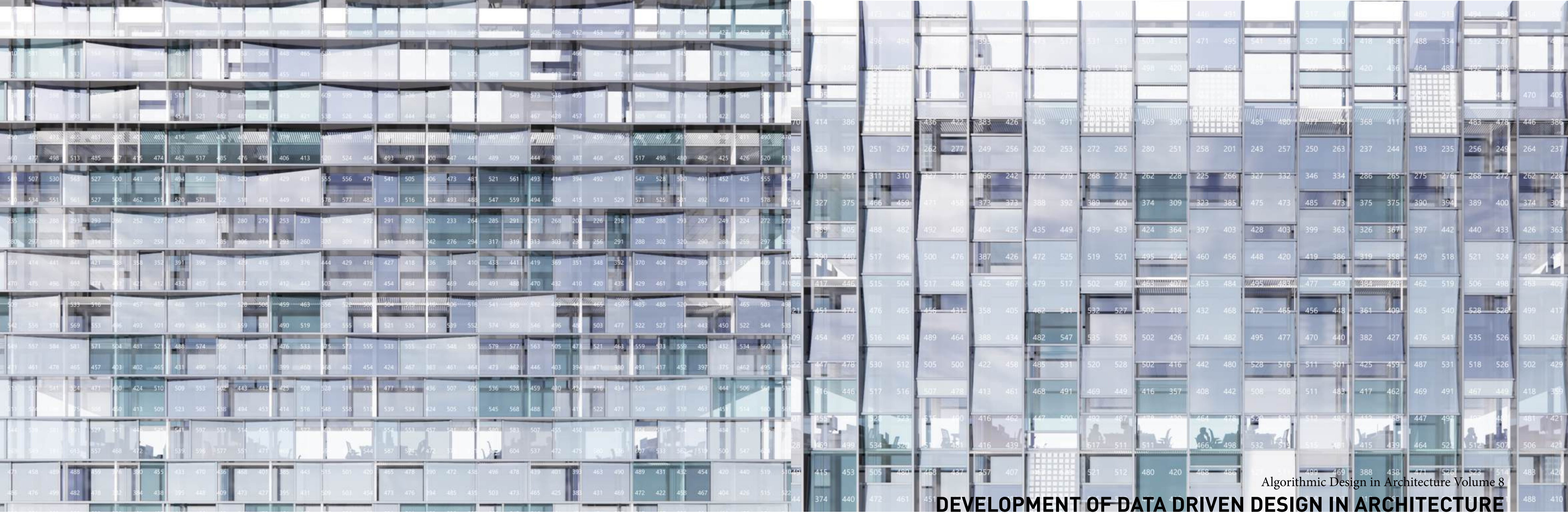


Algorithmic Design in Architecture Volume 8

DEVELOPMENT OF DATA DRIVEN DESIGN IN ARCHITECTURE

PART - I

DEVELOPMENT OF DATA DRIVEN DESIGN IN ARCHITECTURE PT.I

Algorithmic Design in Architecture Volume 8

H Architecture

This research paper was written and edited by Jake Han at H Architecture, 2023.

H Architecture

CONTENTS

ABSTRACT

ABSTRACT

This study is part of the "Computational Design in Building Information Modeling (BIM)" initiative, led by H Architecture P.C. in New York, focusing on integrating computational design research with practical methodologies in architectural practice. Over seven years since its inception in 2017, significant advancements have occurred in data management methodologies, associated technologies, and software accessibility.

The research introduces recent technological advancements in data-driven design and identifies newly pertinent datasets for architectural practice, with Grasshopper serving as the primary design tool.

Environmental analysis capabilities within Grasshopper, such as Ladybug and Honeybee, have evolved into a collaborative platform named 'Pollination', which includes tools like Dragonfly for district-scale energy simulation modeling and Butterfly for Computational Fluid Dynamics (CFD) simulations, facilitating interdisciplinary practice.

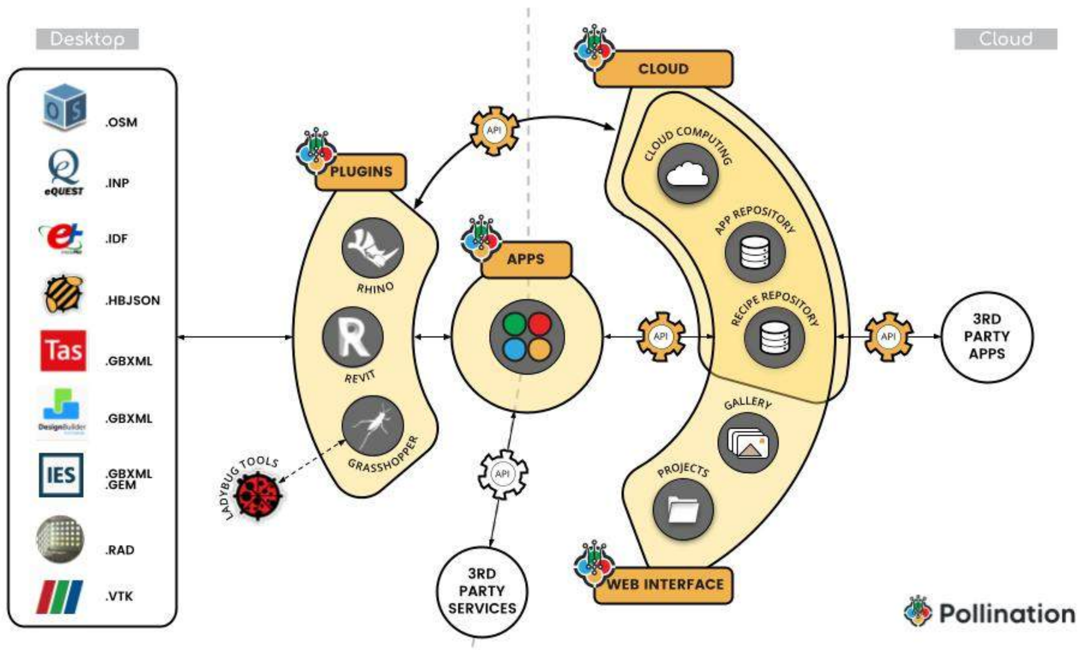
Physics analysis tools like Kangaroo Physics and Karamba 3D, initially introduced in previous volumes, have undergone further development to enhance their capabilities for physical and structural simulation, with Kangaroo Physics integrated into Grasshopper as a built-in plugin and Karamba 3D continues to amass a wealth of case study projects on a global scale.

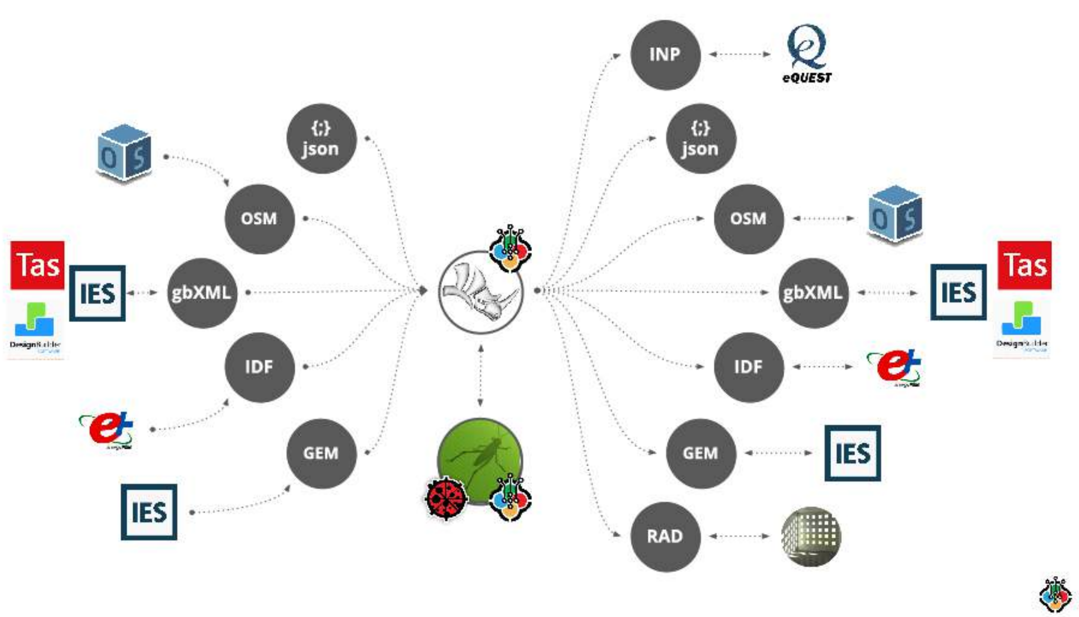
Geographic Information System (GIS) data plays a crucial role in data-centric decision-making processes, with tools like ArcGIS, Elk, TT Toolbox, and Open Street Map aiding in data conversion for compatibility with Grasshopper. These datasets are sourced from governmental or research institutions, with the City of New York's 'NYC Open Data' initiative providing free access to various public datasets, particularly significant during the planning phase for its implications on project outcomes.

The research presents preliminary case studies demonstrating the application of singular or multiple datasets in design and decision-making processes, with future studies aiming to explore more intricate iterations to understand the complexities of integrating diverse datasets within design frameworks.

INTRODUCTION

Pollination, Energy simulation Platform for AEC,
https://www.pollination.solutions/





INTRODUCTION

The culture of data-driven and algorithmic design, closely associated with parametric architecture, has become a foundational element in the architectural discipline over recent decades. This approach transcends mere aesthetic complexity, addressing the pressing environmental responsibilities that define modern architectural practice. As climate challenges grow more acute, the imperative for performance-oriented design—guided by ethical considerations, regulatory frameworks, and incentivized practices—has become increasingly paramount.

Utilizing primary computational tools such as Rhino 8 and Grasshopper, this design methodology enables the exploration of innovative and contextually responsive solutions. Through the strategic application of specialized plugins—including Ladybug for environmental analysis, Kangaroo Physics for structural simulations, and GIS-related programs for spatial data integration—abstract data is systematically translated into actionable design strategies, optimizing both performance and sustainability.

Furthermore, the integration of computational modeling, research, and development within the professional architectural practice serves as a conduit for accessing expert knowledge. This research-driven approach provides a critical interface among designers, project managers, and interdisciplinary teams, fostering a collaborative environment that broadens perspectives and cultivates unique insights. The result is a design process that is not only efficient and precise but also reflective of contemporary environmental and ethical imperatives.

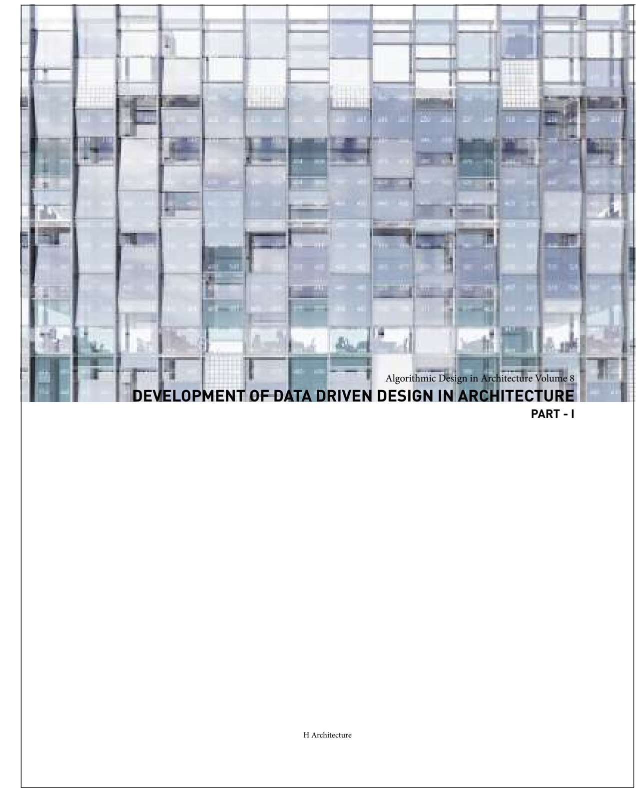
In this context, data and design converge seamlessly, with algorithmic methodologies not only guiding the creation of innovative built environments but also ensuring that these spaces are deeply attuned to the complex, evolving demands of our time—both in terms of sustainability and social responsibility.

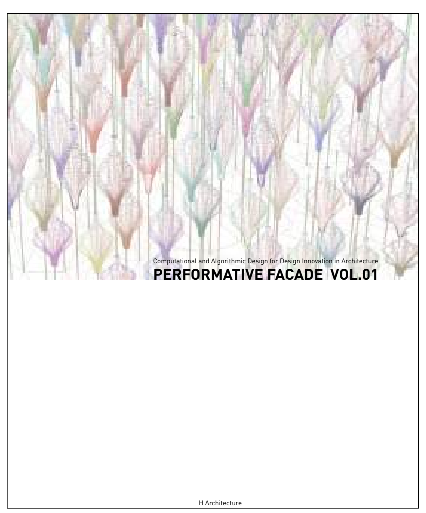
DEVELOPMENT OF THE DATA TREATMENT TECHNOLOGY

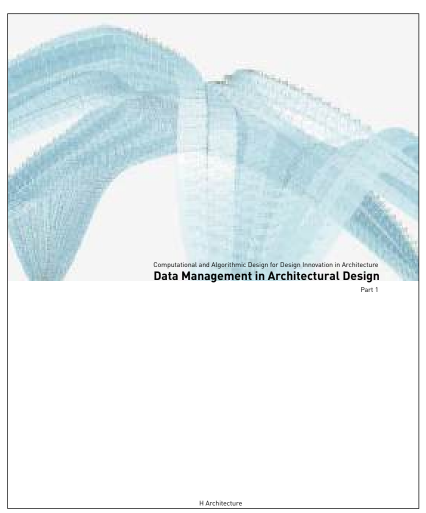
H Architecture, esteemed for its ongoing research and application in various projects, has conducted a decade of independent research. Over the past seven years, this focus has sharpened around data-driven design techniques and their application within design decision-making processes. As technological advancements persist, the emergence of new methods and applications necessitates the continual refinement of previously established approaches.

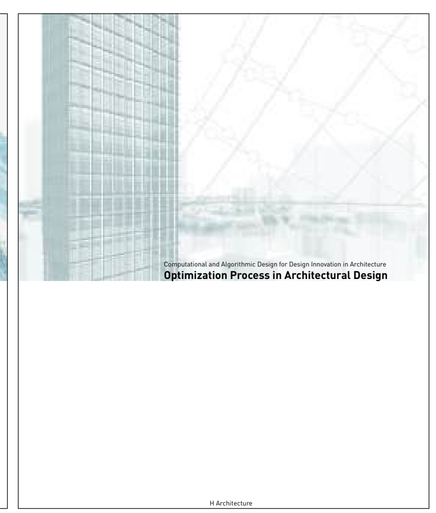
Environmental data, initially gathered through Ladybug Tools, has been significantly enhanced by the integration of custom Python scripts designed for daylight and energy simulations, district-scale weather and energy analyses, and advanced computational fluid dynamics (CFD) simulations. This integrated approach, referred to as Pollination, is offered as an open-source data collection platform within the Grasshopper environment, facilitating interdisciplinary collaboration among architects, engineers, computational specialists, and construction professionals.

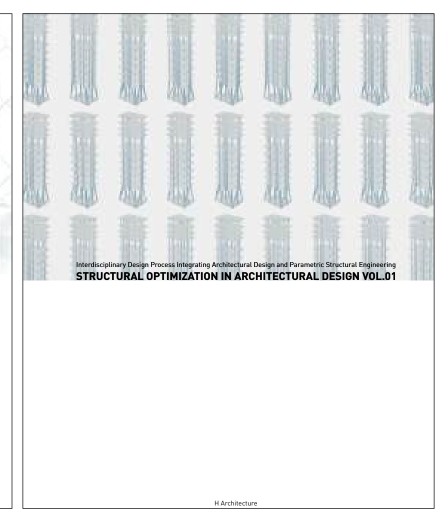
Physics data, accessible through Kangaroo Physics, adheres to principles such as Hooke's Law and geometric relationships that reflect the elastic behavior of materials, governed by their inherent properties and units. The transition from the earlier version of Kangaroo Physics (K1), which employed 'Dynamic Relaxation,' to the more recent version (K2), introduces a methodology known as 'Projective Dynamics.' This evolution enables more direct and real-time simulation results, providing a more efficient and precise form-finding process

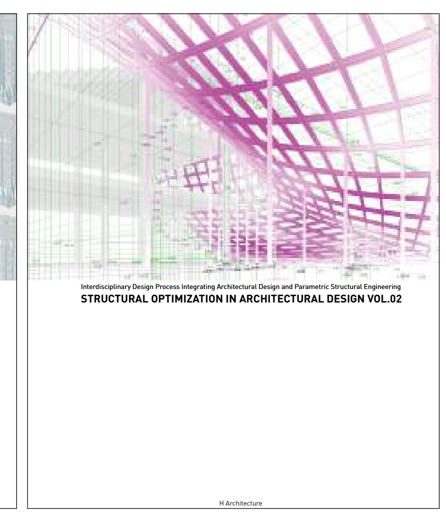


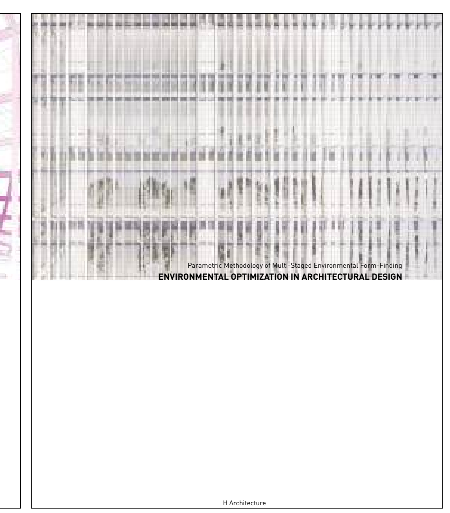


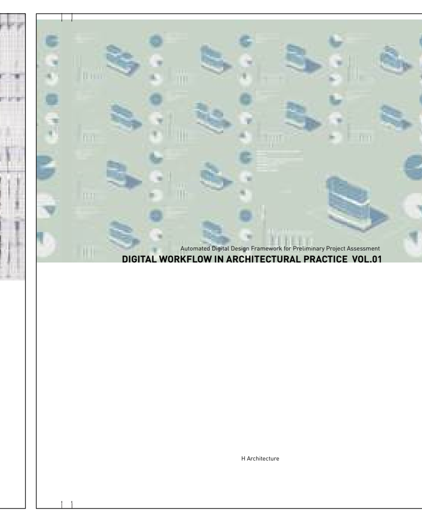










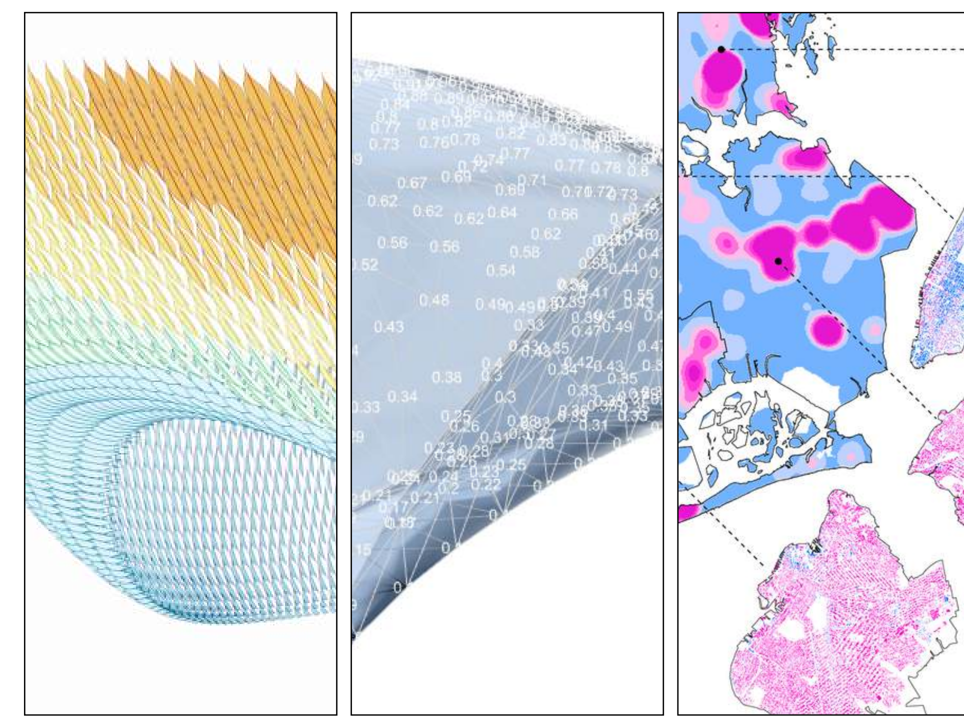


CSVCC , Roof design options for simulation evaluation

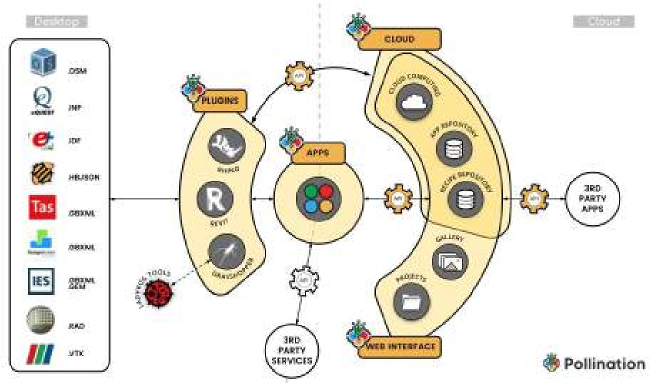
OBJECTIVES

This paper updates previously introduced energy analysis and physical form-finding techniques, emphasizing the significant advancements achieved compared to earlier methodologies. Additionally, it introduces GIS data and explores its application within the design process, showcasing its potential to enrich the interdisciplinary discourse among all stakeholders.

GIS data is newly introduced as a powerful tool for analyzing and understanding the artificial, cultural, and social dimensions of urban environments. GIS data is sourced from various platforms, including governmental agencies, research institutions, corporate entities, infrastructure authorities, and military organizations, thereby enhancing the contextual analysis within the design process.



ENVIRONMENTAL DATA



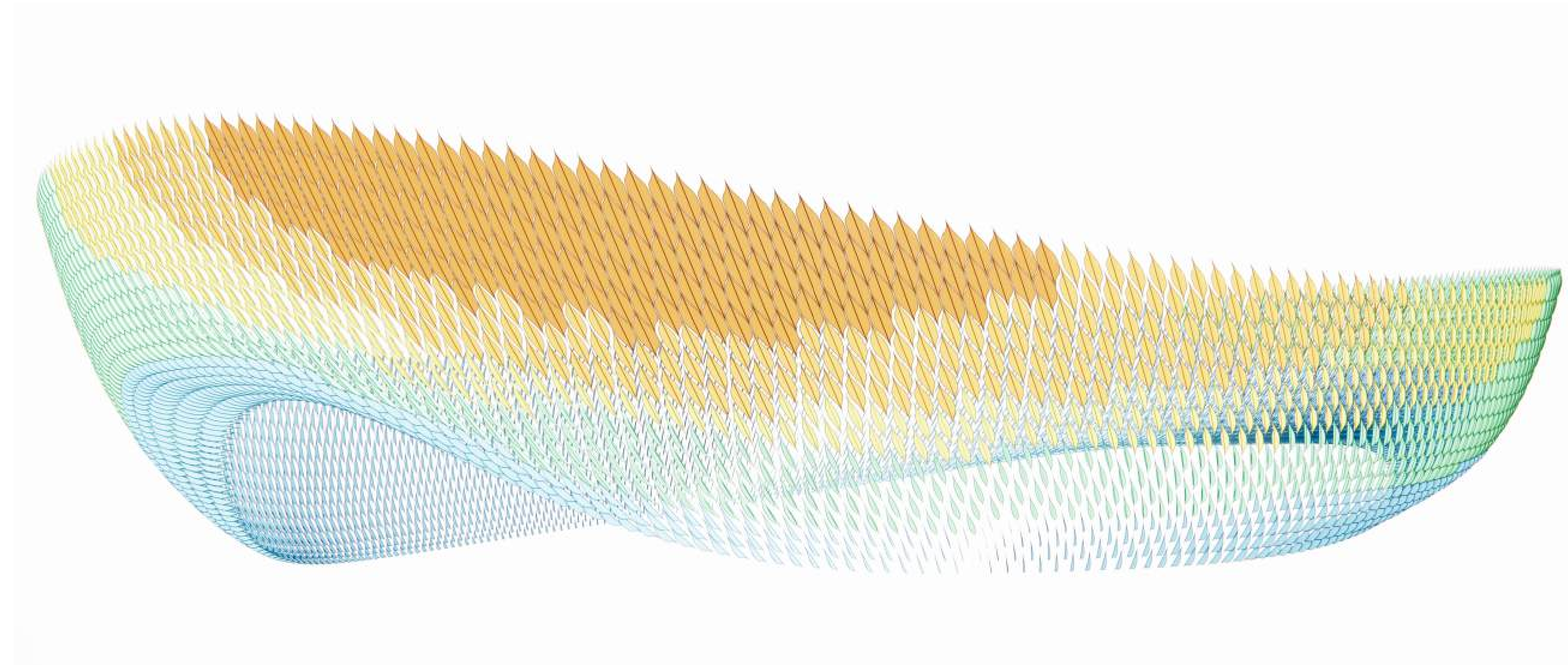
ENVIRONMENTAL DATA

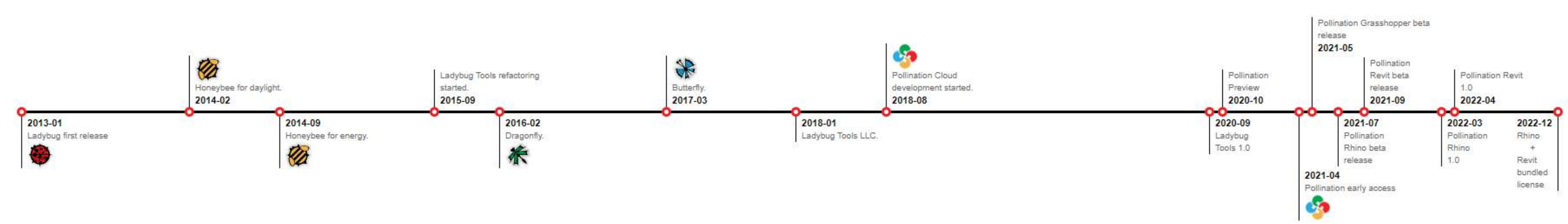
Environmental data in architectural design refers to the quantitative and qualitative information related to the natural and built environment that influences and informs the design process. This data encompasses a wide range of factors that affect building performance, occupant comfort, and the overall sustainability of the project. These environmental data include
Climate data, Daylighting, Solar Access, Thermal comfort, Efficiency in Energy usage, Air quality and movement, Acoustics, etc.

Ladybug Tools is a suite of free and open-source applications that allows the access and analysis of the above environmental data. Developed for architects, engineers, and environmental consultants, Ladybug Tools facilitates the creation of sustainable building designs by providing a robust platform for energy and daylighting simulations. The tools are widely used within the computational design community due to their integration with popular software such as Rhinoceros 3D and Grasshopper.

Ladybug Tools comprises several components, each serving a specific purpose in environmental analysis. Ladybug focuses on climate data analysis, providing users with visualizations of weather data and its impact on building performance. Honeybee enhances energy modeling and daylighting analysis, offering compatibility with industry-standard engines like EnergyPlus and Radiance. Other components, such as Butterfly and Dragonfly, extend the capabilities to computational fluid dynamics (CFD) simulations and urban scale modeling, respectively.

The comprehensive nature of Ladybug Tools allows professionals to conduct detailed environmental assessments, optimize building performance, and make informed decisions during the design process. By enabling the simulation of various environmental factors, Ladybug Tools plays a crucial role in the advancement of sustainable architecture and engineering practices.



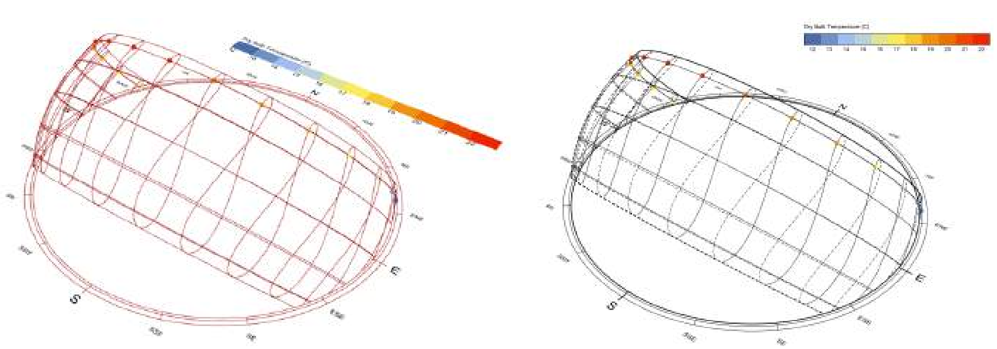


FEATURED TECHNICAL IMPROVEMENT

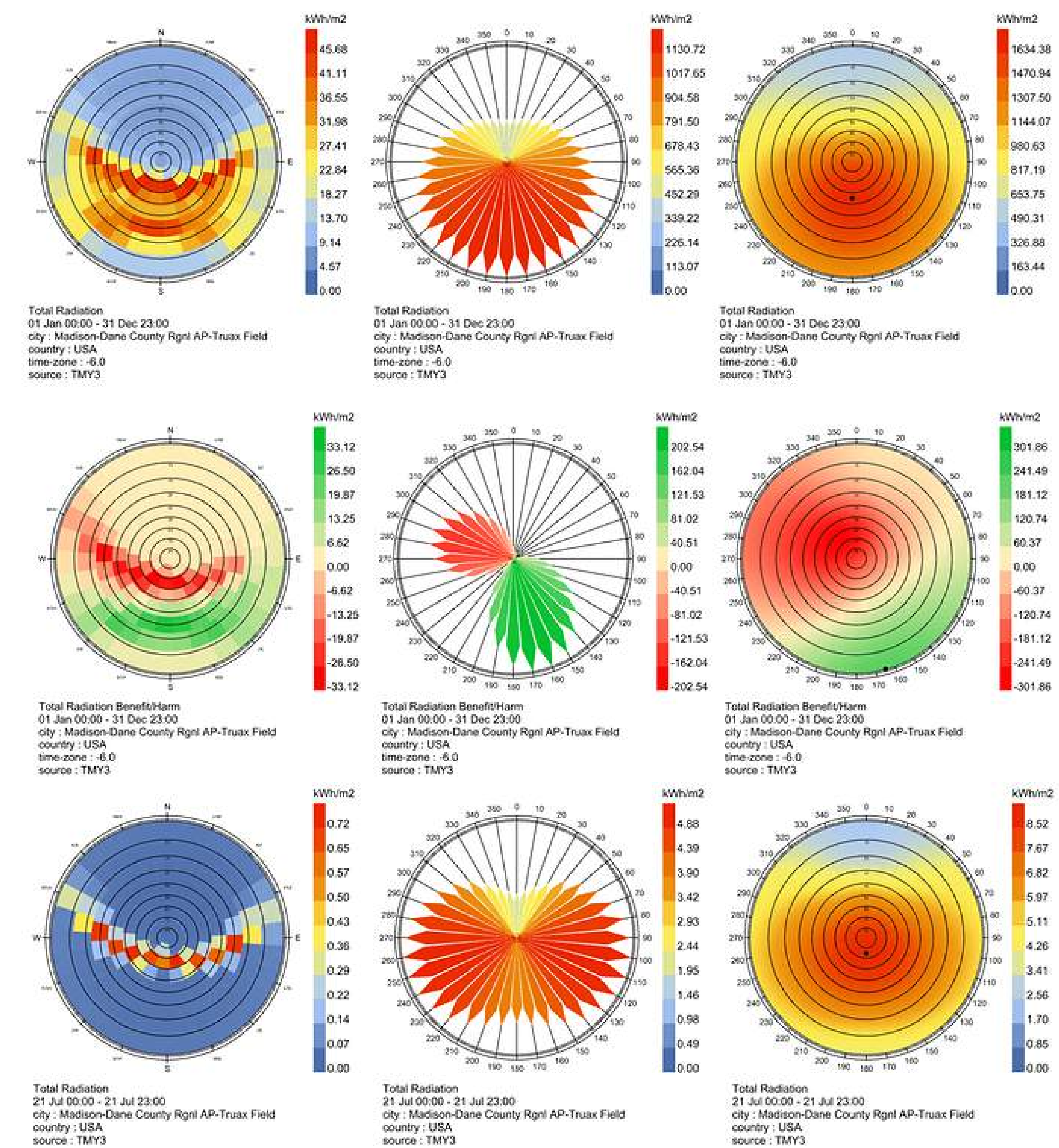
Pollination, which includes various environmental simulation plug-ins such as Ladybug, Honeybee, Dragonfly, Ironbug, and others, has introduced several key features that impact the practical use of the program. These features include improvements in EPW access, visualization enhancements, new functions, chart capabilities, diagram representation, surface ray tracing, annual data enhancement, and an HDR feature for daylight analysis.

With these advancements, the enhanced functions of the newer versions of Ladybug and Honeybee enable faster simulations with improved accuracy and a more comprehensive database, in contrast to the earlier versions.

This research script utilizes these advancements and compares them to the older script to gain a deeper understanding of the improvements. By evaluating the differences in simulation speed, accuracy, and data handling, the study aims to demonstrate how the new features enhance overall performance and provide more reliable results.



Left: Old Ladybug sun path diagram (Before release version 1.6.0)
Right: Refined Ladybug sun path diagram (After release version 1.6.0)



New Radiation Graphics, including Radiation Benefit.
From the Top : Maximizing Passive solar Heating while mininminzing Photovoltaics,
Maximizing Passive Solar Hearing While Minimizing Cooling Load,
Minimizing Solar Gain on the Summer Design Day

ENVIRONMENTAL DATA

CASE INTRODUCTION

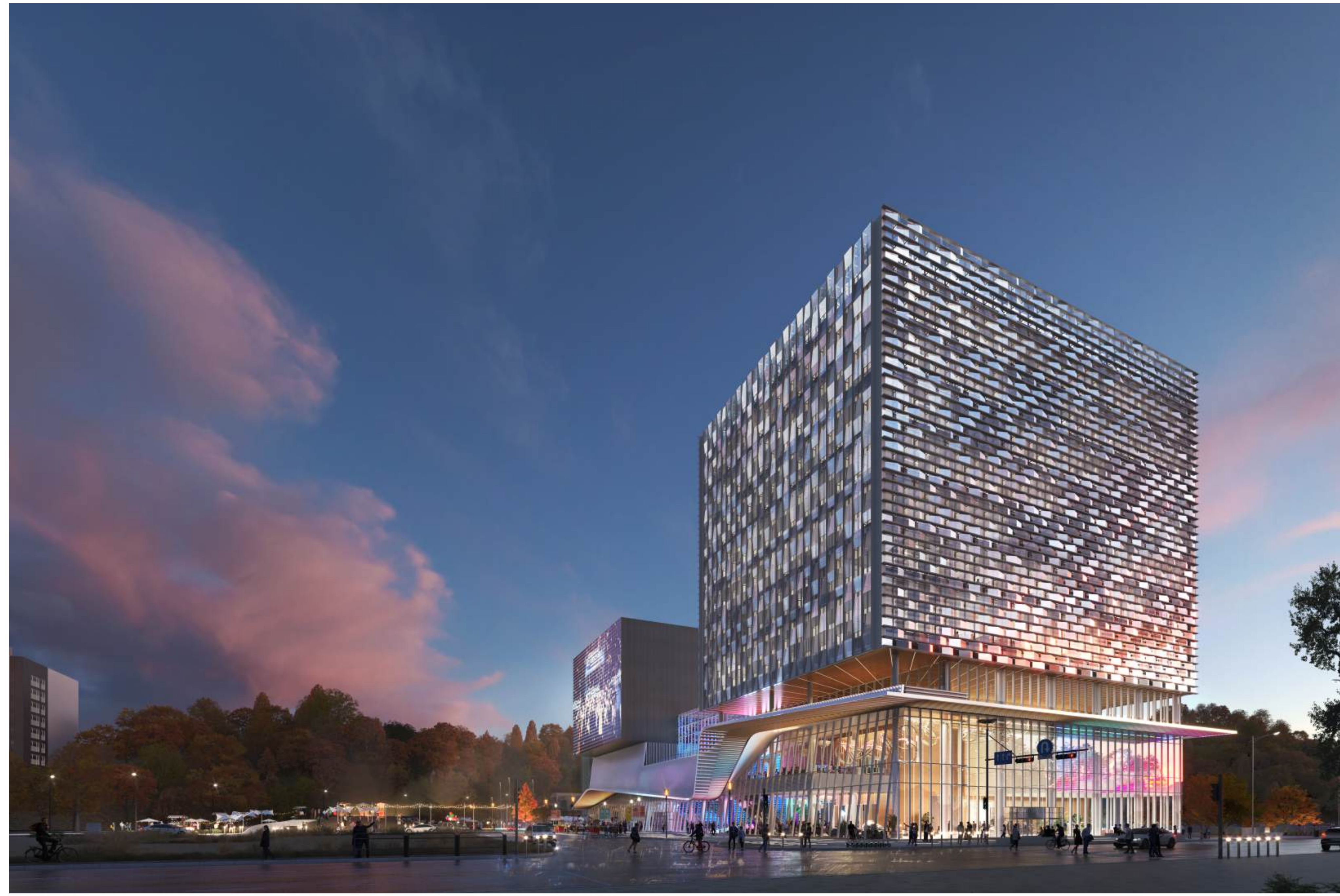
Convergence Special Video Content Cluster

CASE STUDIES

Roof Design for Exhibition Atrium
Double Skin Facade for Office Space

CONVERGENCE SPECIAL VIDEO CONTENT CLUSTER

The project is located historic science park complex in Dajeon, South Korea. As a new building for the video contents center, the building contains programs of studios for video contents and special video effects creation, office space for leasing and atrium space connects the two programs. Due to the nature of the site character, studio box and office towers are aligned in south-north axis with office to have an exposure to the south side, which requires specific shading devices for the interior daylighting quality. Also, as project proceeds, atrium space in the middle required to hold a temporal exhibition, the program requires the daylighting control as well.



ENVIRONMENTAL DATA DRIVEN DESIGN

Roof Design for Exhibition Atrium

The original design of the roof for the glass atrium has been revised to accommodate an exhibition program. It must regulate both annual direct and indirect daylighting while providing sufficient space and structural support for projection devices. Appropriate standard measurements of lighting levels are required, supported by proper simulation techniques to guarantee the operable level of light for the exhibition.

Double Skin Facade for Office Space

The office space requires specialized shading devices to optimize environmental performance. The facade must balance thermal efficiency with anti-glare double skins to enhance both energy performance and user comfort. The design of facade modules and shading devices is tailored to the orientation of each façade. The south-facing facade features louvers, while the east- and west-facing facades are equipped with fins to ensure effective thermal regulation and shading.


Roof Design For Exhibition Atrium

Design Criteria

During the competition phase of the project, atrium was originally designed for rest area with some installation art and multi-purpose space with abundant natural light, which create outdoor-like indoor space that smoothly connecting two buildings with different programs. During the design development, the atrium changed to hold exhibition program, which requires specific light level requirements, and the original design with the glazing needed to be revised for changed use of the space.

Simulation Objectives

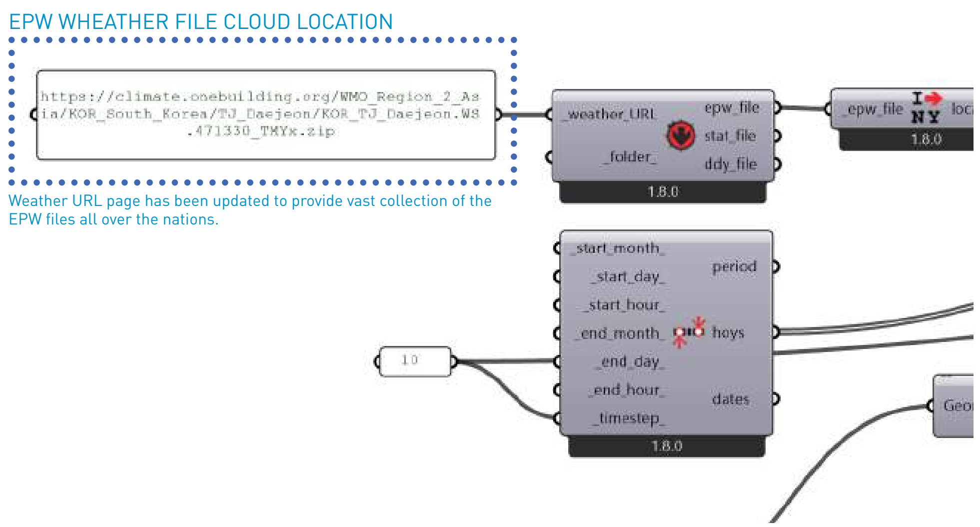
Environmental simulation used in this case is to identify the problem, suggest solution and evaluate design option for the decision making. Direct sun hour analysis and HB Daylight analysis are used to identify the problem and HB daylight analysis and additional quantitative representation techniques are used for the evaluation. Appropriate light level was set based on international lighting standard like by CIBSE(Charted Institute of Building Services Engineers) and ASHRAE (American Society of Heating, Refrigerating and Air-conditioning Engineers).

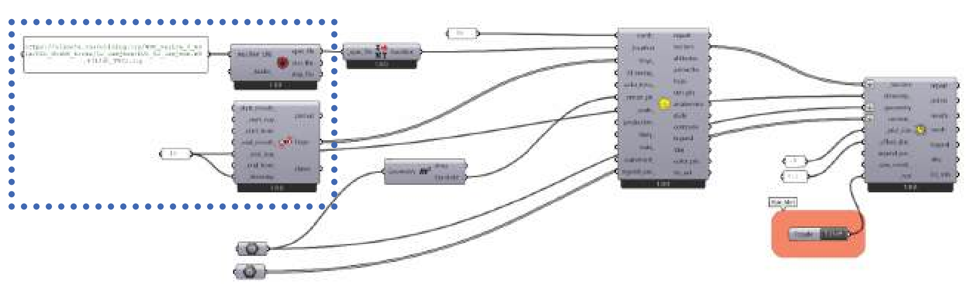
Pre-defined Restrictions

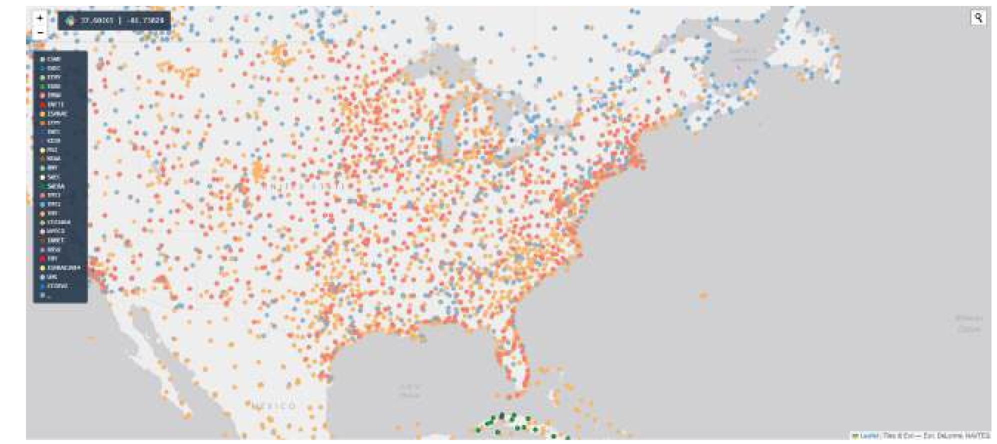
Structural restrictions over roof structure is governed by third party. Also, parametric modeling is limited on this project, so pre-defined options in rhino geometry was used as a boundary representation in grasshopper environment. Design-decision making was based on limited number of the options, which can possibly turns out that none of the options are being optimized and appropriate for the situation.

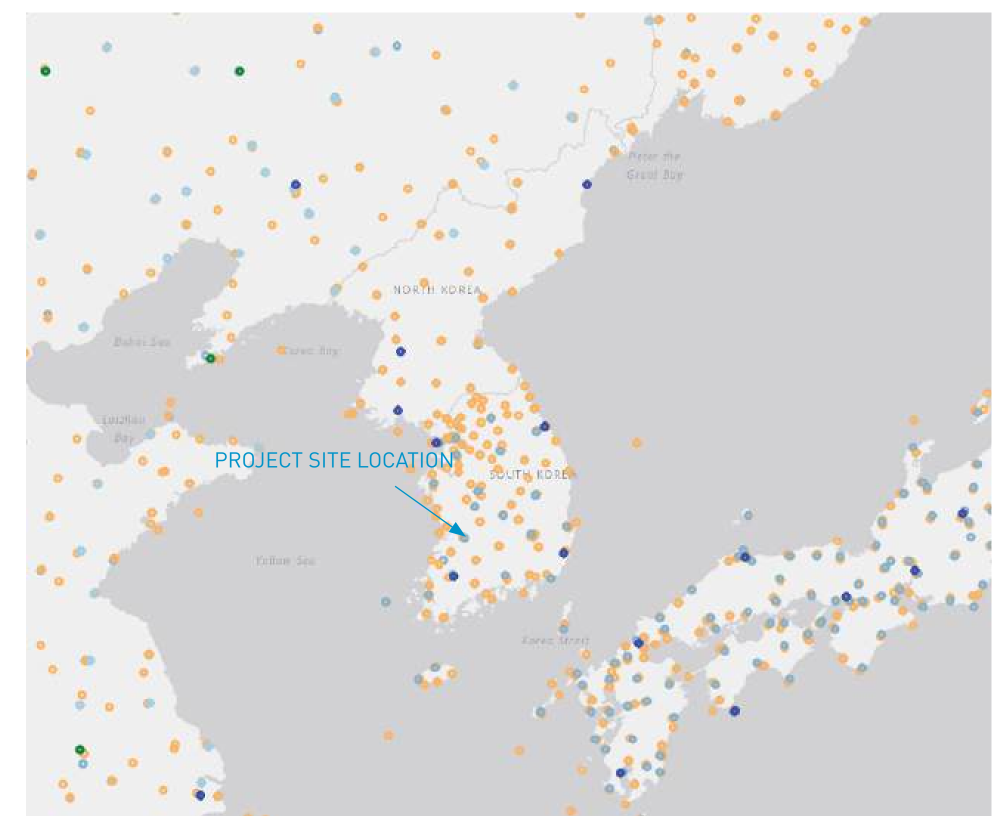
Original Atrium Program Submitted for Competition

Modified Program for the Atrium space







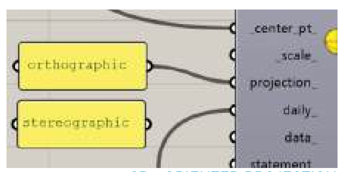


EPW WEATHER FILE

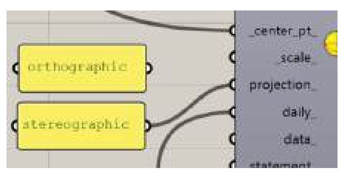
1) Find EPW weather file URL from the epw map (https://www.ladybug.tools/epwmap/)
2) Paste the URL to the GH note and connect to the weather URL input

EPW MAP

Ladybug's EPW map has developed to accommodate vast amount of EPW files regardless of the file types. the observation mainly took place in airport or research institute. For the use of the file in architectural practice, using the EPW files from vicinity is good enough to figure out the reliable result.

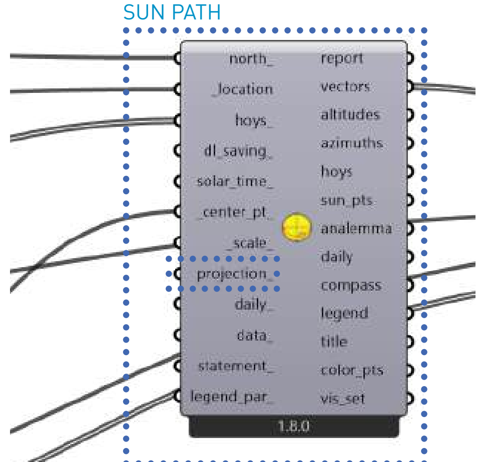


3D - ORIENTED PROJECTION

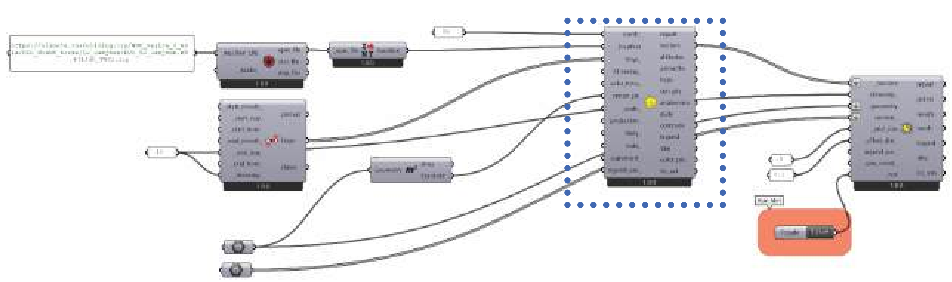


2D - ORIENTED PROJECTION

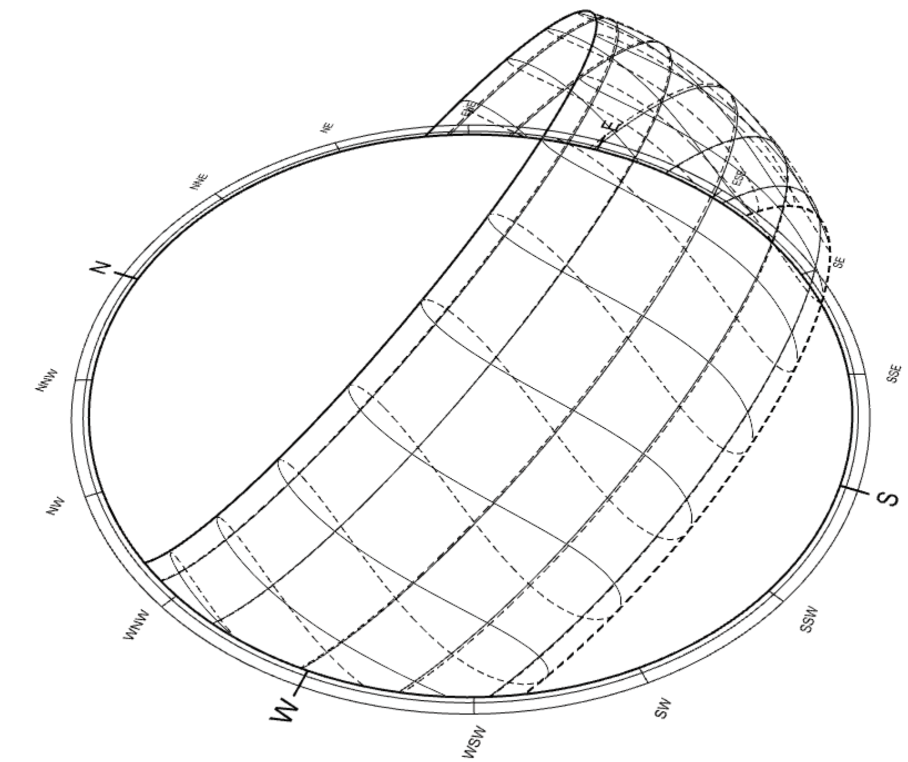
SUN PATH



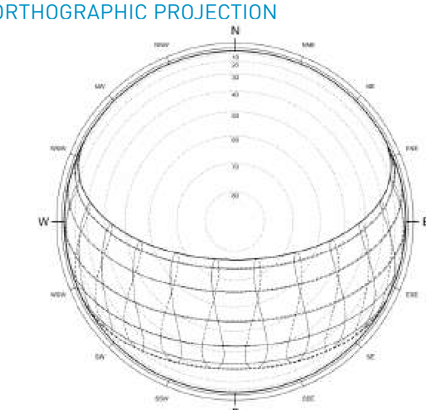
This compnent creates sun path geometry and its improved representation with relevant input



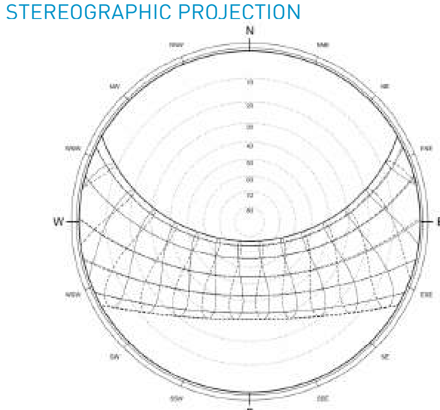
SUN PATH 3D



ORTHOGRAPHIC PROJECTION



STEREOGRAPHIC PROJECTION

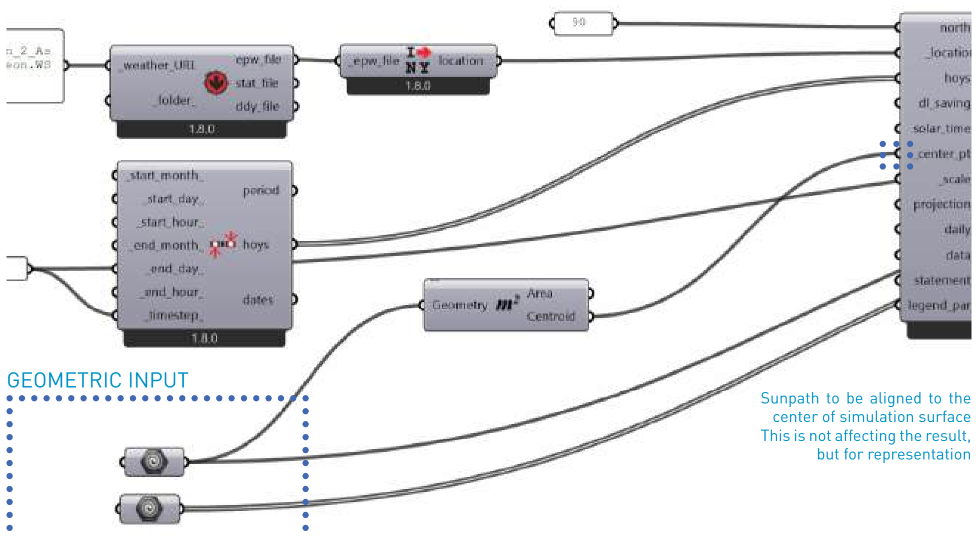


SUN PATH REPRESENTATION

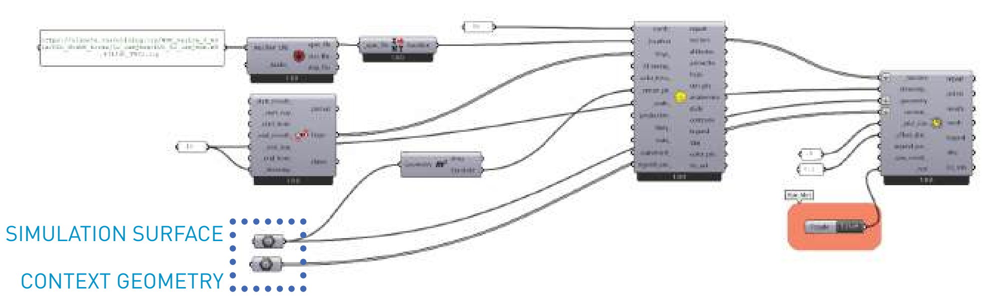
1) Connect designated vector in north direction
2) Connect EPW weather file to location input of the sun path via LB import location
3) Connect 'orthographic' or 'stereographic' for different projection representation

PROJECTION TYPES

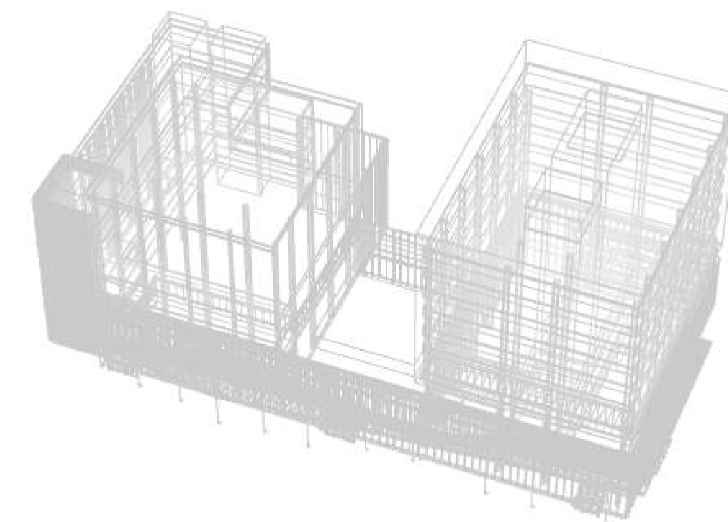
Ladybug's EPW map has developed to accommodate vast amount of EPW files regardless of the file types. The observation mainly took place in airport or research institute.



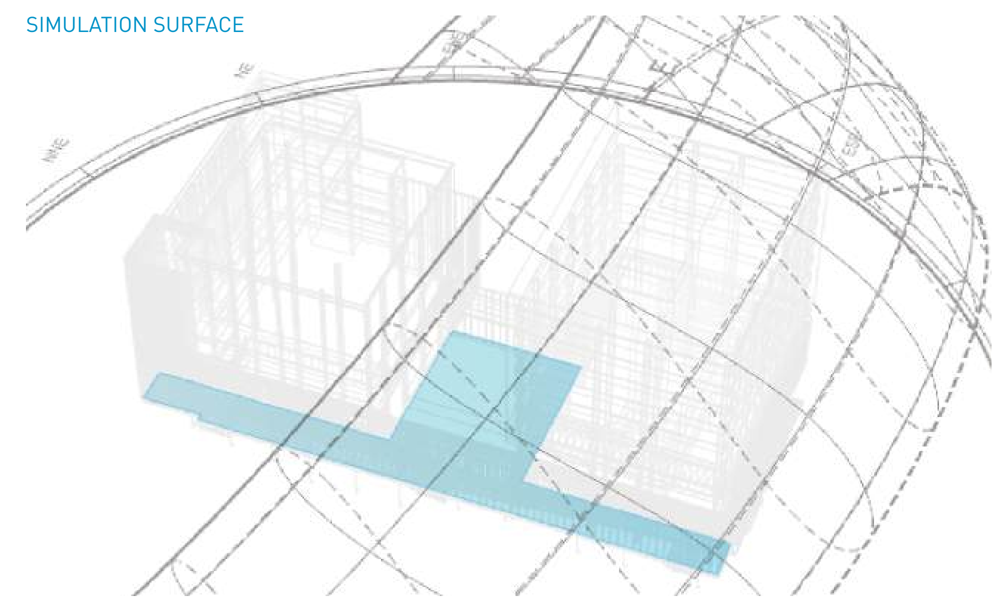
Designated simulation surface (above) & Context geometry



CONTEXT GEOMETRY



SIMULATION SURFACE

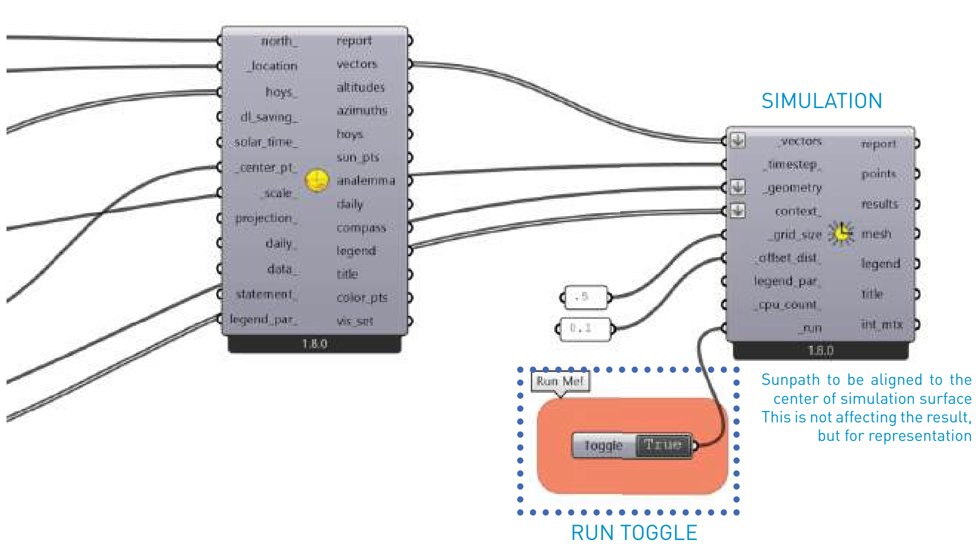


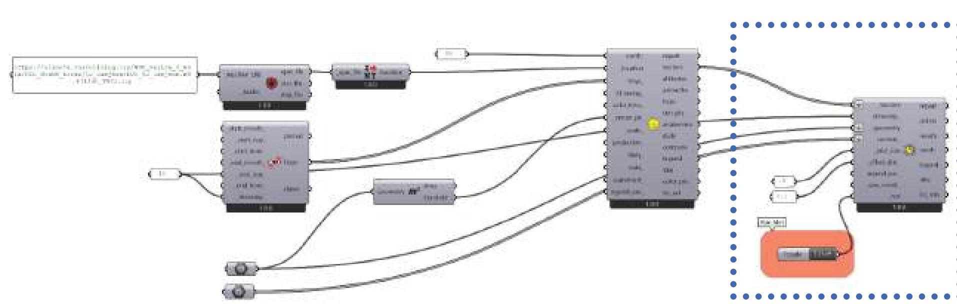
GEOMETRIC INPUT

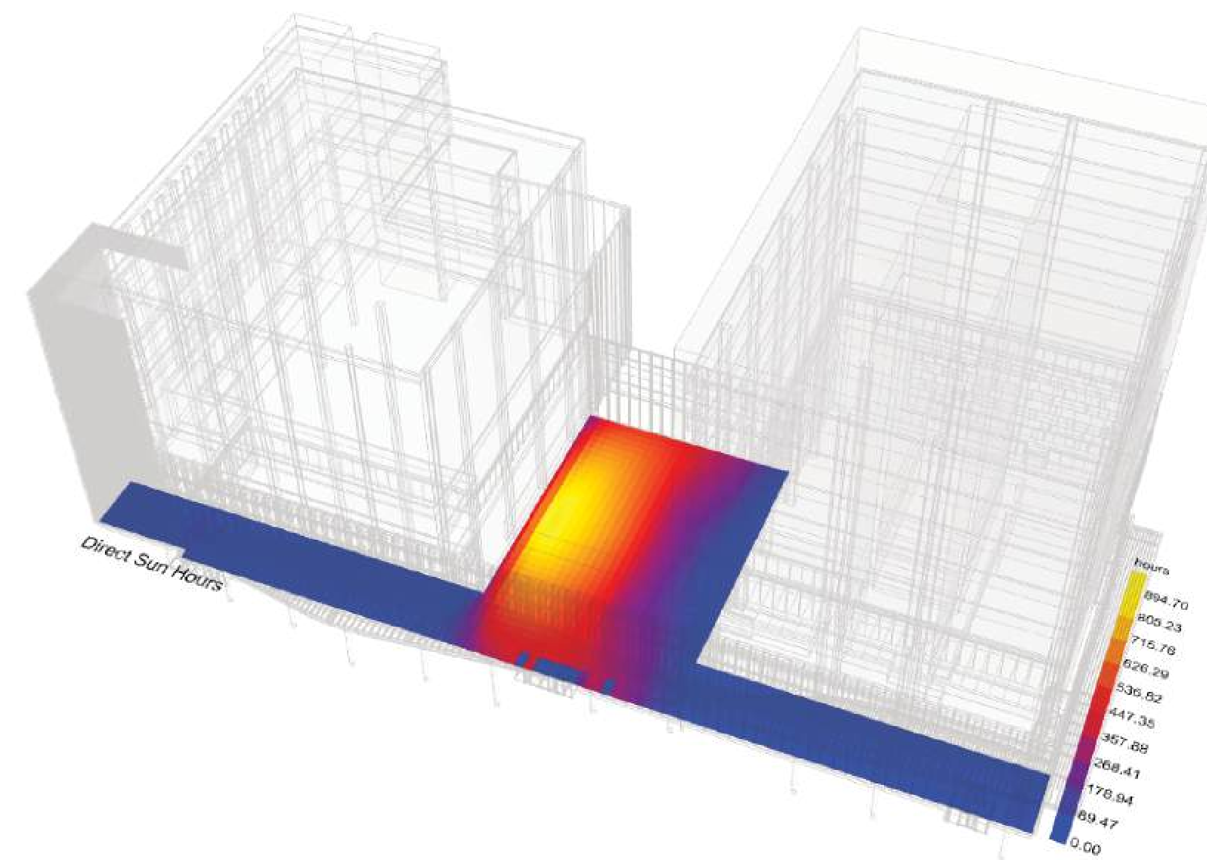
1) Connect simulation surface geometry to the 'geometry' tab of LB direct sun hours component
2) Connect surrounding geometries to the 'context' tab of LB direct sun hours component
3) Set up grid size and offset distance in numerical value

DESIGNATED SURFACE & SELF-SHADOWING

Atrium is located in the middle of the building, so self-shadowing was the crucial factor for the simulation. In this situation, all other building geometries become 'Context' and atrium and lobby space floor surface become designated 'Simulation surface'





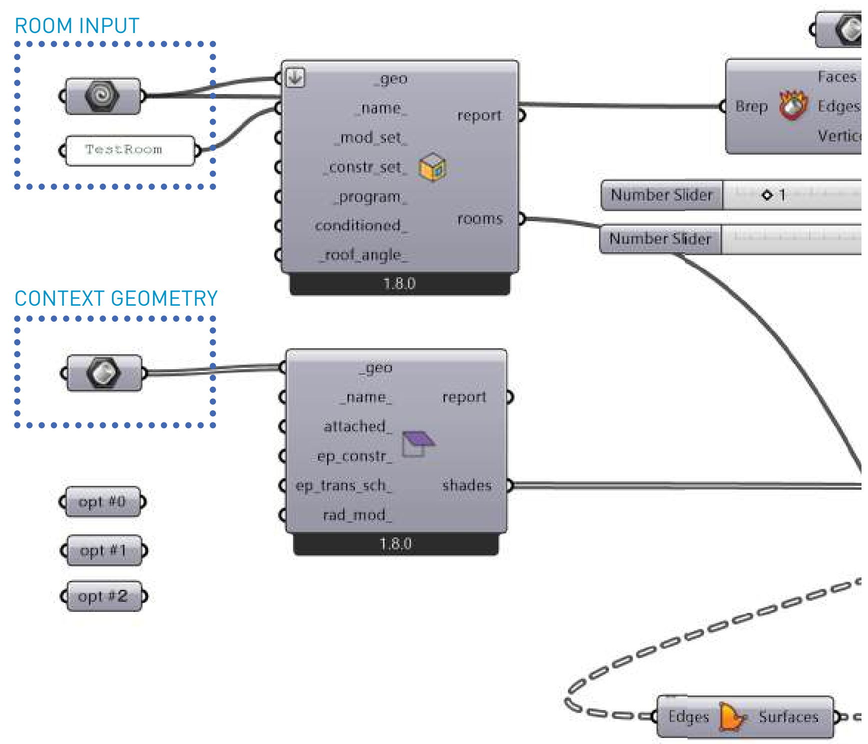


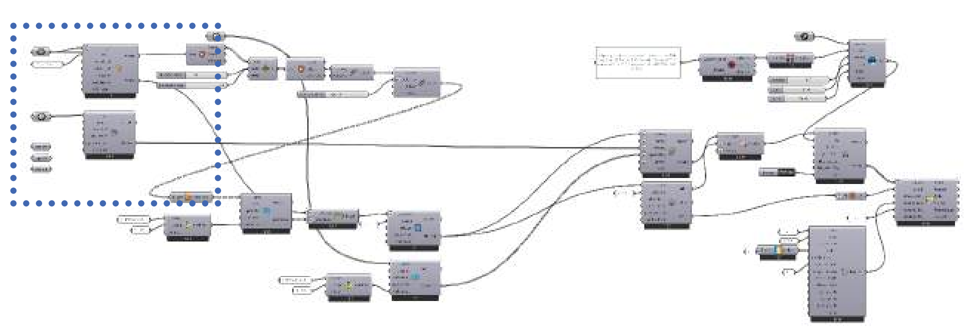
GEOMETRIC INPUT

1) Run simulation

PROBLEM IDENTIFICATION

Atrium is located in the middle of the building, so self-shadowing was the crucial factor for the simulation. In this situation, all other building geometries become 'Context' and atrium and lobby space floor surface become designated 'Simulation surface'

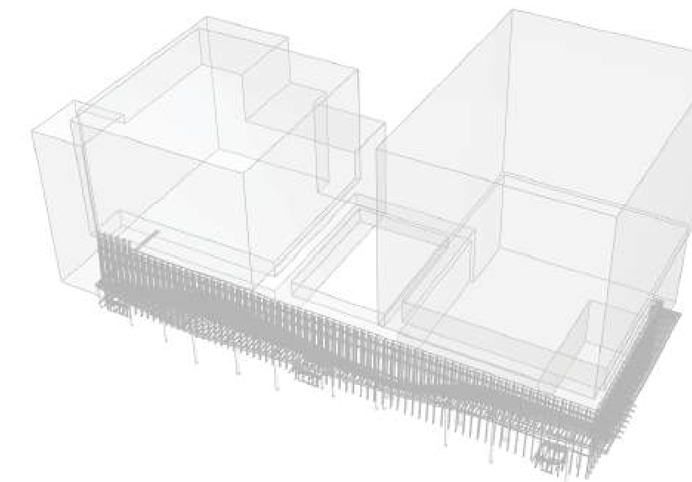




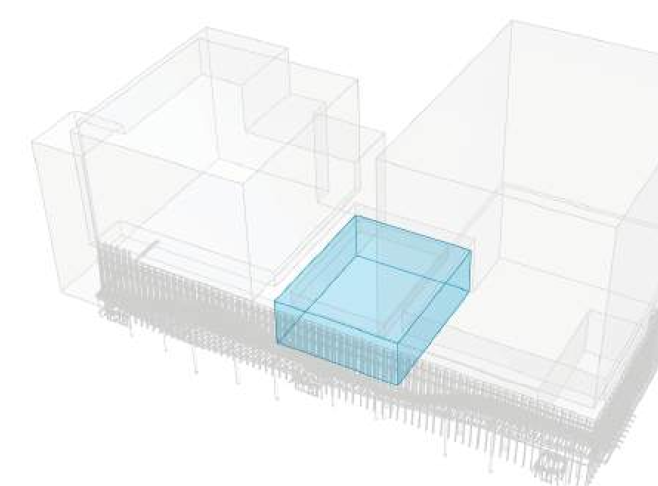
GEOMETRIC INPUT

1) Connect room geometry to HB room from Solid component
2) Connect context geometry to HB Shade component

CONTEXT GEOMETRY

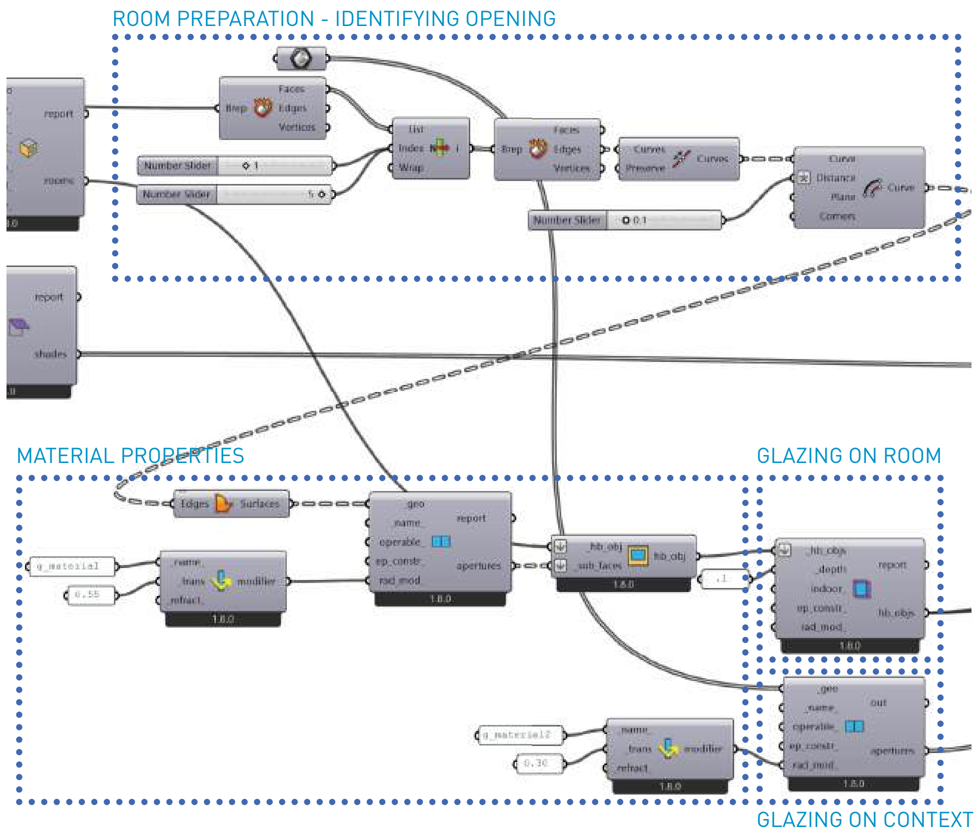


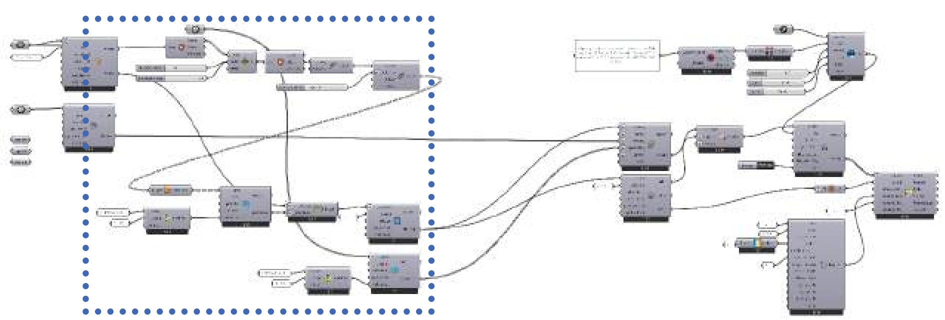
SIMULATION ROOM



DESIGNATED SURFACE & SELF-SHADOWING

Atrium is located in the middle of the building, so self-shadowing was the crucial factor for the simulation. In this situation, all other building geometries become 'Context' and atrium and lobby space floor surface become designated 'Room geometry'

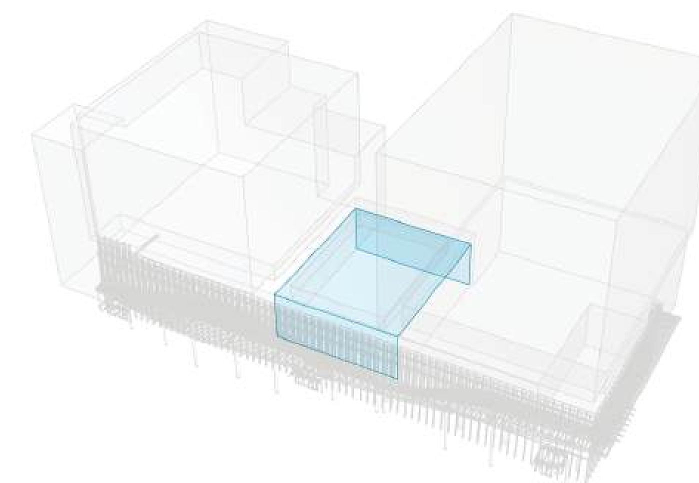




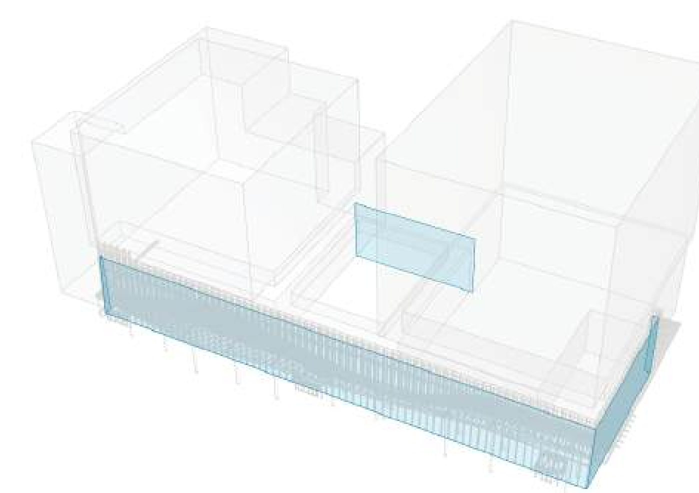
GEOMETRIC INPUT

1) Room geometry to be subdivided to each surface with proper material properties
2) Open surfaces to be connected to glazed material property to mimic the actual setting
3) Opening ratio of the surface facing west backyard to be base on designated opening ratio

GLAZING ON ROOM

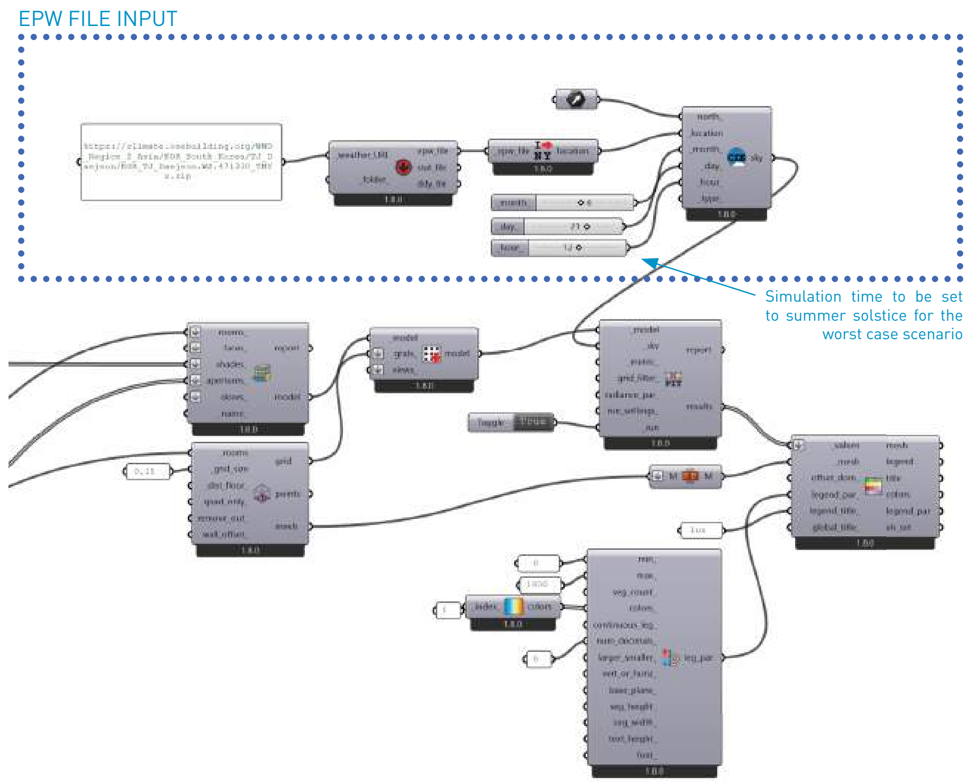


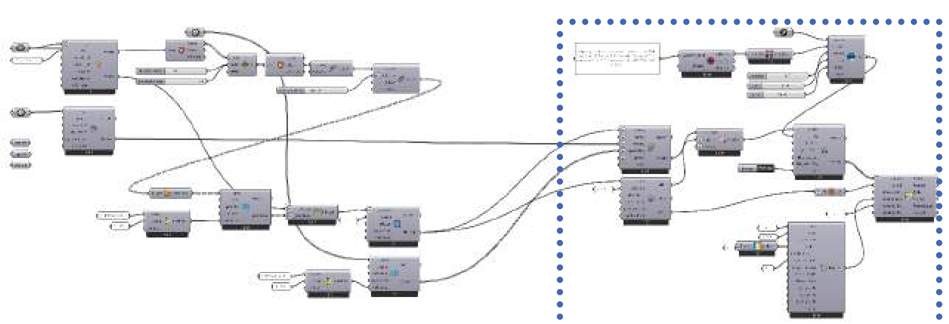
GLAZING ON CONTEXT



OPENING IDENTIFICATION

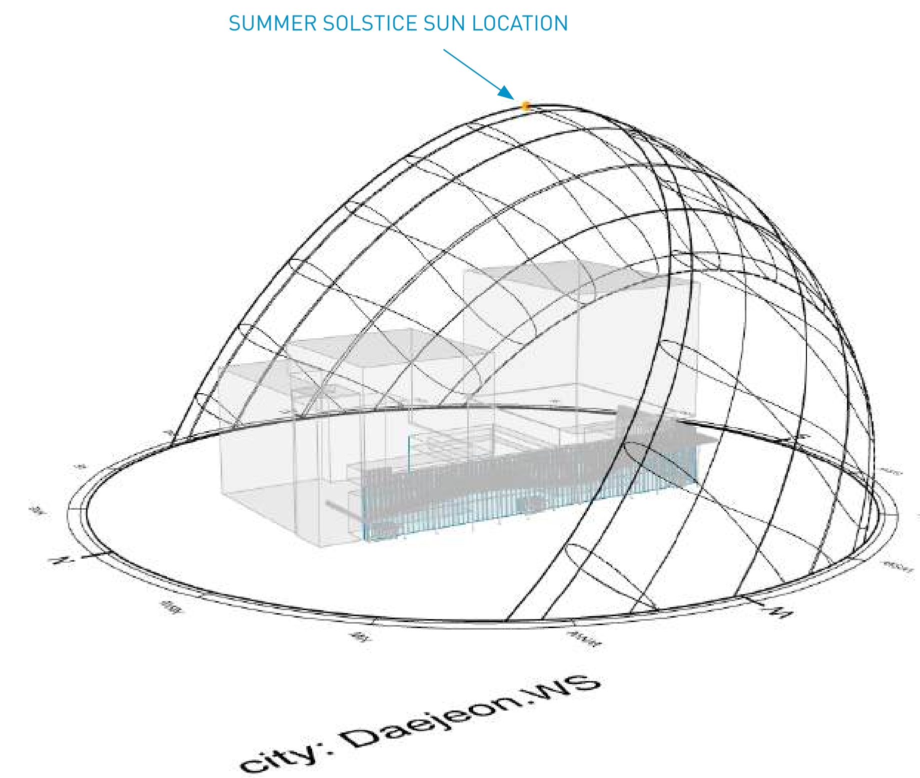
Honeybee room geometry requires each facet to form a 3D box typology. For a completely open environment, each facet of the 3D geometry is treated as a 100% open window setting. The ceiling and glazing surfaces are modeled as surfaces with 99.9% openness to mimic the actual conditions.





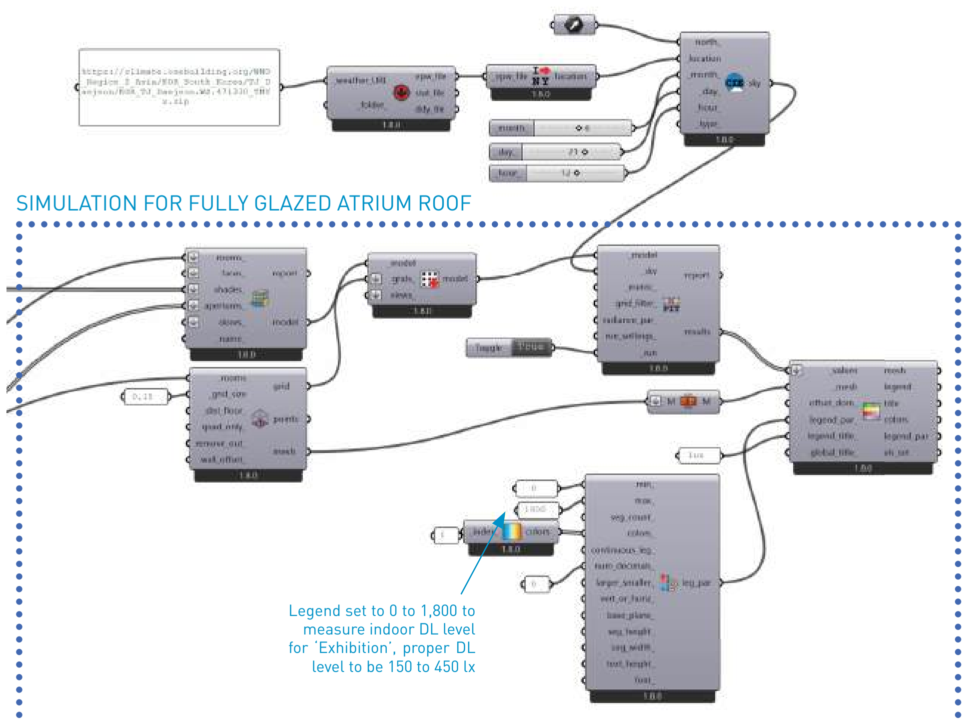
CREATE CLIMATE INFORMATION FOR HB TOOL

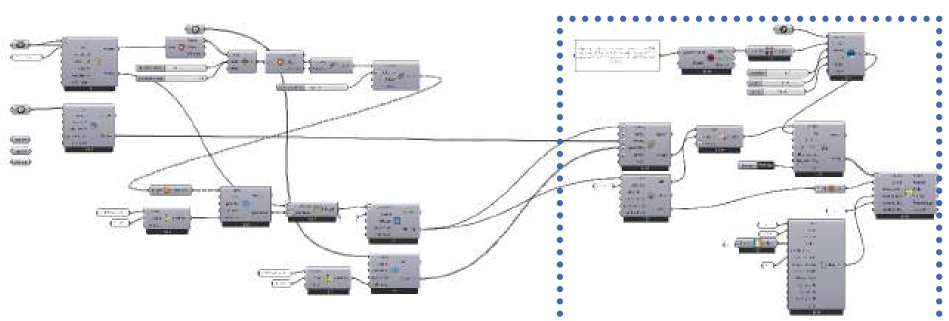
1) Import relevant EPW weather file from web and connect it to the HB CIE standard Sky component
2) Connect 'sky' output to '_sky' input to HB PIT grid-based component



CLIMATE INFORMATION & CIE SKY

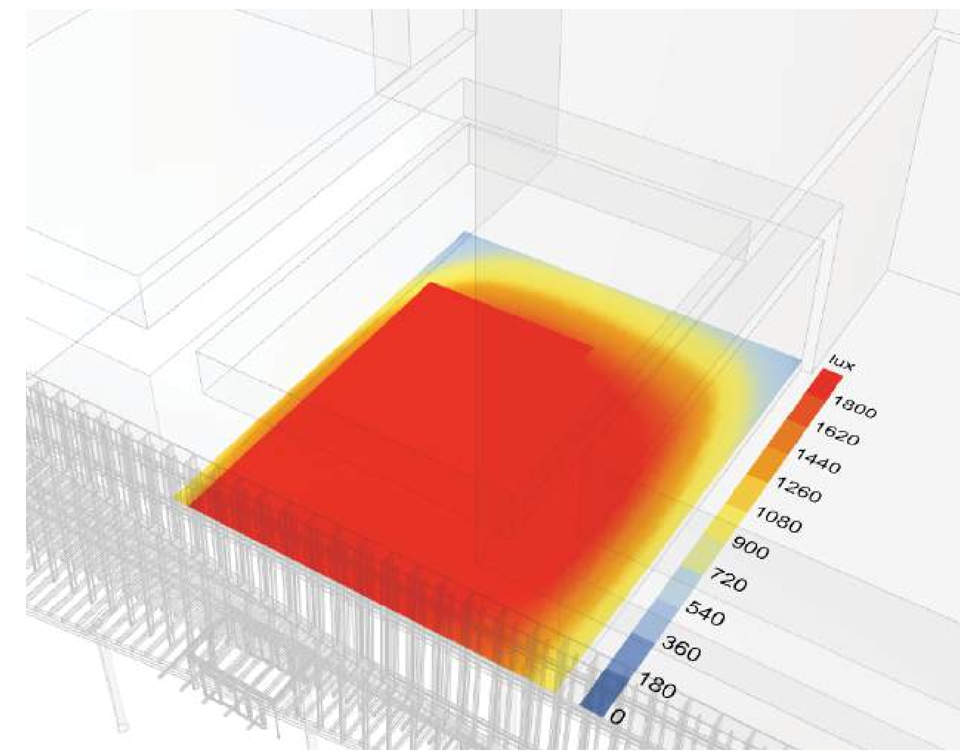
HB components converting EPW weather files to CIE (abbreviated from its french name Commion internationale de l'eclairage) sky model, which represent average daylight and has a correlated colour temperature of approximately 6500 K. This process of converting is similar to that of the LB tool's creation of the skymatrix.





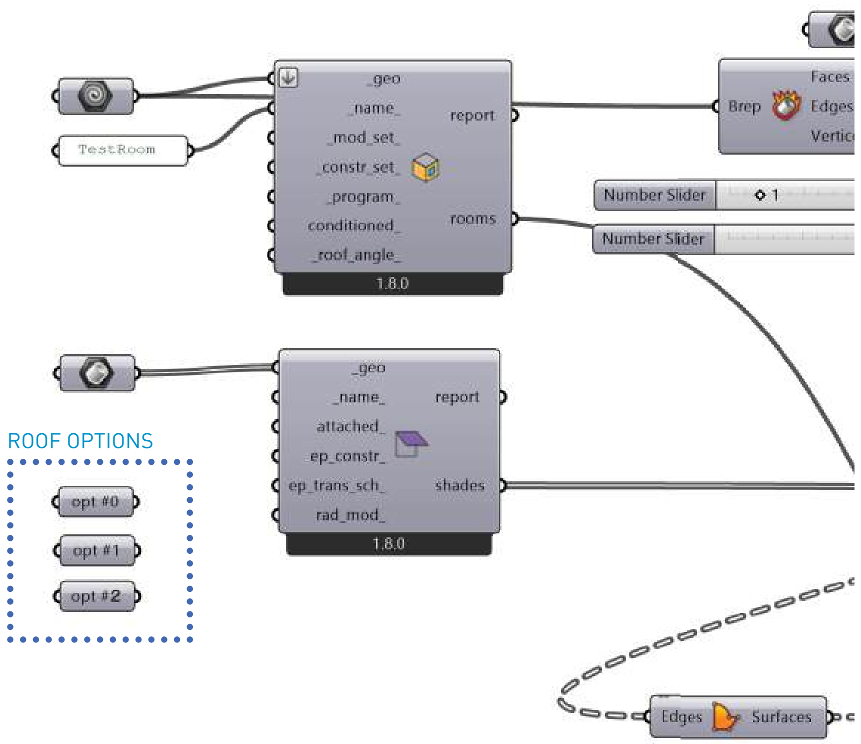
SIMULATION & REPRESENTATION

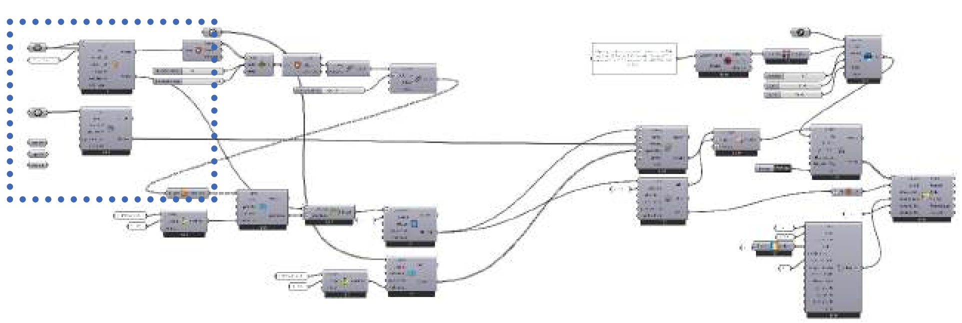
1) Connect room, context and glazing geometry to HB model component
2) Connect room geometry to HB sensor grid component for floor setting
3) Connect sky matrix, HB model to HB PIT grid component
4) Connect 'results' output to LB spatial Heatmap with Legend parameter setting illustrated above



PROBLEM FINDING

Due to its nature, atrium is usually create excessive daylight level. Although it is acceptable by considering the atrium is filled with supplemental function of the building and treated as an alpha room of the main building. In this case, during the design development phase, the program of the atrium has been changed to accommodate exhibition and convention function, which functions extremely difficult in original daylight level designed

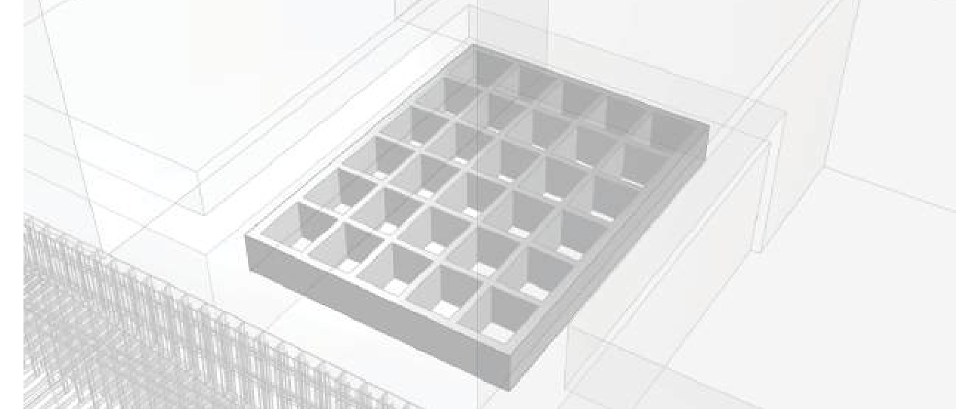




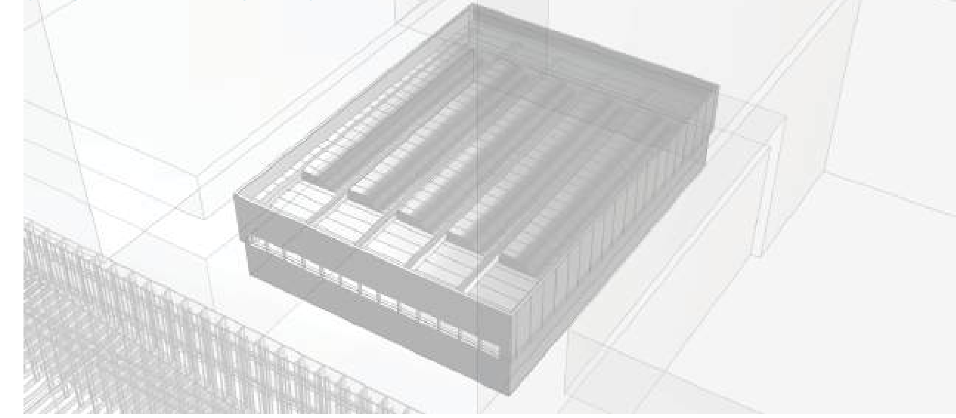
IMPORTING DESIGN OPTIONS

1) Import pre-defined roof shading options as a brep (boundary representation)

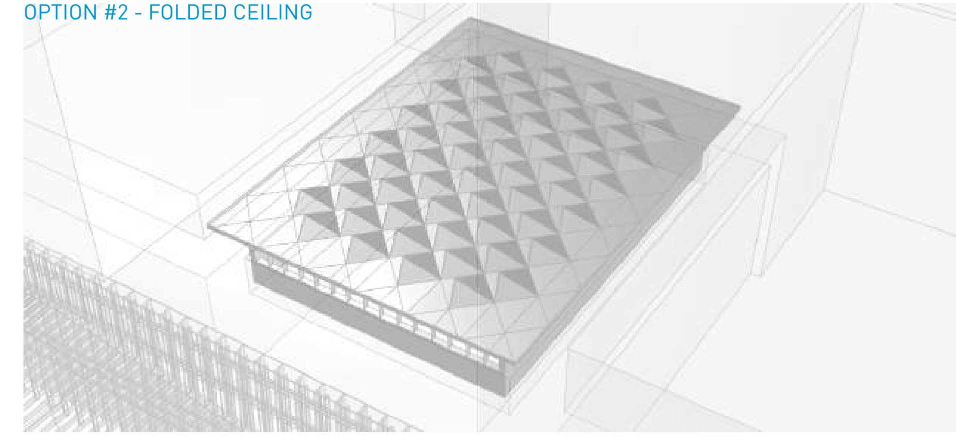
OPTION #1 - GRID EXTRUSION



OPTION #2 - BENDED CEILING

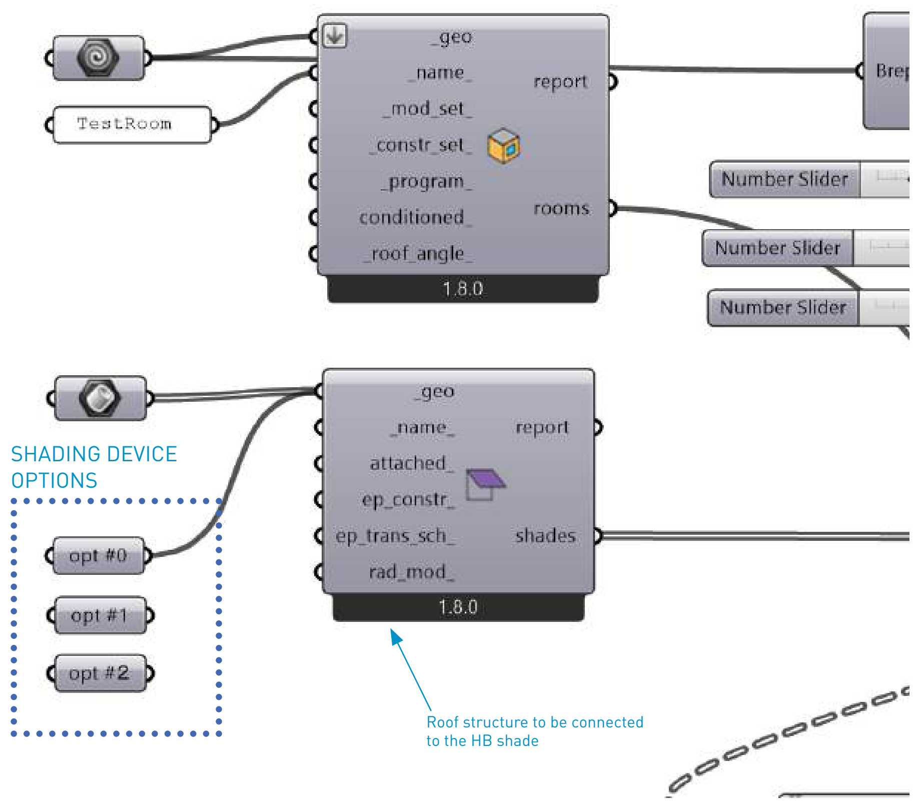


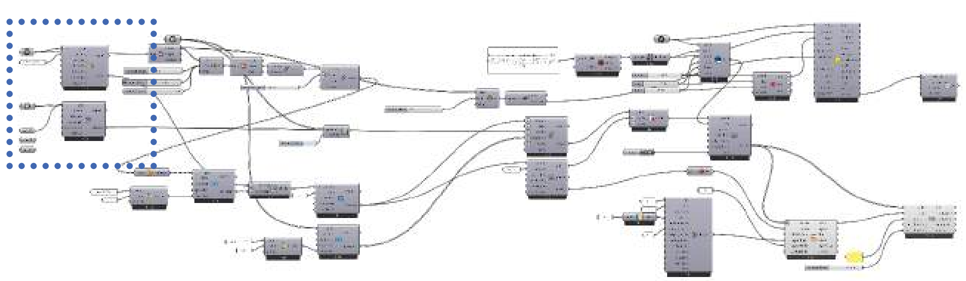
OPTION #2 - FOLDED CEILING



DESIGN OPTIONS

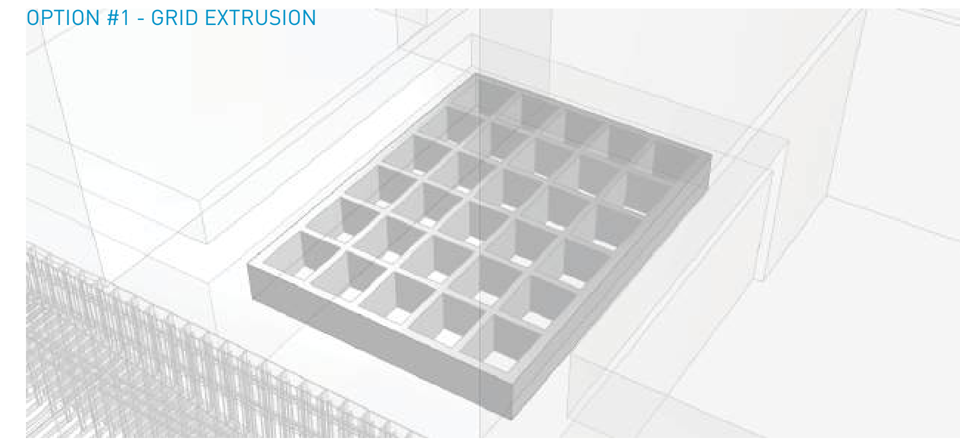
Roof structure options above atrium for regulating daylight level in the space can be compared and evaluated. For each options, material properties are ignored for absolute comparison and only a direction, ratio or other geometry related information of the openings are considered

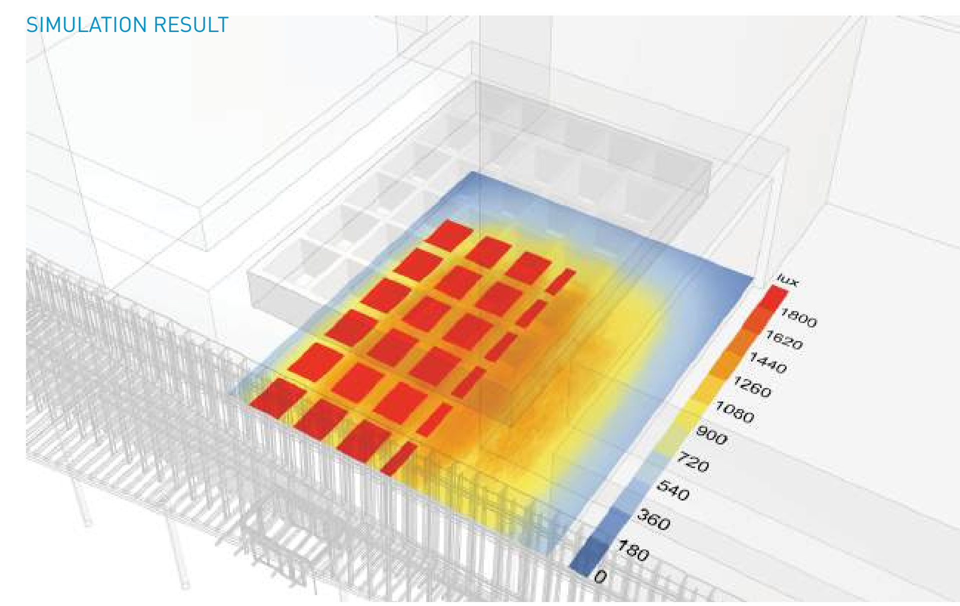




PERFORMANCE COMPARISON

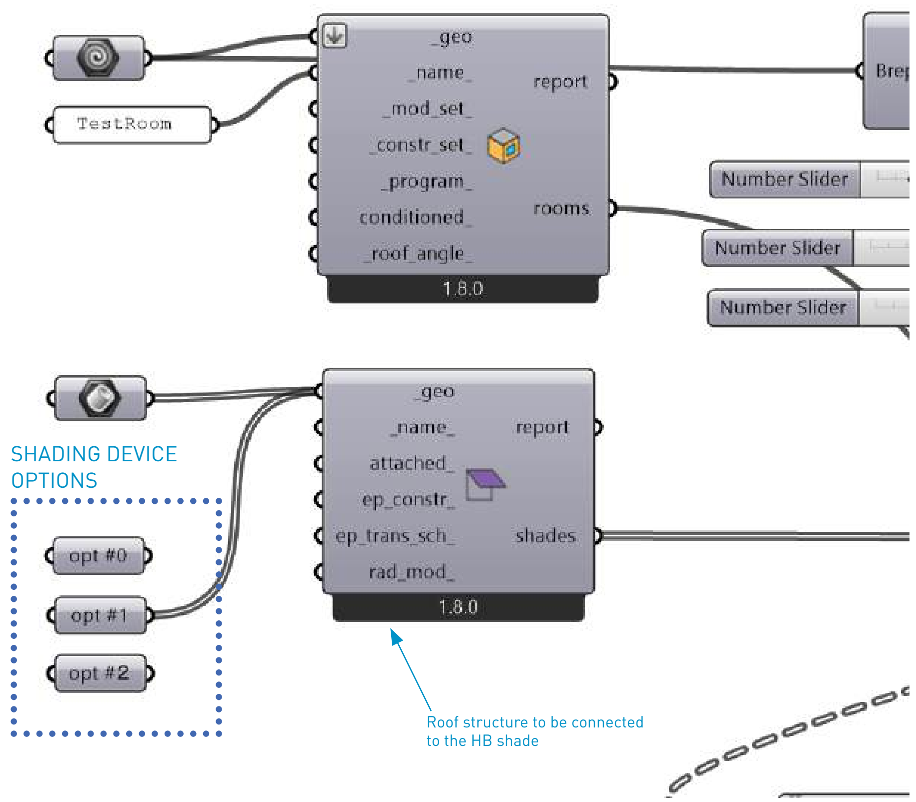
1) Connect roof option geometry to HB shade component.
2) Simulation to be updated

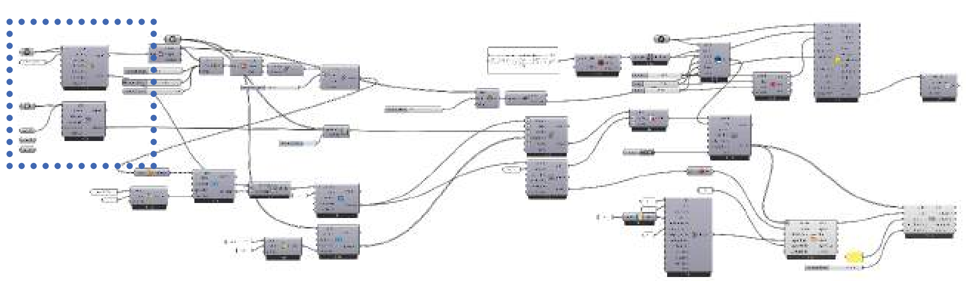




GRID EXTRUSION

Although this option regulates some of the daylighting in the space, it also creates overcasted sunlay at certain points of the space, which cannot satisfy the daylight value for spatial needs

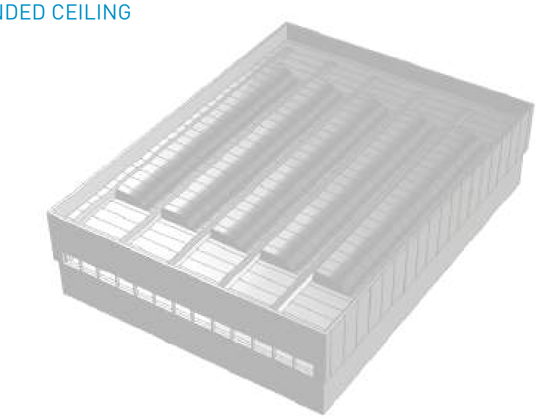




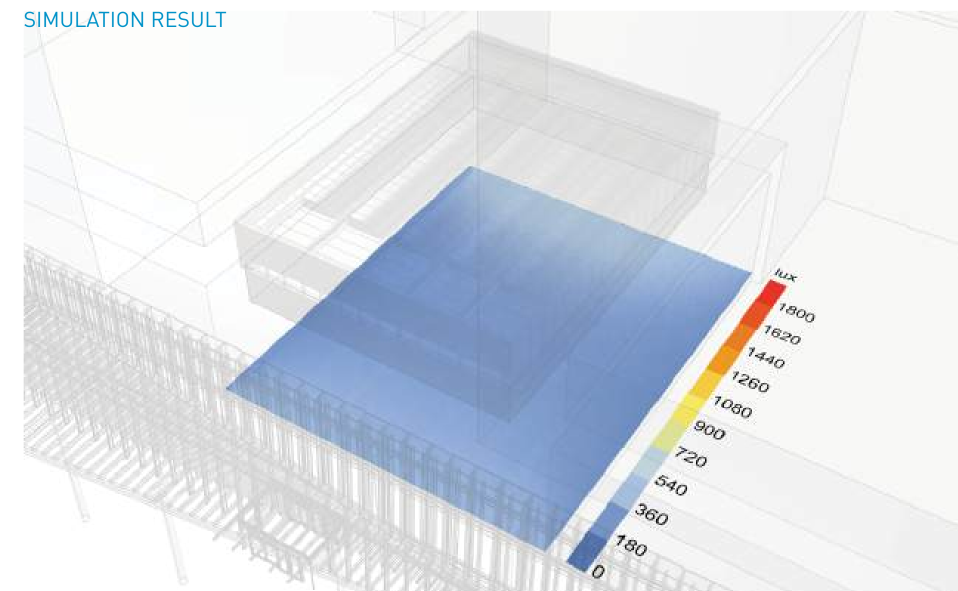
PERFORMANCE COMPARISON

1) Connect roof option geometry to HB shade component.
2) Simulation to be updated

OPTION #2 - BENDED CEILING

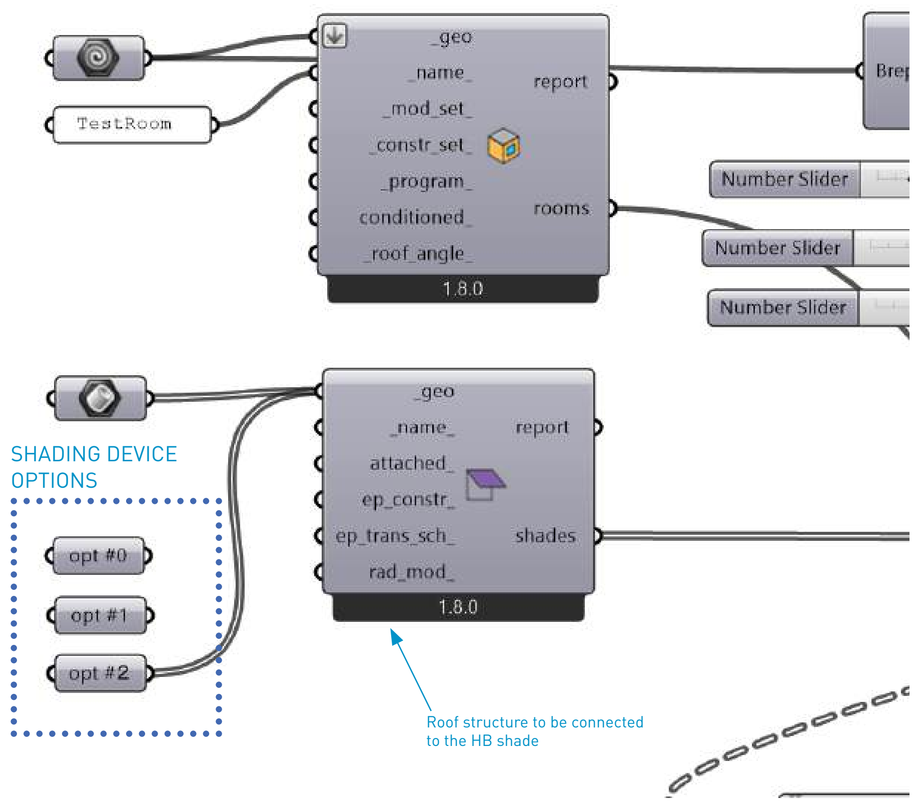


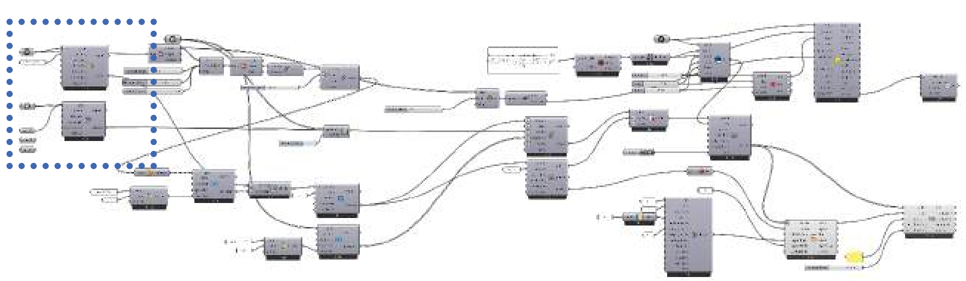
SIMULATION RESULT



BENDED CEILING

The second option is one of the most typical approaches to the musuem roof, which provide smoothly filtered natural lights to the interior space. Simultation result shows improved lighting levels for the exhibition program.

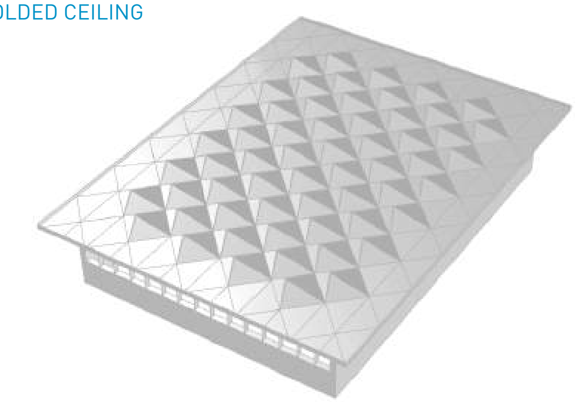




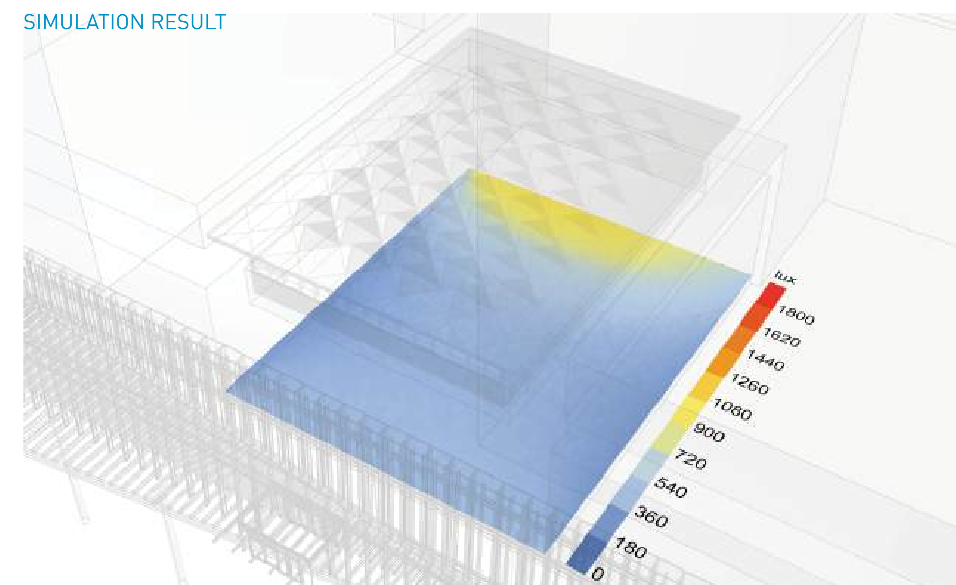
PERFORMANCE COMPARISON

1) Connect roof option geometry to HB shade component.
2) Simulation to be updated

OPTION #3 - FOLDED CEILING

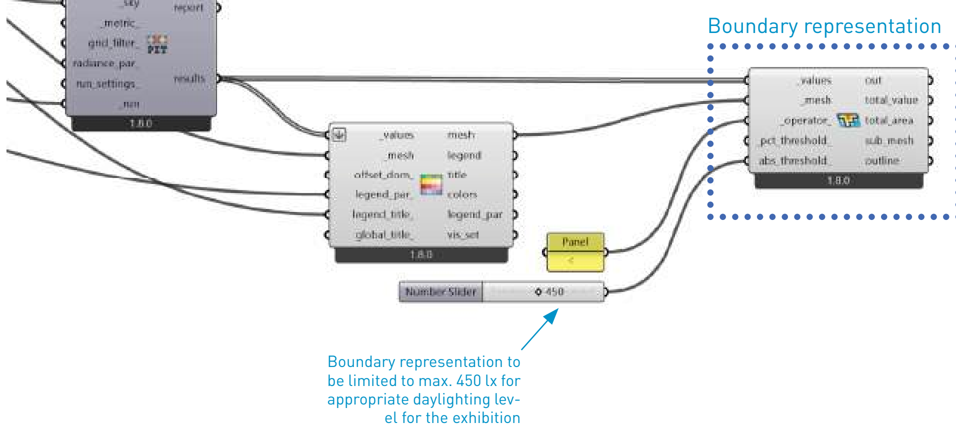


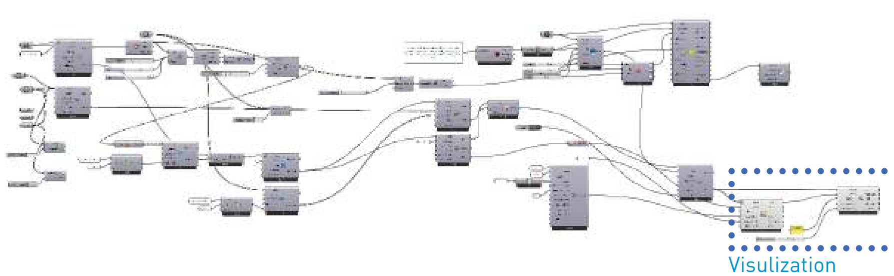
SIMULATION RESULT



FOLDED CEILING

The third option also shows well regulated lighting level for the exhibition space. However, at certain hours, the geometry allowed east and west part of the space to be exposed to the direct sunlight with an acceptable lighting level.



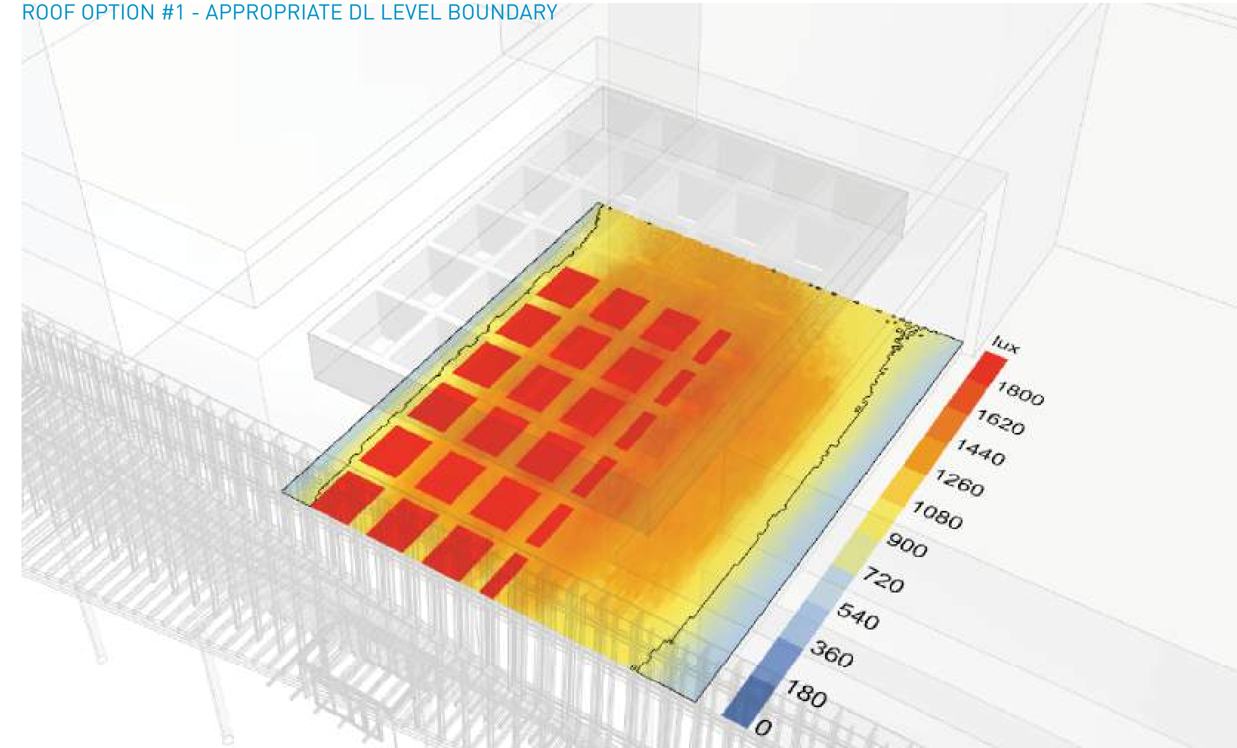


ADDITIONAL REPRESENTATION

1) Connect simulation data to LB mesh threshold Selector component as illustrated above
2) Boudary with the appropriate DL level to be represented for quantitative analysis

ROOF OPTION #1

ROOF OPTION #1 - APPROPRIATE DL LEVEL BOUNDARY

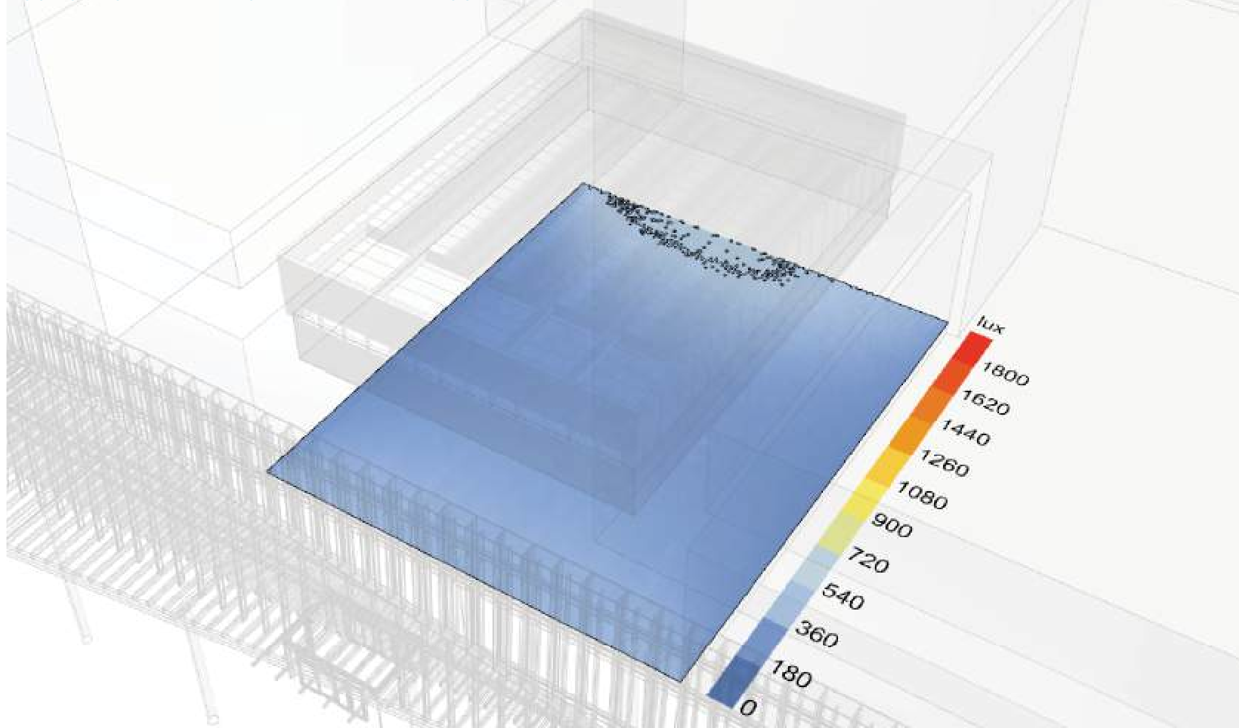


OPTION #1

This representation helps to quantitate the floor area have appropriate light level for designated space program. Option #1 have 127.76 square meter of less than 800 lux light level, which is maxium threshold for exhibition space

ROOF OPTION #2

ROOF OPTION #2 - APPROPRIATE DL LEVEL BOUNDARY

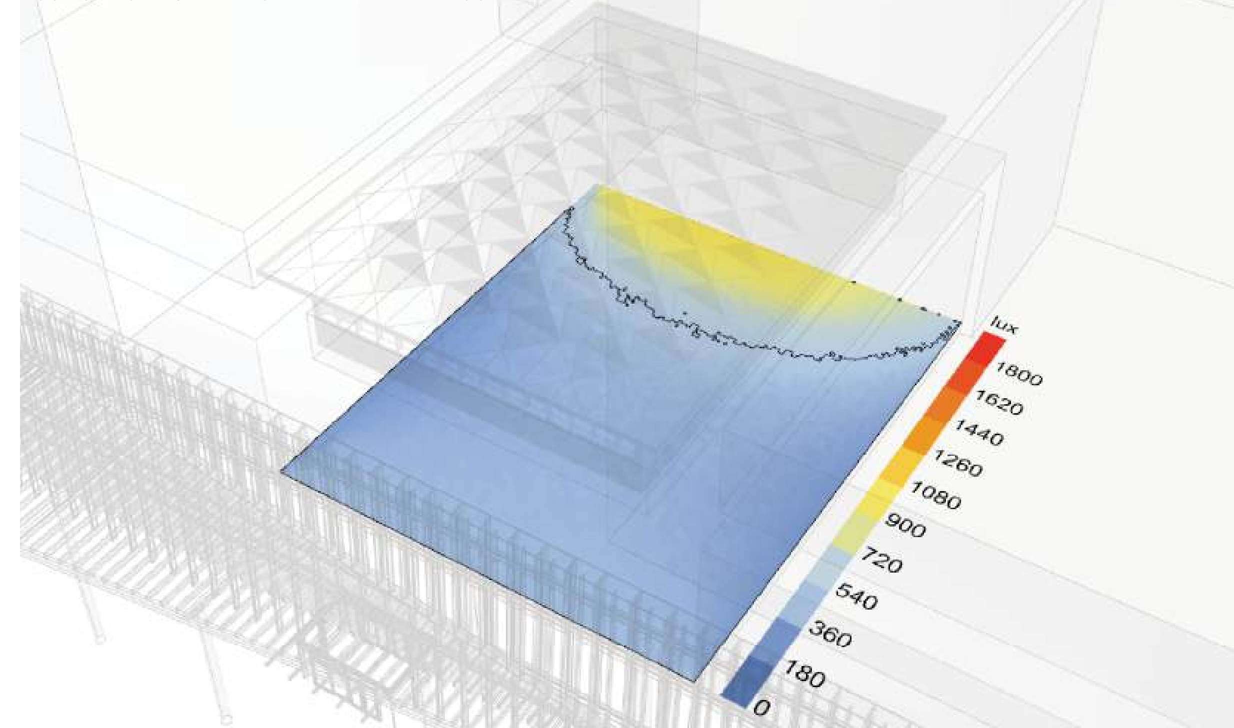


OPTION #2 - SELECTED OPTION

This representation helps to quantitate the floor area have appropriate light level for designated space program. option #1 have 782.30 square meter of less than 800 lux light level, which is maxium threshold for exhibition space

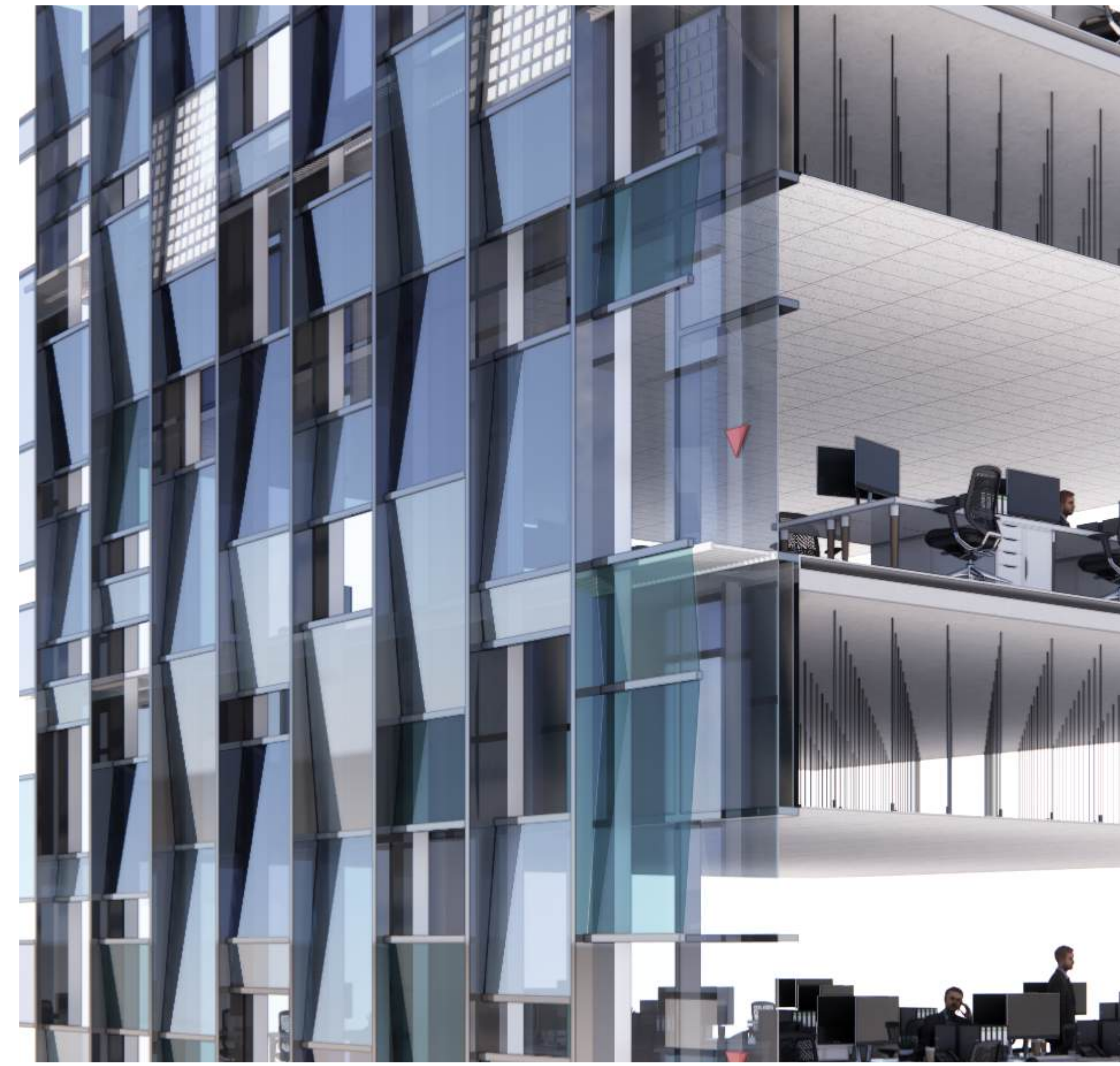
ROOF OPTION #3

ROOF OPTION #3 - APPROPRIATE DL LEVEL BOUNDARY



OPTIONS #3

This representation helps to quantitate the floor area have appropriate light level for designated space program. option #1 have 618.22 square meter of less than 800 lux light level, which is maxium threshold for exhibition space



Double Skin Facade for Office Space

Design Criteria

Facade design of the tower have straight-forward strategy in terms of environmental performance. The south side of the tower is having double skin with a louver while the east and west side facade is having double skin with a fin. These approach based on the shading performance. Louver on the south side will bring winter sunlights to the deeper interior for winter heat gain, while blocks the summer sunlights. Fins on the east and west side facade regulate the complicated eastern/western sunlight comes from lower angle. Addtional tinted glazing as a double skin facade regulated the glaring of the office space. Glare effect is program related optimization criteria. Modern office program, which conducts monitors and other screen devices needs to deal with glaring, double skin in this project not only deal with the thermal performance, but also has the function of glare effect control.

Simulation Objectives

Facade simulation is focusing on two optimization. One is thermal performance improvement via parametric catwalk & shading device depth change, and another is indoor glare effect control via double skin tinted glazing. While each facade elements are solution for the optimizations, former one is more flexible in final geometry, so that depth of the catwalks and shadings are parametrically tested and selected geometry, latter one is more about ready-designed geometry with flexible material properties - window tint degree.

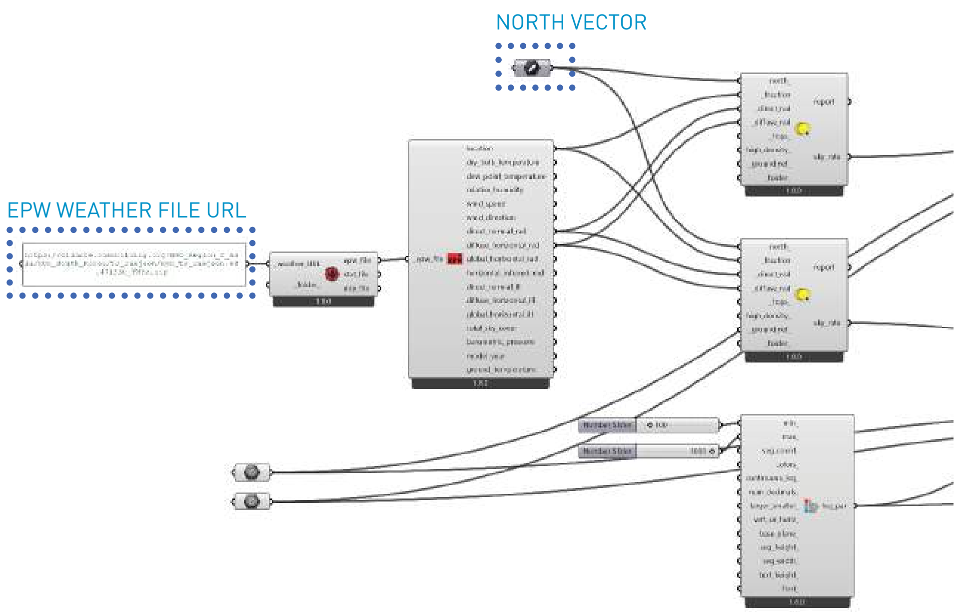
Pre-defined Restrictions

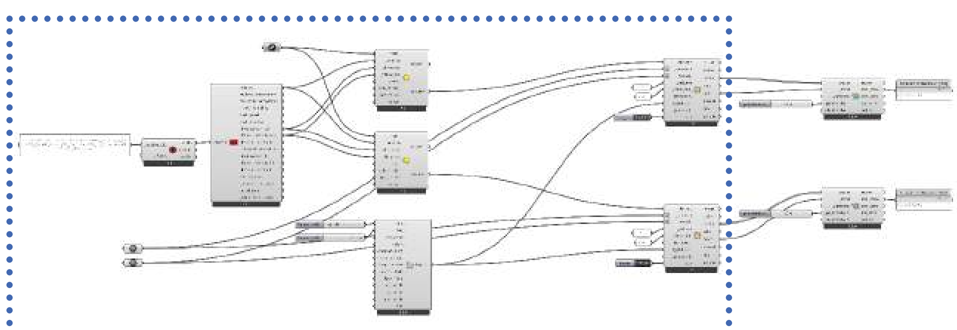
Local regulation are not favorable for the double skin building, thus openings for windows and dimension, location of the specific window types such as fire-fighter access windows are pre-defined. Dimension of the facade subdivision is more about these regulations, but double skin facades' offset dimensions and material properties are playground for the optimization.

Office double skin facade design

Office space glare effect control

EPW Weather map, https://www.ladybug.tools/epwmap/

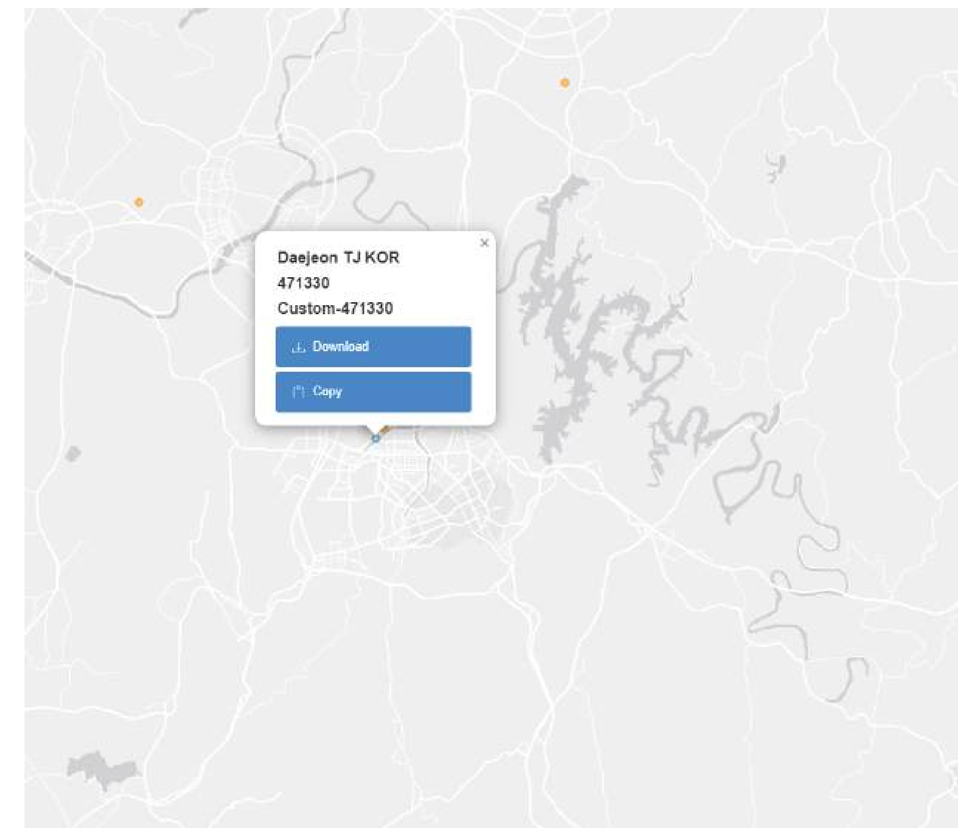




LOCATION SET UP

1) Input EPW weather file URL to create location data

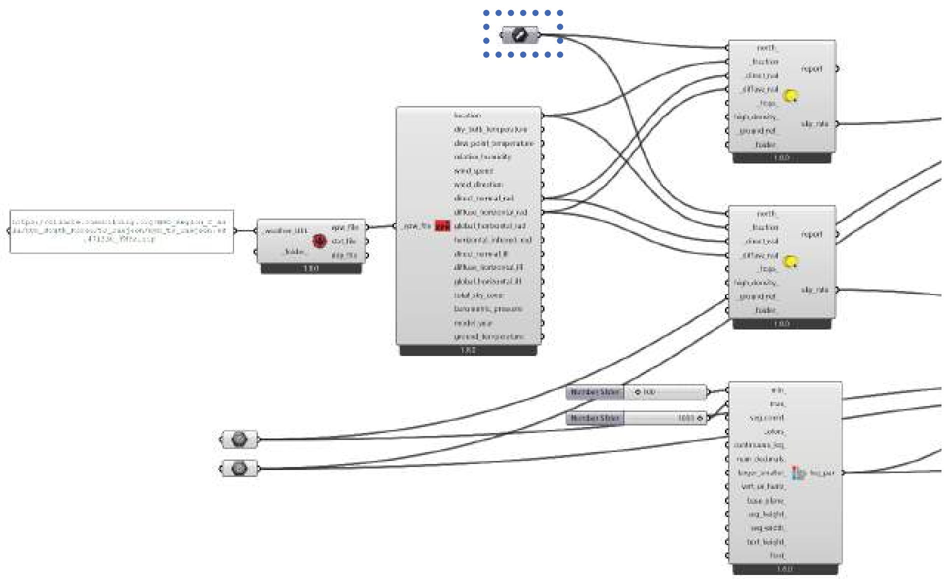
Finding EPW weather file from the closest/available locale

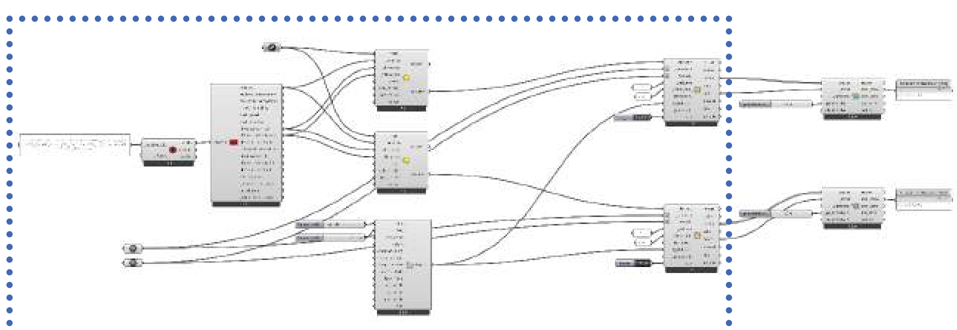


EPW weather data

The project location is Daejeon, South korea. EPW weather files are usually located in university, military base, or airport. The files are normally distributed publicly and EPW weather map collects these information in one website. Otherwise, these data is accessble via relevant institution's website or via inquiry.

NORTH VECTOR

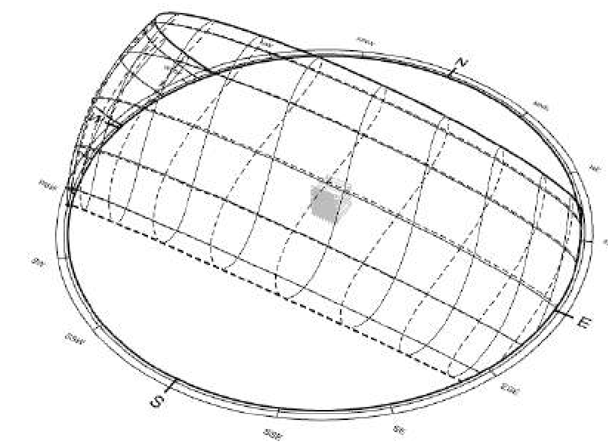


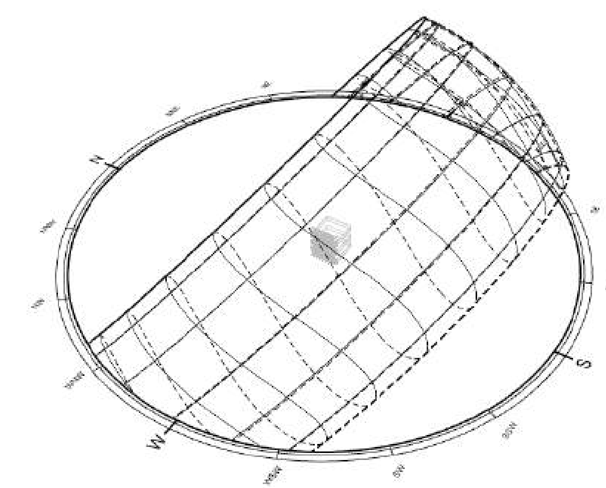


GEOMETRIC INPUT

1) Set North direction via vector component and connect it to LB skymatrix component

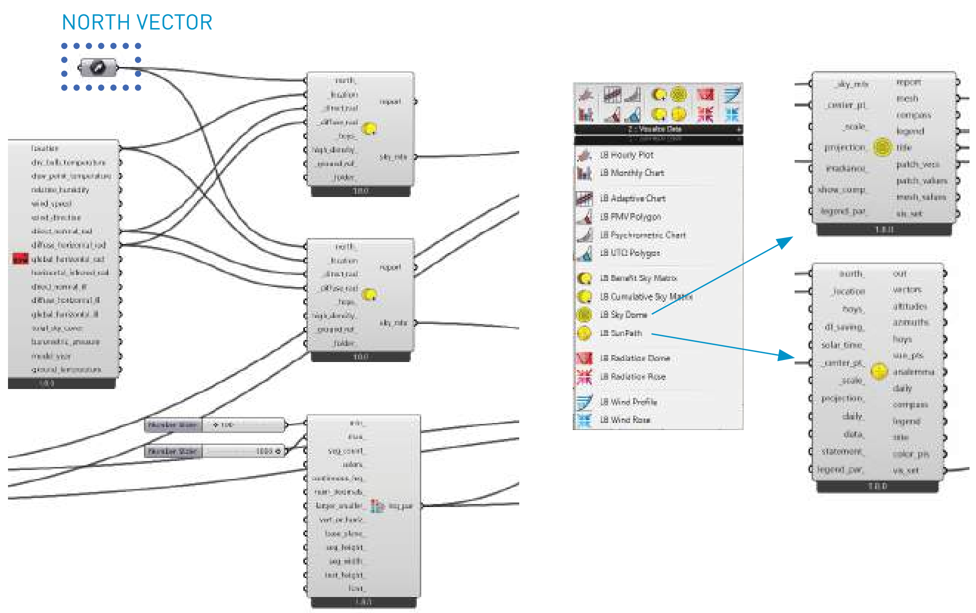
Finding EPW weather file from the closest/available locale

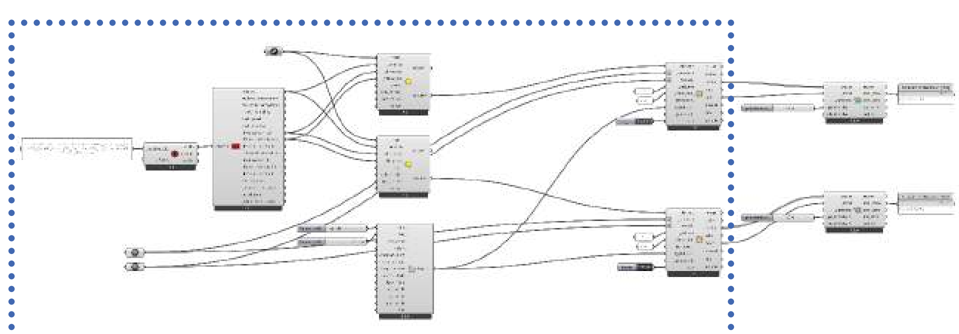




MATCHING DIRECTION

Set up the right north direction is crucial for accurate simulation. With using different north direction, simulation for the same geometry in different direction is possible.

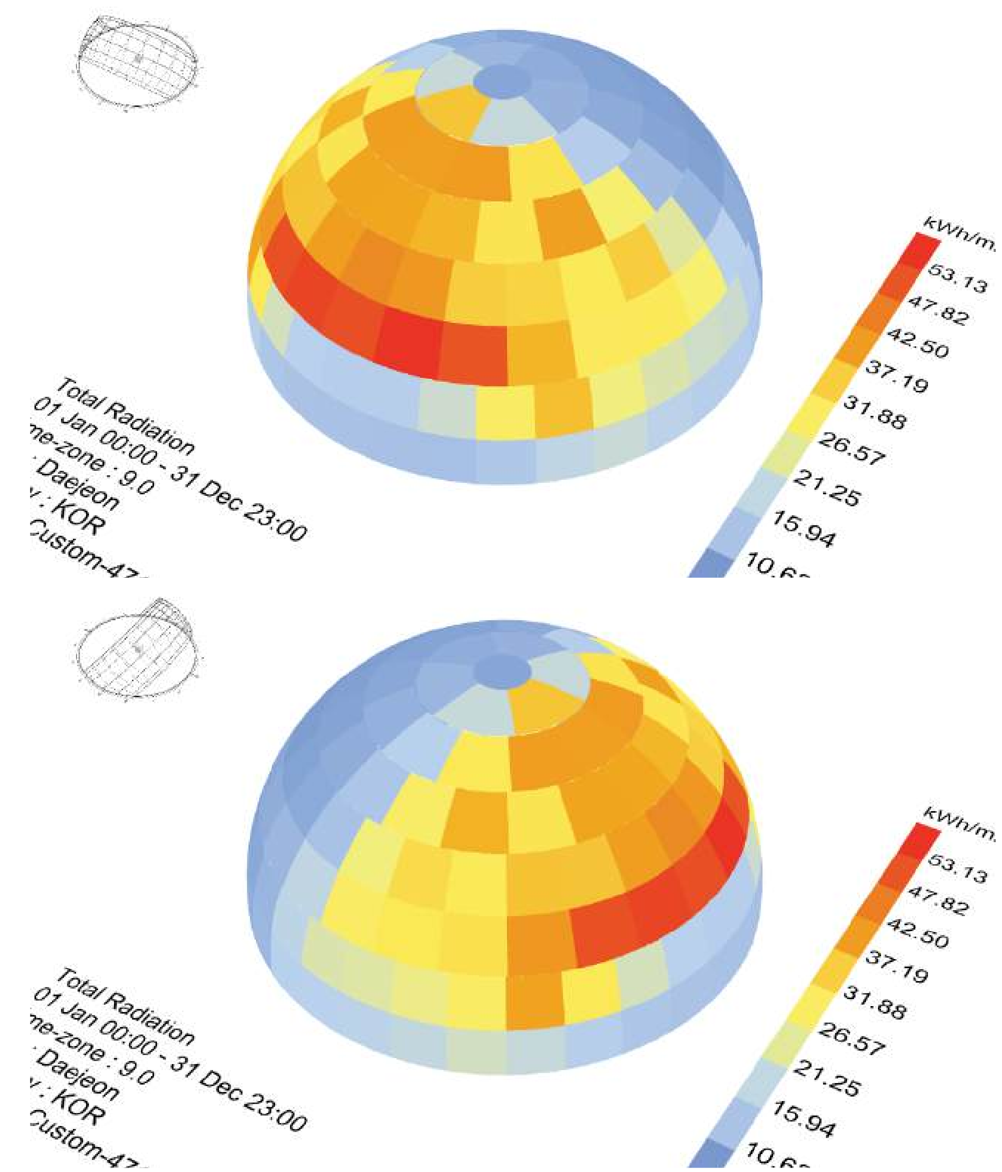




SKYDOME / SUNPATH CREATION

1) Connect all data connected to the sunpath components to the LB sky dome components

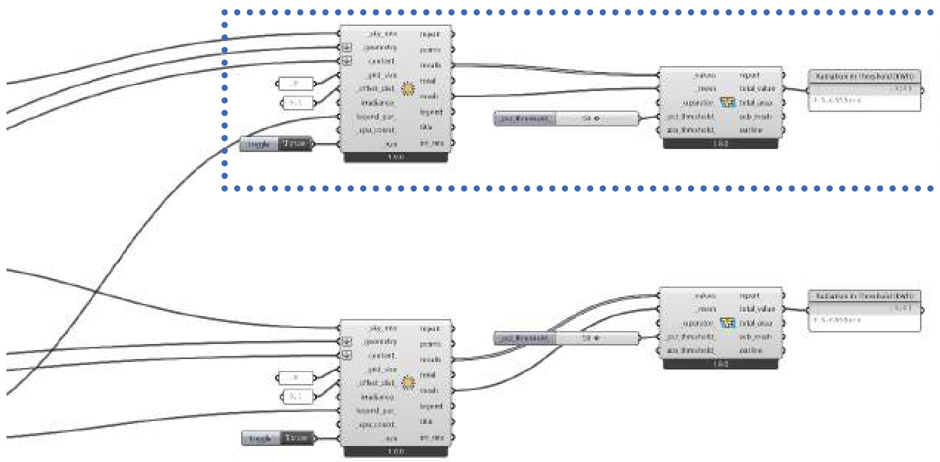
Finding EPW weather file from the closest/available locale

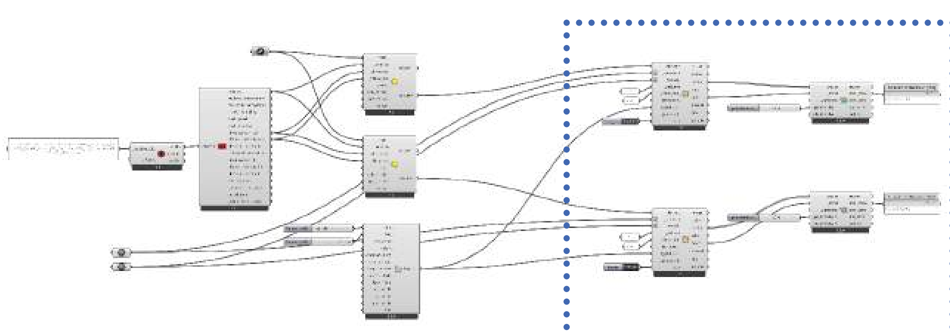


SKYDOME REPRESENTATION

While the result is somewhat similar to a sunpath diagram, it focuses more on quantitative data, whereas the sunpath diagram emphasizes geometry.

SIMULATION - FIN FOR SHADING





FIN SHADING ON SOUTH FACADE

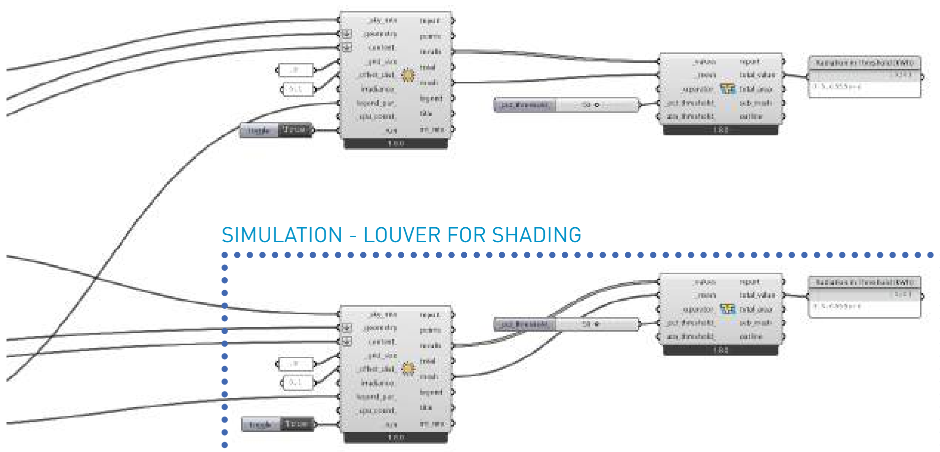
1) Connect shading geometry to the context input of LB incedent radiation component
2) Connect Facade surface geometry to the geometry input of LB incedent radiation component
3) Turn the toggle swith to true to run the simulation

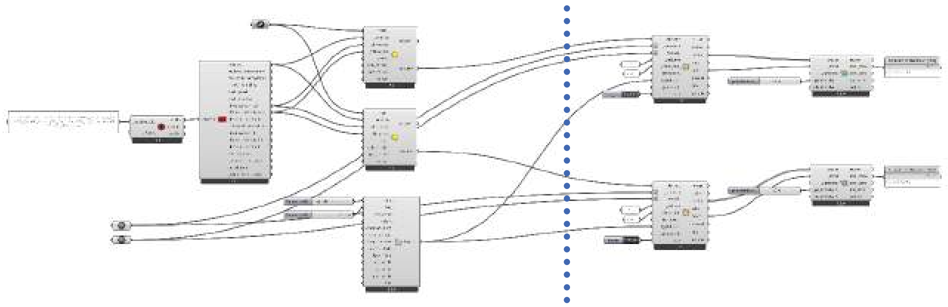
SOUTH FACING FACADE - FIN SHADING SIMULATION

FIN - 59,268 KW/H

FIN FOR SOUTH

This is process of checking whether vertical shading is superior for the south facing facade, or horizontal one is better. Although vertical shading (Fin) is working as a shading device for the facade, it shows higher thermal load for the surface than the one with a louver on next page.

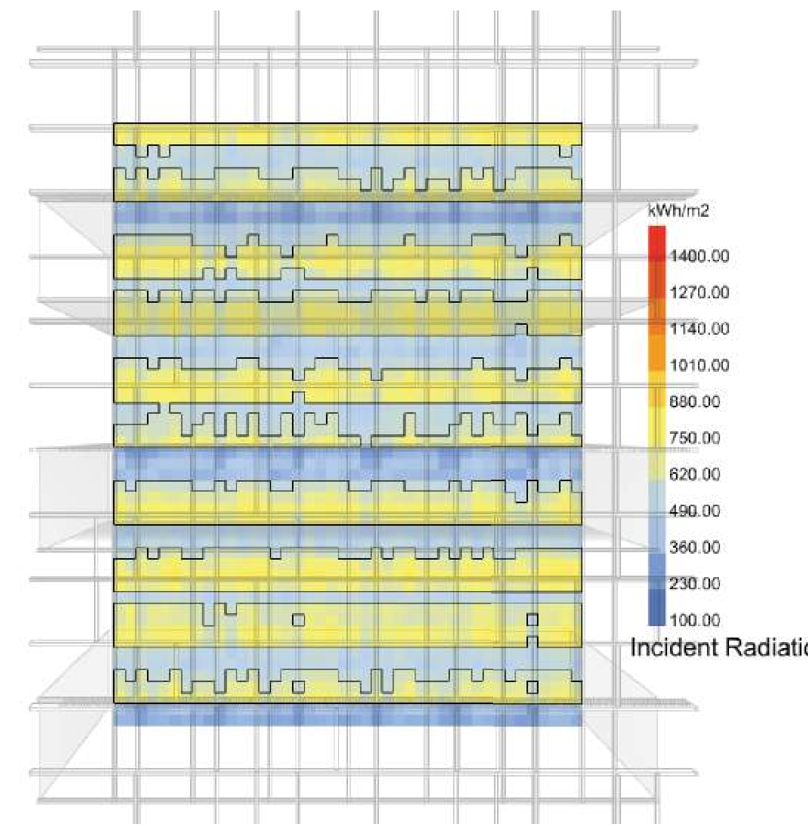




LOUVER SHADING ON SOUTH FACADE

1) Connect shading geometry to the context input of LB incident radiation component
2) Connect Facade surface geometry to the geometry input of LB incedent radiation component
3) Turn the toggle swith to true to run the simulation

SOUTH FACING FACADE - LOUVER SHADING SIMULATION

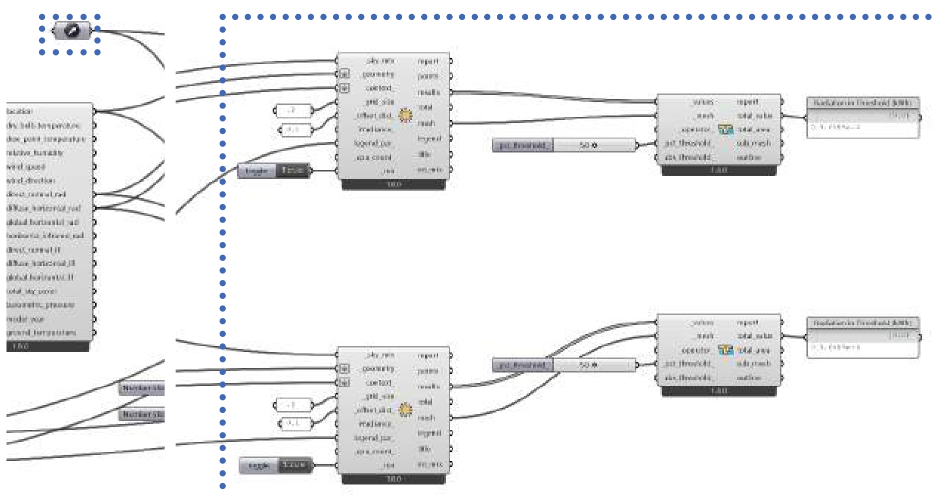


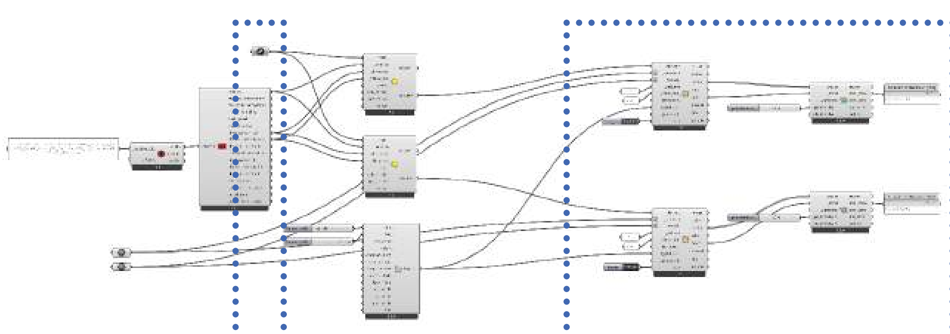
LOUVER - 48,159 KW/H

LOUVER FOR SOUTH

Compare to the previous simulation, louver is having superior quality in terms of thermal performance for the south facing facade in the project site. However, this result can be changed by different longitude and lattitude, where different sun positions are provided annually.

SIMULATION - LOUVER FOR SHADING

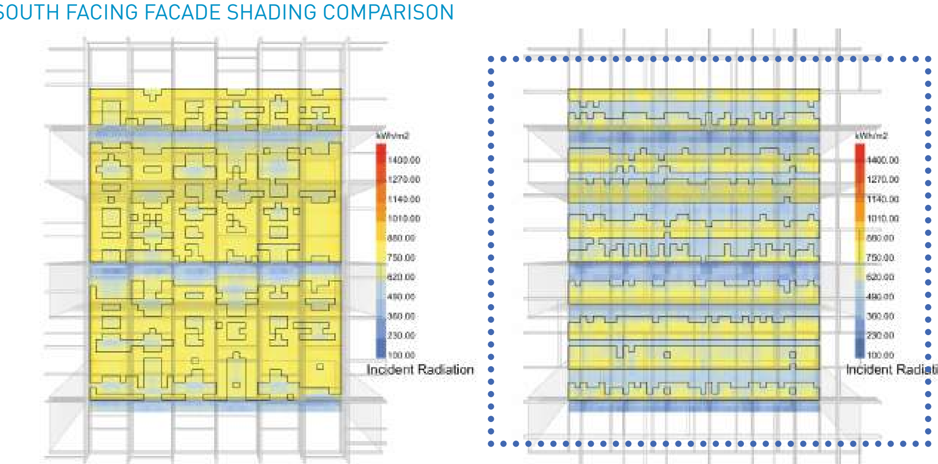




SIMULATION FOR EAST/WEST FACADE

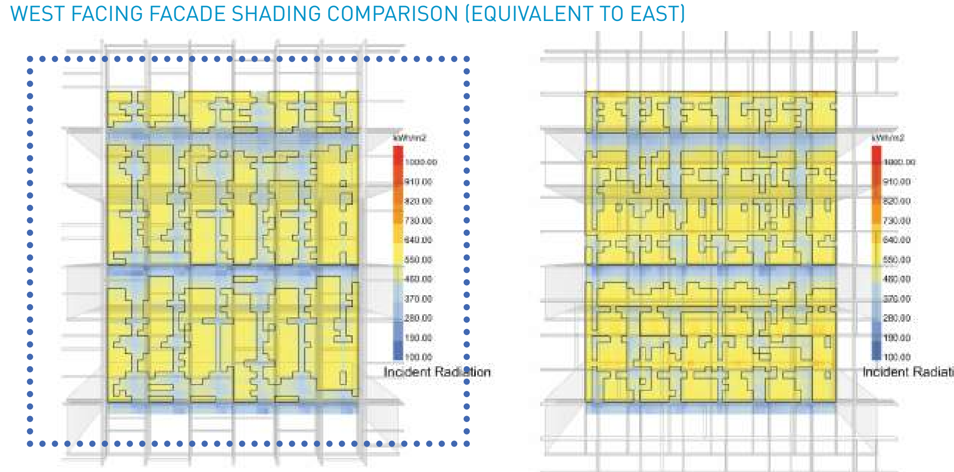
1) Repeat the same process to the east facade (west facade is having similar value with the east)

SOUTH FACING FACADE SHADING COMPARISON



FIN - 59,268 KW/H LOUVER - 48,159 KW/H

WEST FACING FACADE SHADING COMPARISON (EQUIVALENT TO EAST)

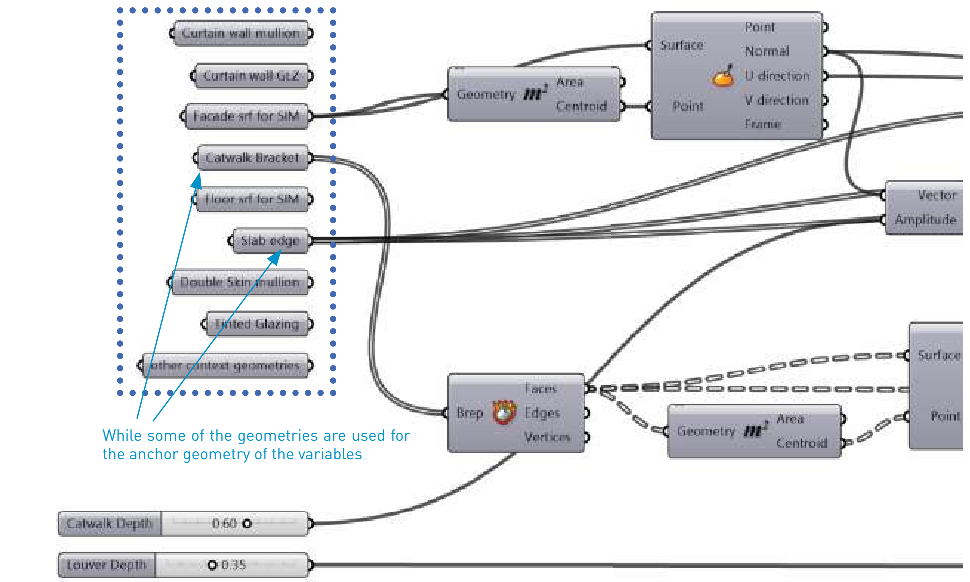


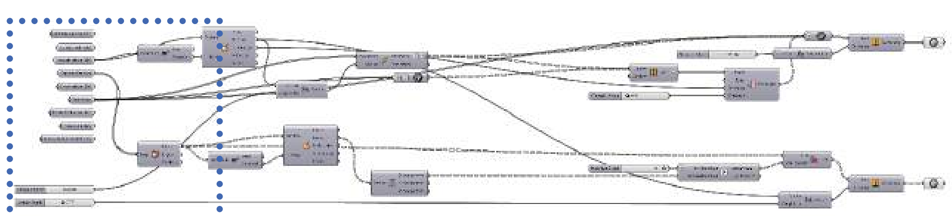
FIN - 38,679 KW/H LOUVER - 42,493 KW/H

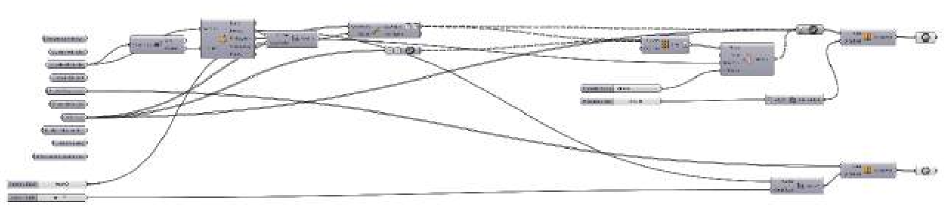
PROPER SHADING FOR EACH FACADE DIRECTION

The result came out that the louver shading is showing superior performance for the south facade and the fin shading is superior for the east/west facade.

Base (Fixed) Geometries as a Simulation Context



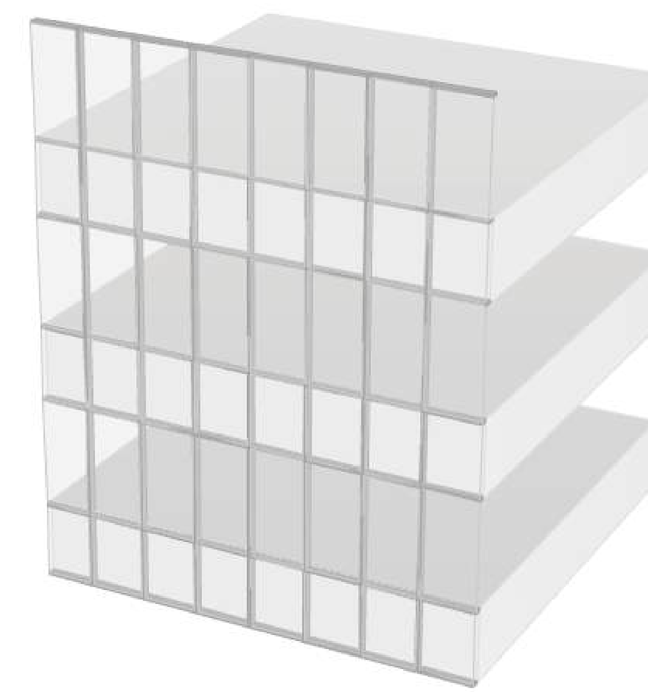




EAST & WEST FACADE GEOMETRY INPUT

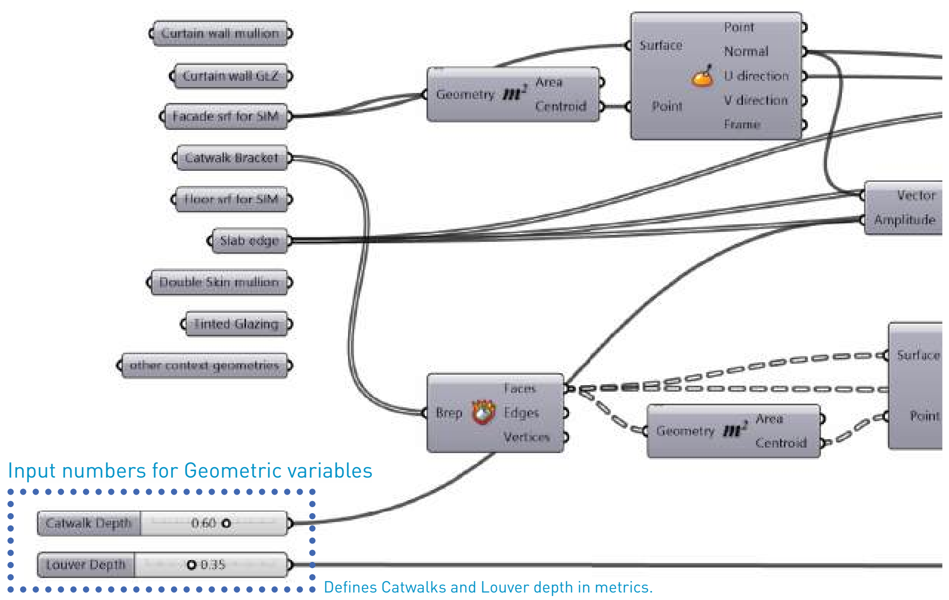
1) Import base geometries from thino to GH as Brep (boundary representation)

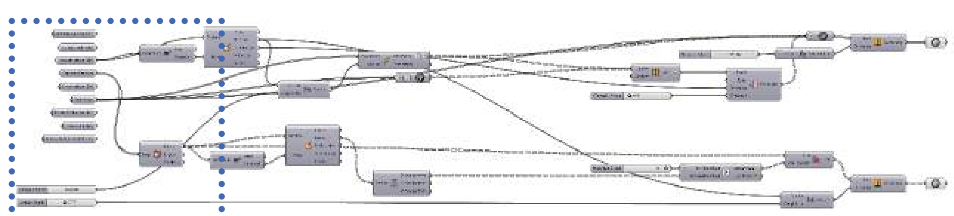
Base Geometry & Variable Geometry

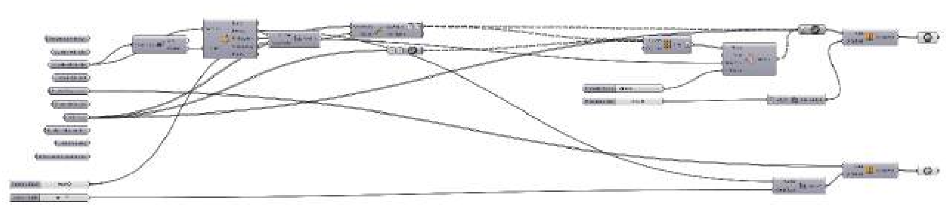


BASE GEOMETRIES

Fixed base geometries are imported from rhino modeling. These are fixed via local regulation for facade elements, structural coordination, or product size limit.



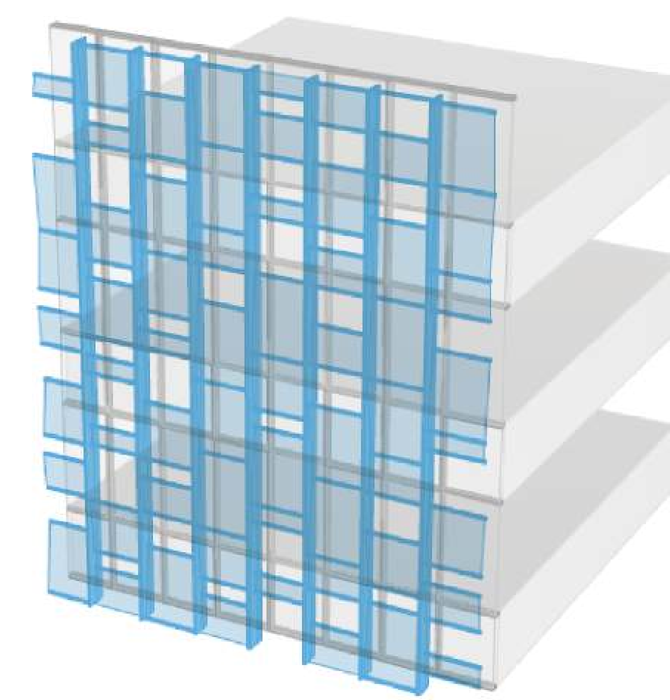




VARIABLE INPUT

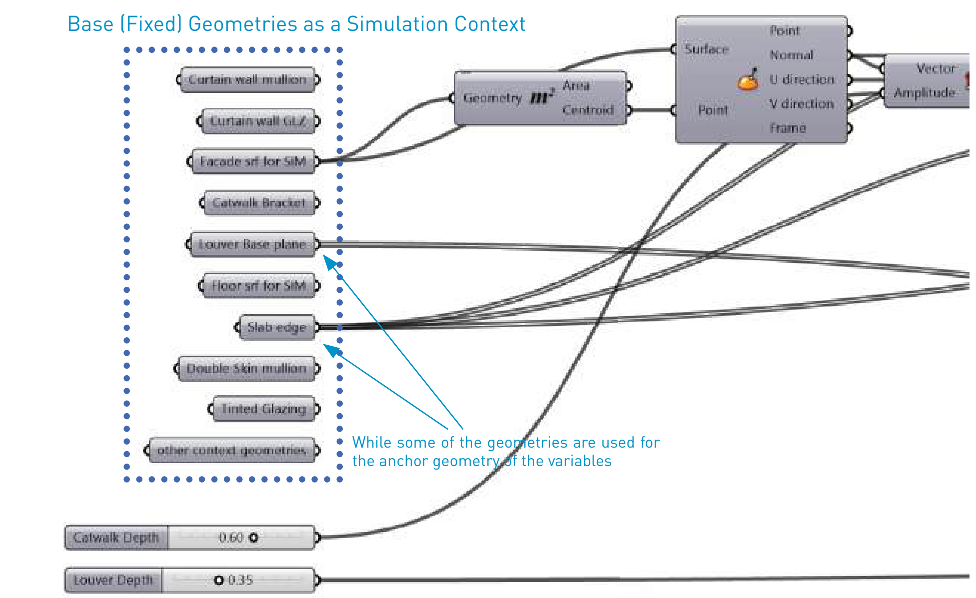
1) Some of the parametric variables are connected to create variable geometries
2) Catwalks and Louvers are created based on base geometry imported and input numbers

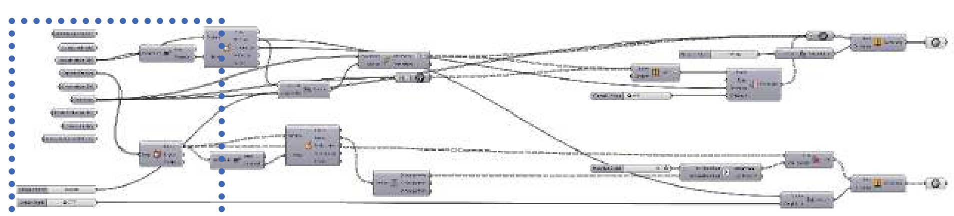
Base Geometry & Variable Geometry

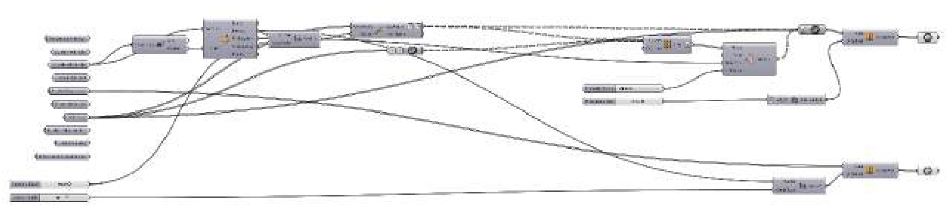


VARIABLE GEOMETRIES FOR EAST/WEST FACADE

East and west facade are having fins and vertically jagged and tinted double skin glazing surface. While the surfaces are fixed geometry, depth of the fins and catwalks are variable geometries for optimization simulation.



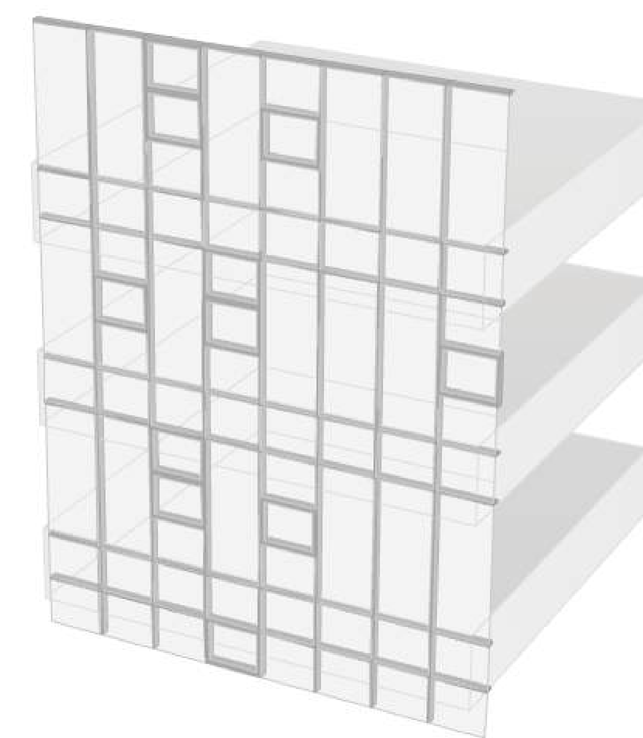




SOUTH FACADE GEOMETRY INPUT

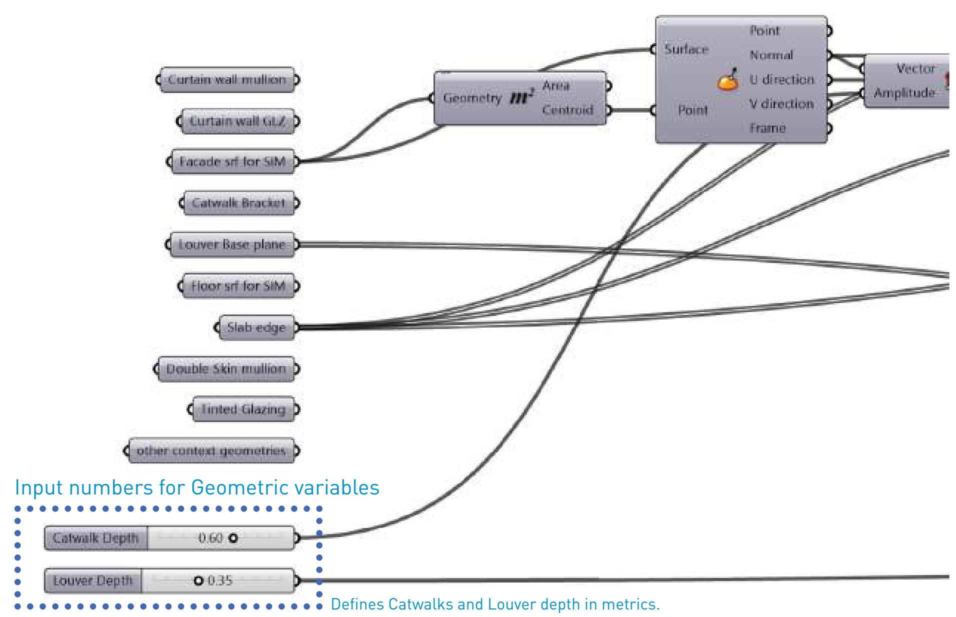
1) Import base geometries from thino to GH as Brep (boundary representation)

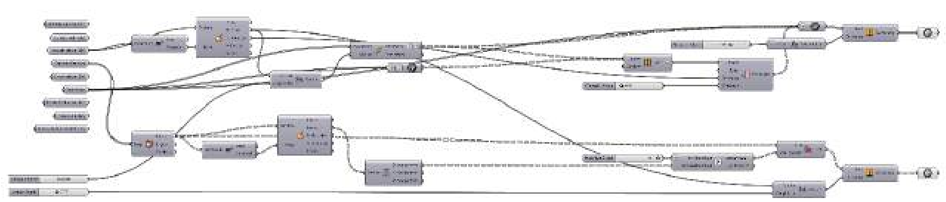
Base Geometry & Variable Geometry

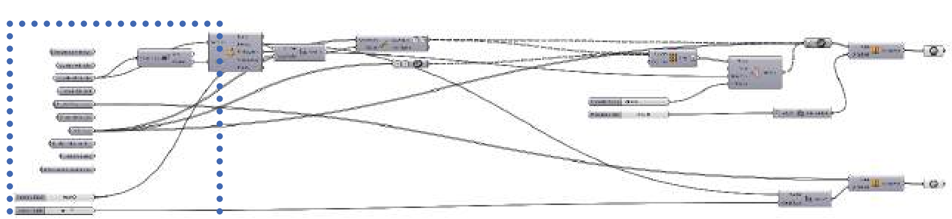


BASE GEOMETRIES

Fixed base geometries are imported from rhino modeling. These are fixed via local regulation for facade elements, structural coordination, or product size limit.



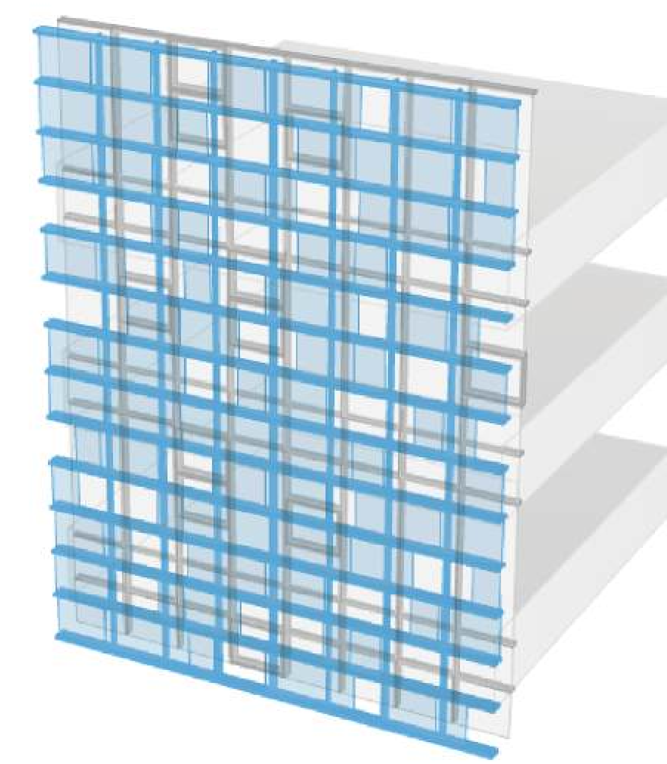




VARIABLE INPUT

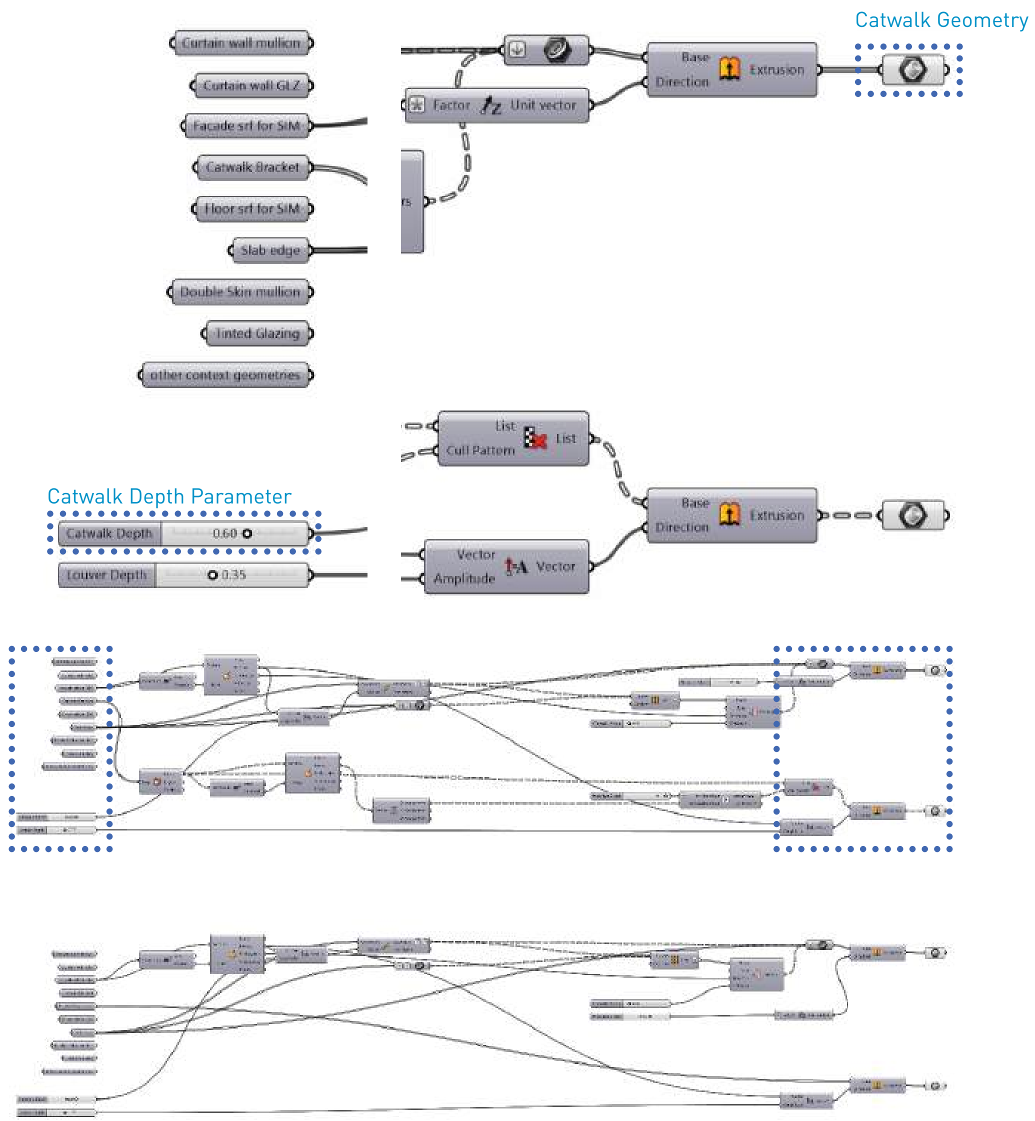
1) Some of the parametric variables are connected to create variable geometries
2) Catwalks and Louvers are created based on base geometry imported and uinput numbers

Base Geometry & Variable Geometry



VARIABLE GEOMETRIES FOR SOUTH FACADE

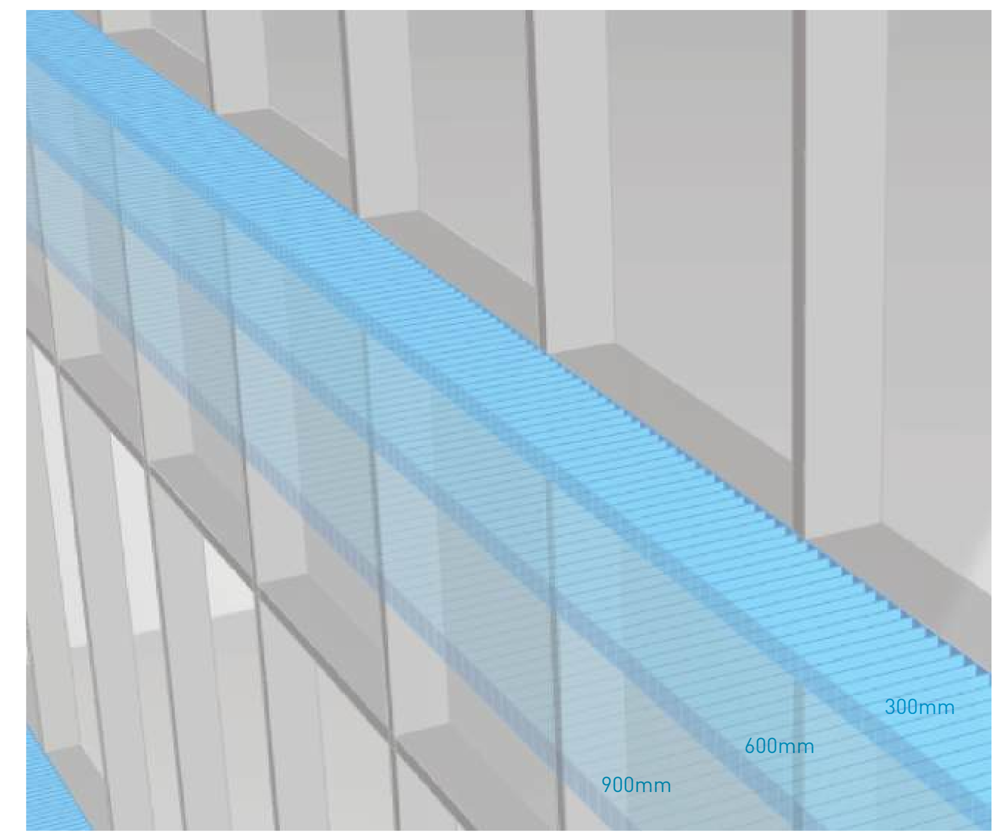
East and west facade is having louvers and horizontally jagged and tinted double skin glazing surface. While the surfaces are fixed geometry, depth of the louvers and catwalks are variable geometries for optimization simulation.



CATWALK DEPTH

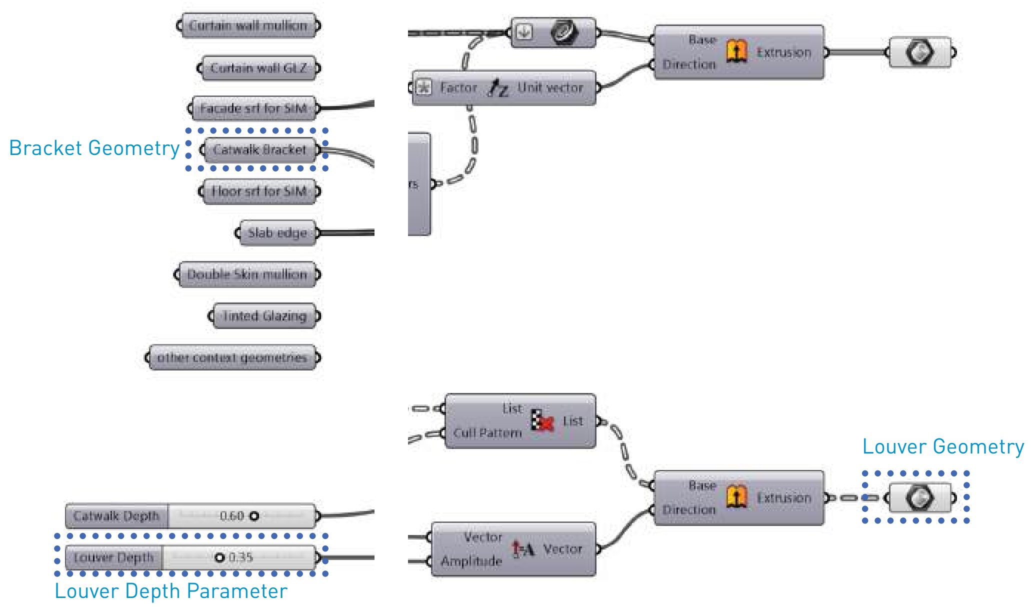
1) Set catwalk depth to be moduled in 300mm for constructability

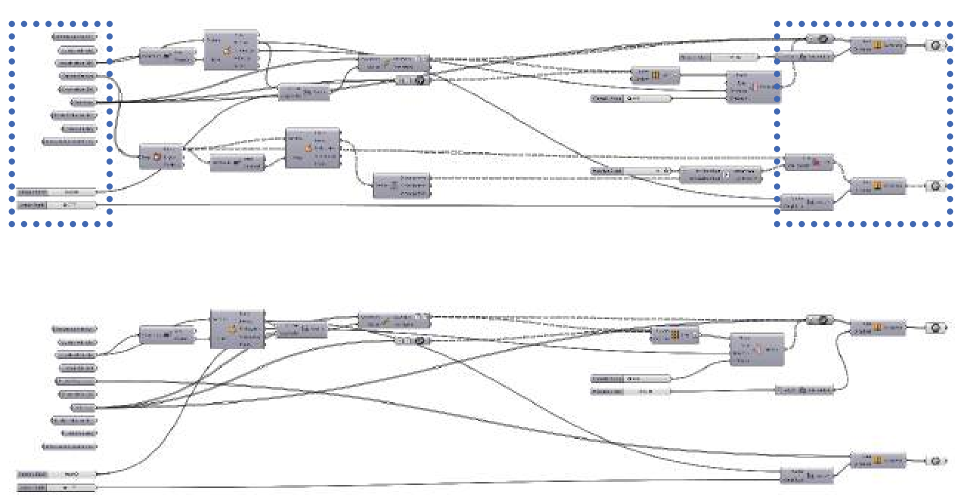
Base Geometry & Variable Geometry



MODULE FOR VARIABLE OPTIONS

Catwalk module size is set to 300mm/600mm/900mm in consideration with the window size, corner modules and overall dimension aesthetic of the project.

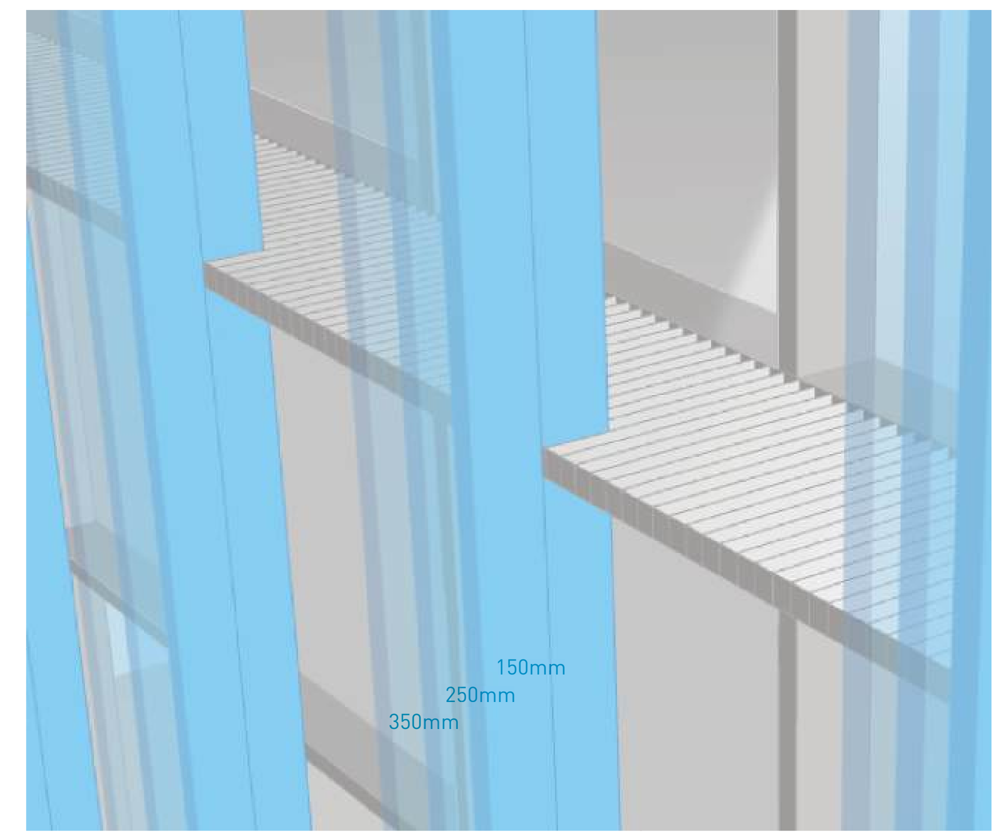




LOUVER DEPTH

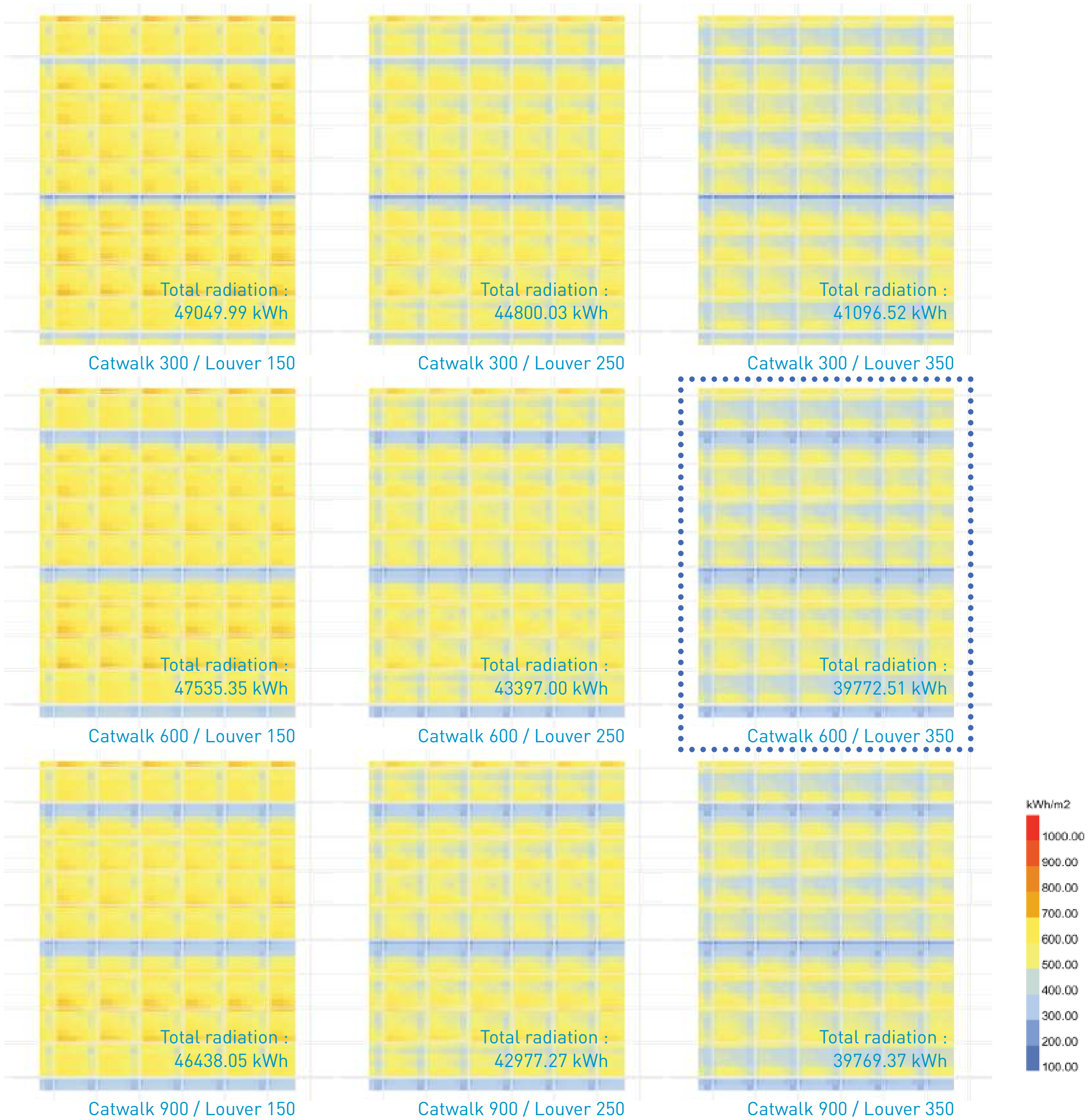
1) Set louver depth to be moduled for constructability

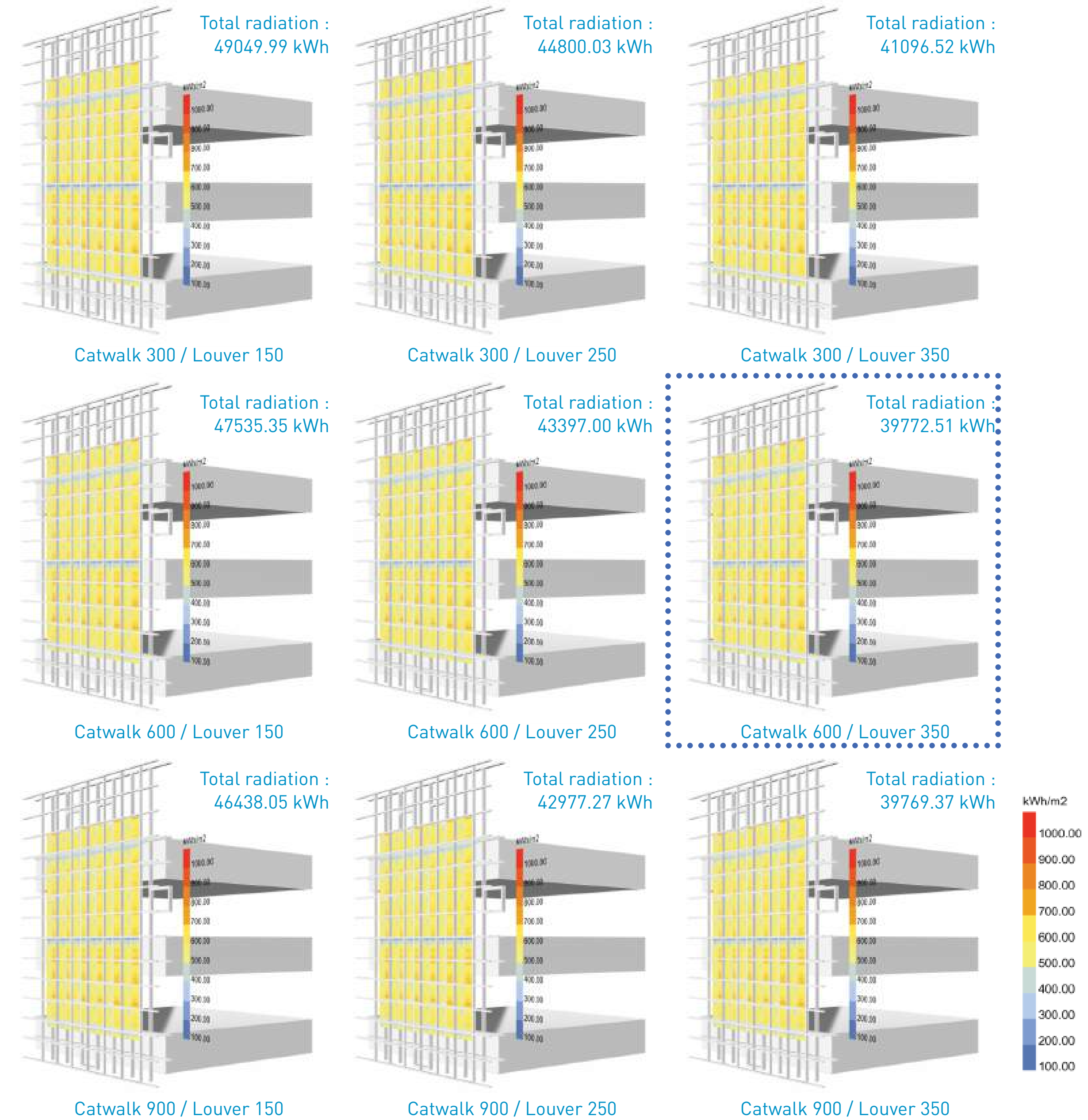
Base Geometry & Variable Geometry



MODULE FOR VARIABLE OPTIONS

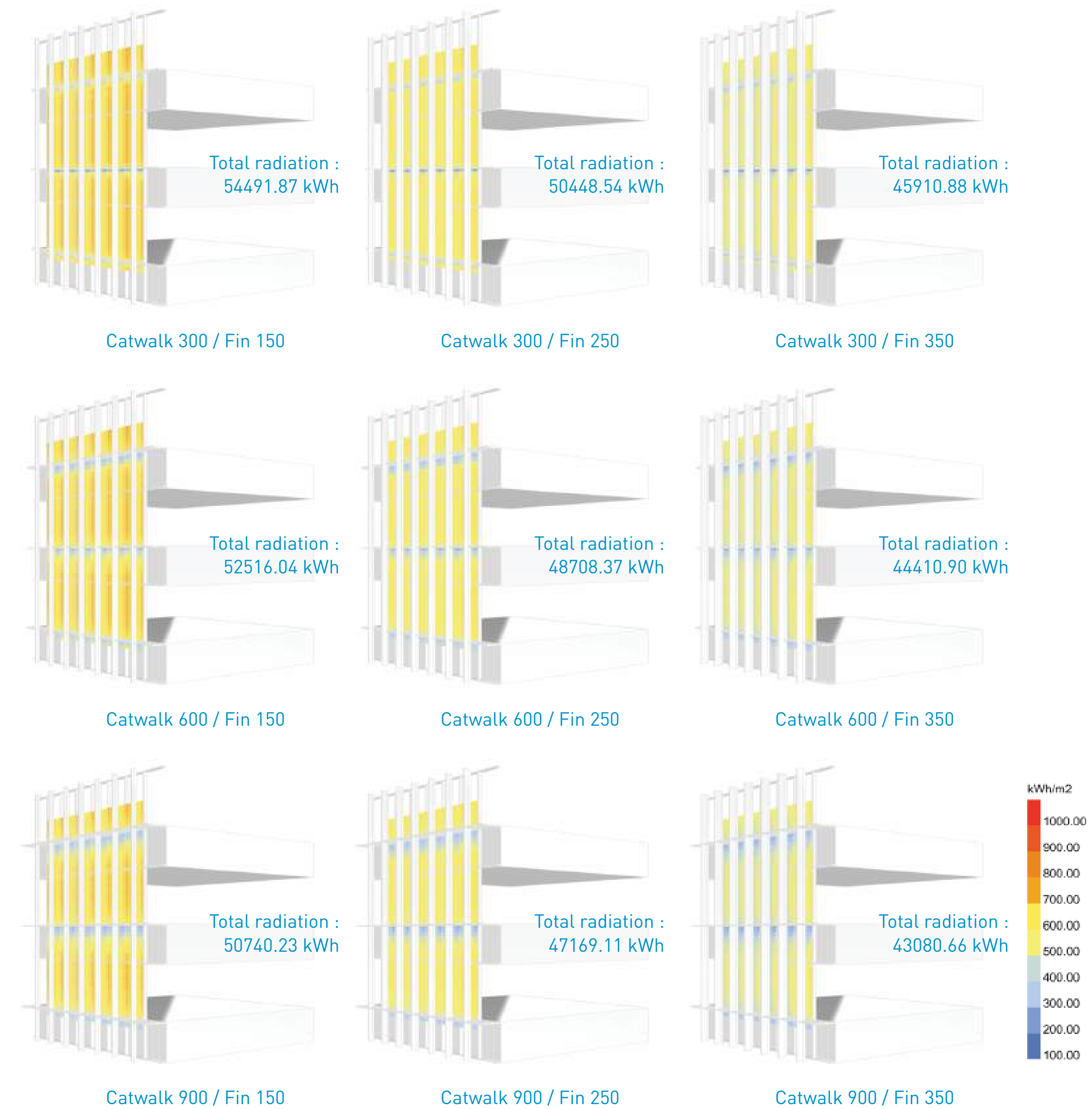
louver module size is set to 150mm to 350mm with 100mm difference in consideration with the self load, ease of fabrication and overall dimension aesthetic of the project.





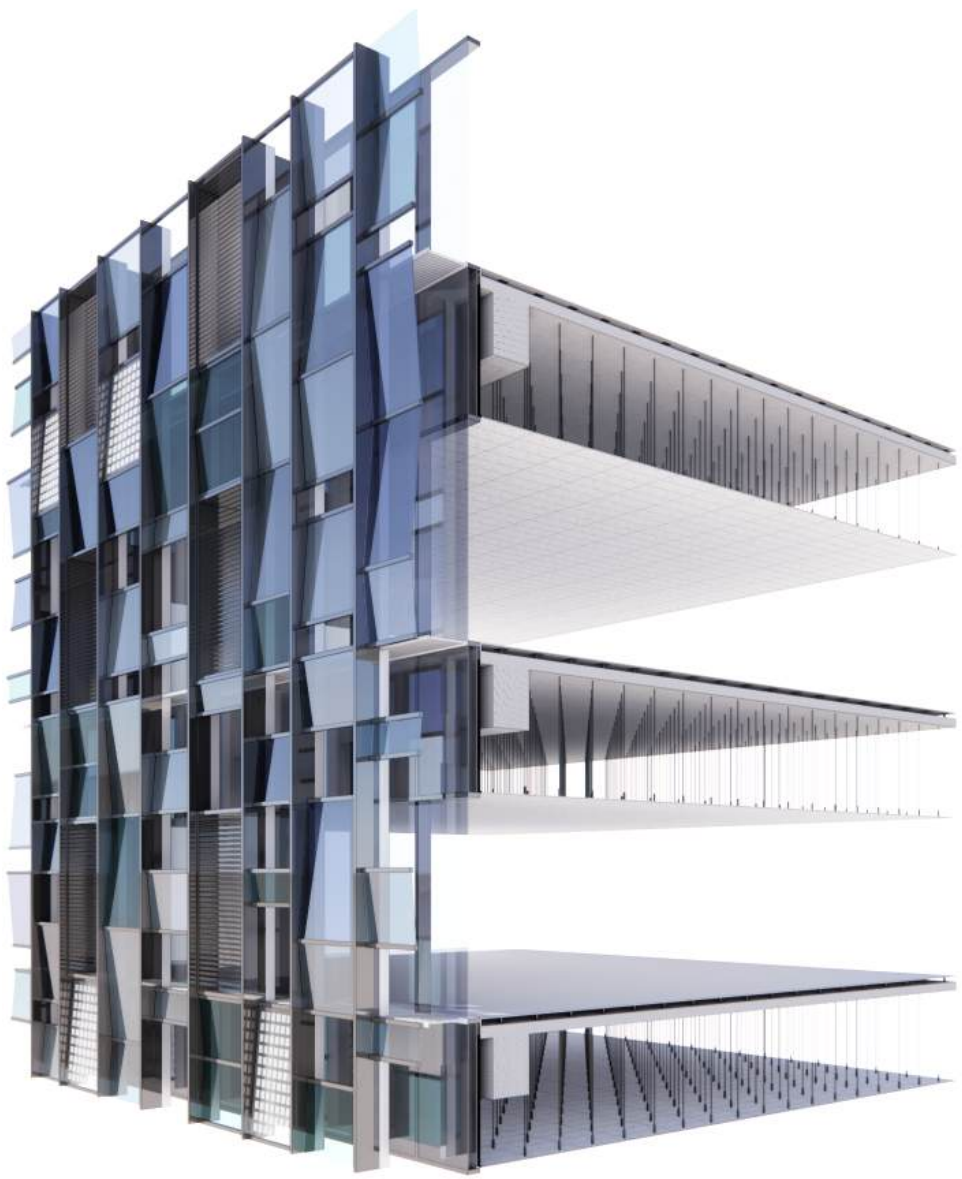
SIMULATION RESULT

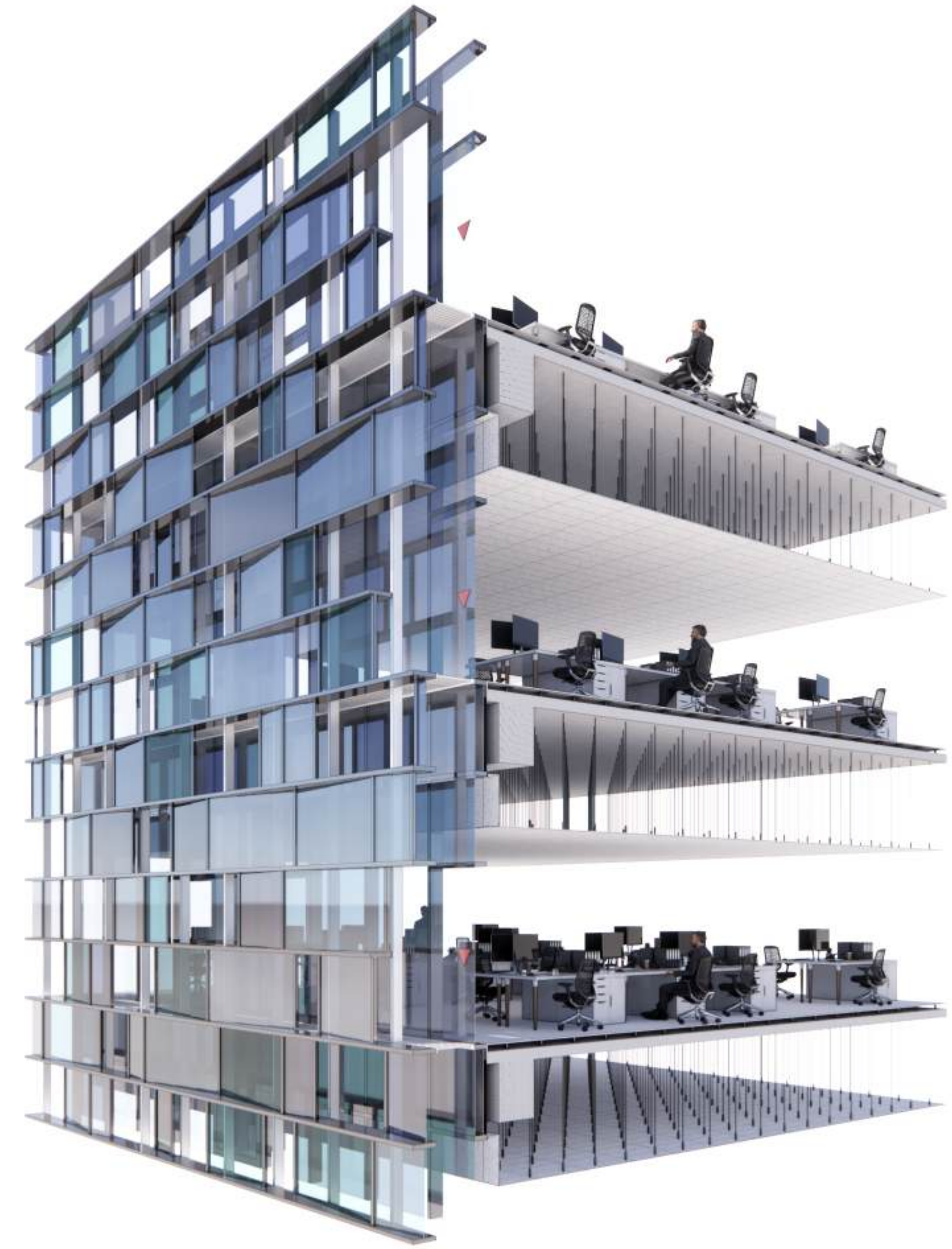
Catwalk depth of 600 and louver depth 350 is the best option in terms of the thermal performance of the building. Although, catwalk depth of 900 and Louber depth of 350 option is having slightly better performance, former options are showing very similar performance with less building material



SIMULATION RESULT

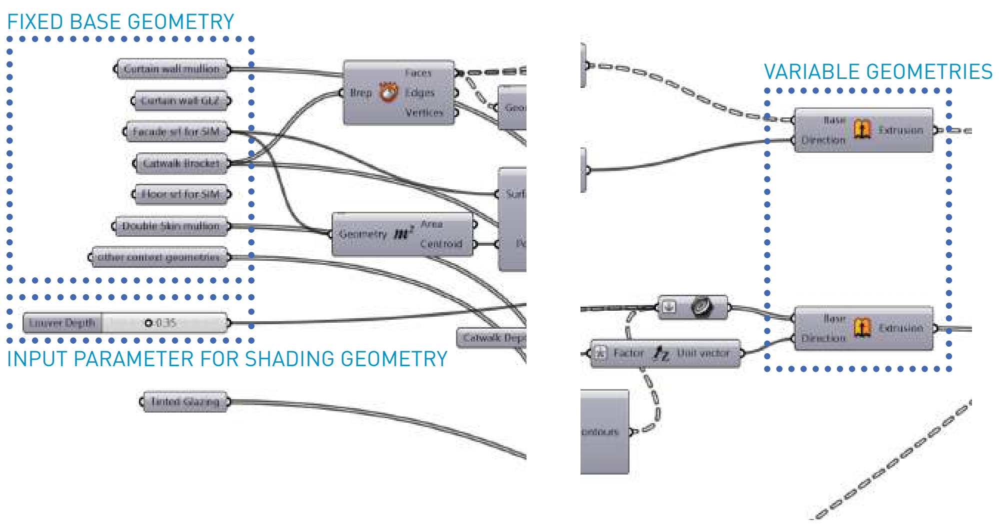
Catwalk depth of 900 and Fin depth 350 is the best option in terms of the thermal performance of the building. Performance of the fin and catwalk geometry is gradually increased as the variable parameter increased, thus 900/350 combination is the best tier option for the performance.

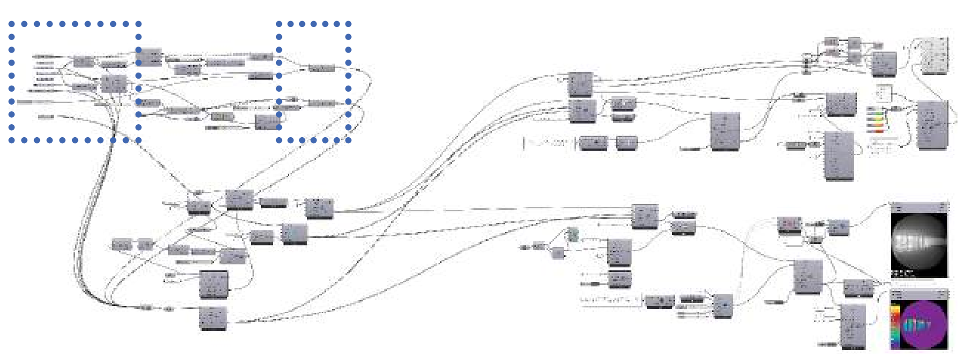




FACADE DESIGN STRATEGY BY SIMULATION

East, West and South facades are designed and fine-tuned under geometric design strategy derived from environmental simulation. From problem identification to the final fine tuning of the design, simulation played a pivotal role in design decision making by providing quantative data sets and comparison in between potential design options



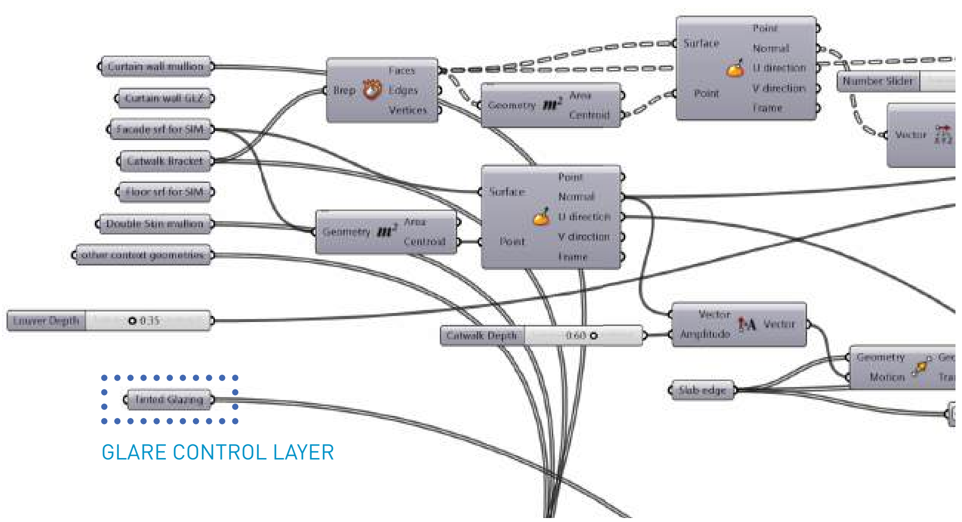


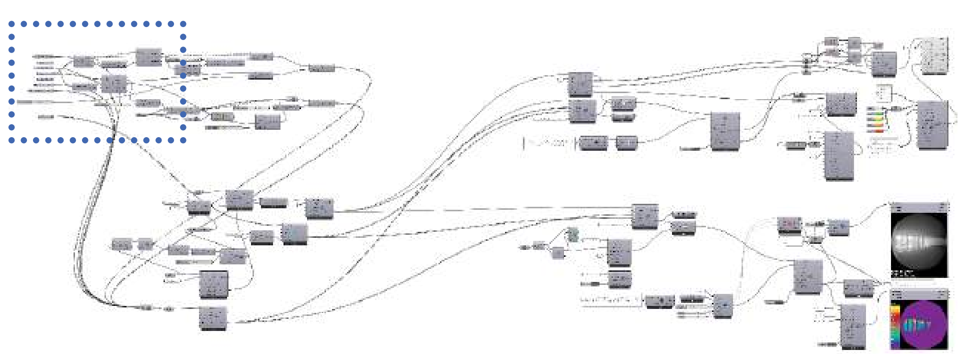
GEOMETRY INPUT

1) Import base geometries from rhino to GH as Brep (boundary representation)
2) Set variable input parameter as previously selected

GLARE SIMULATION FOR INTERIOR ENVIRONMENT

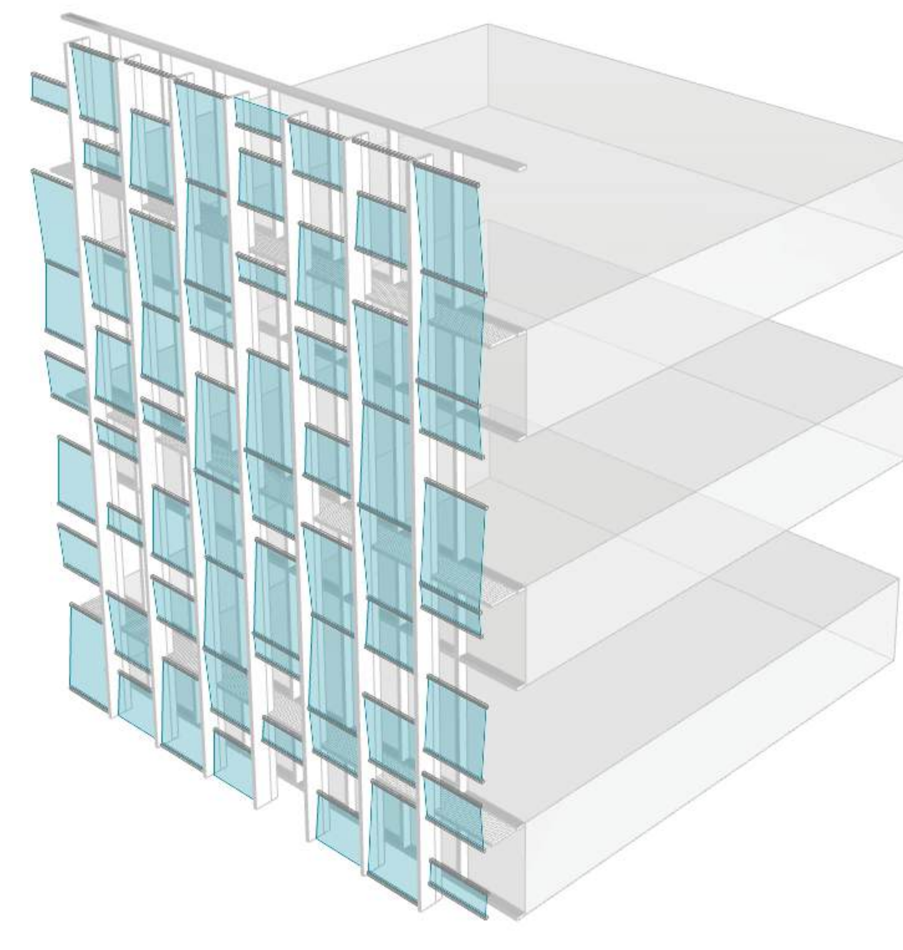
Modern office program requires minimal glare environment due to its usage of monitor, regular light level for focusing, etc. While the shading device takes some part of regulating the thermal performance of the building facade, tinted double skin glazing is more responsible for this interior environment effect.





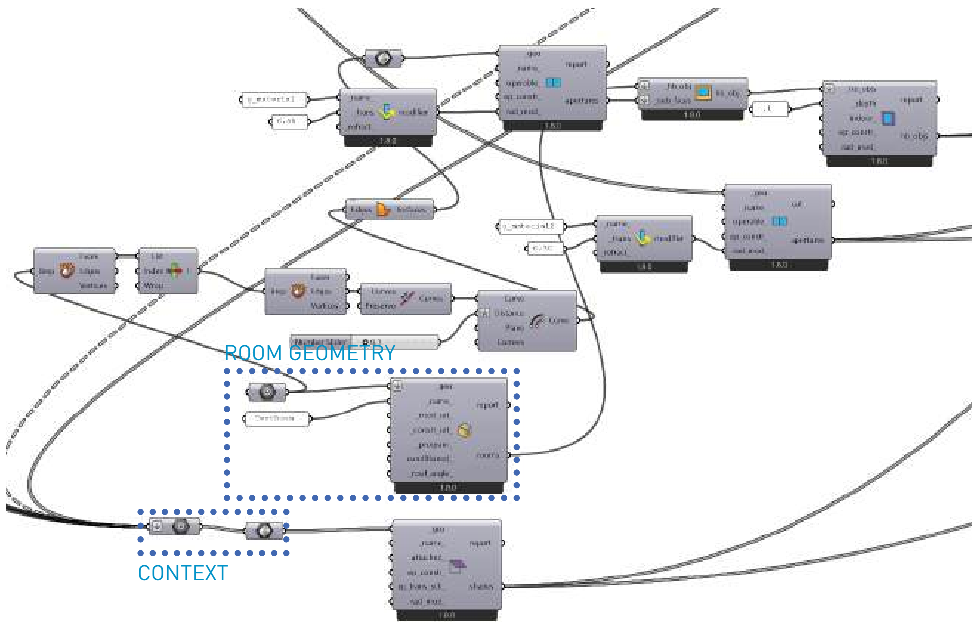
GEOMETRIC INPUT

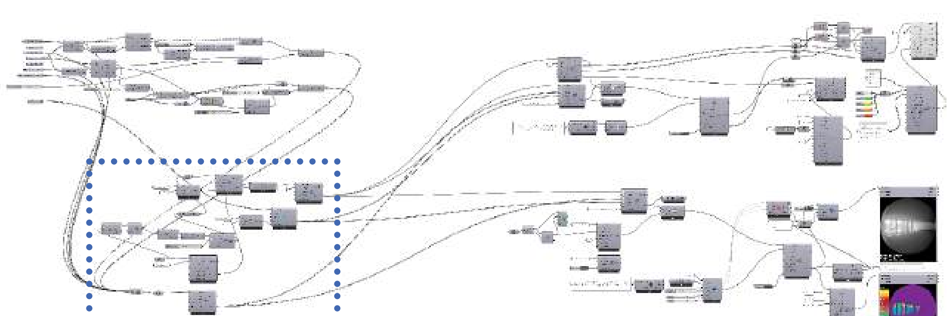
1) Import base geometries from rhino to GH as Brep (boundary representation)



GLARE CONTROL LAYER

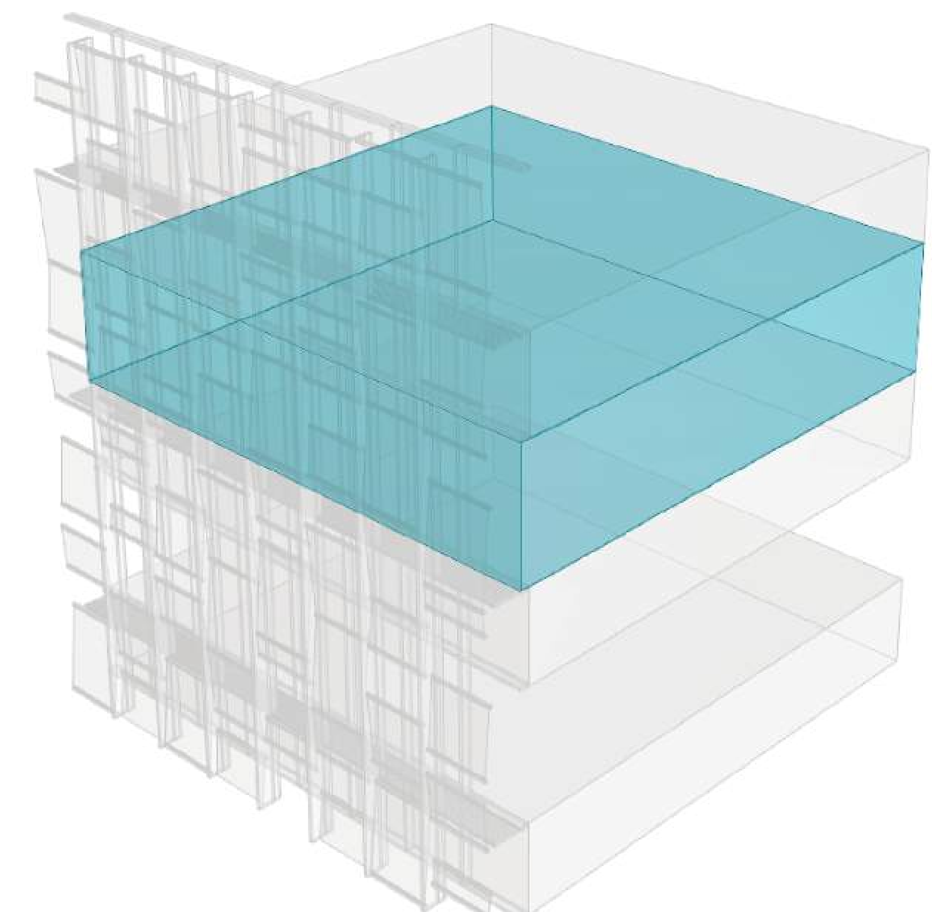
Outermost glazing layer on this facade system regulates the glare effect with its material property. Powder coated tinted glazing can have designated value of the tint via glare simulation.





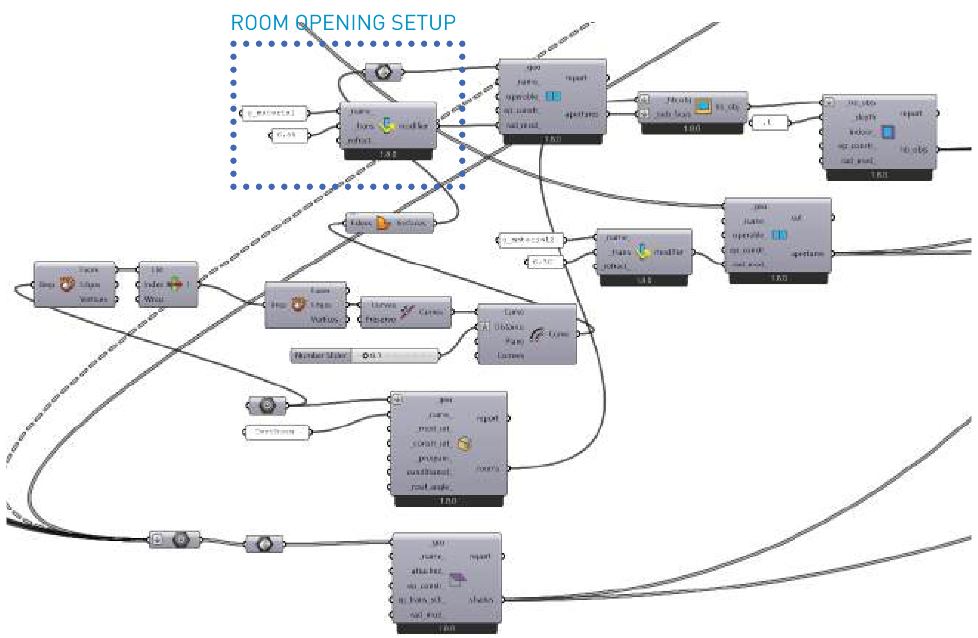
GEOMETRIC INPUT

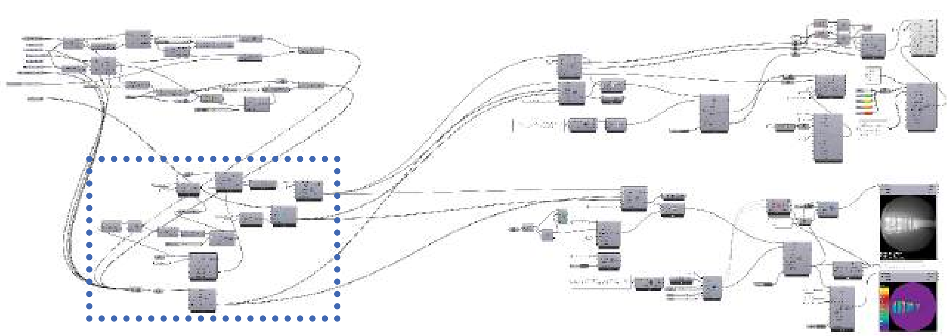
1) Set Room geometry and connect it to HB room component
2) Connect all other base geometries to HB shade as a context geometry, except glare control geometry



CONTEXT GEOMETRY

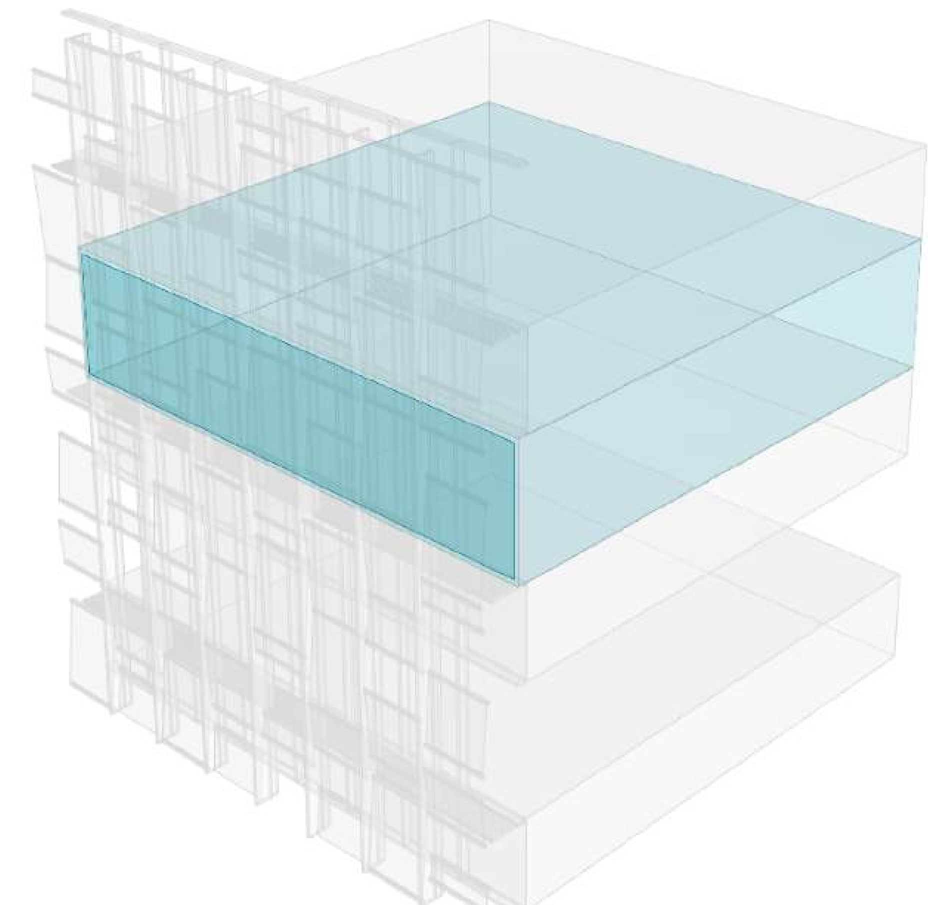
Shading devices are treated as context geometry while the glazing control layer is treated as a semi-transparent, anti-glare geometry with relevant material. In this simulation, only glazing parts will be targeted to have a material property, thus, all other geometries in facade system are treated as a context geometry





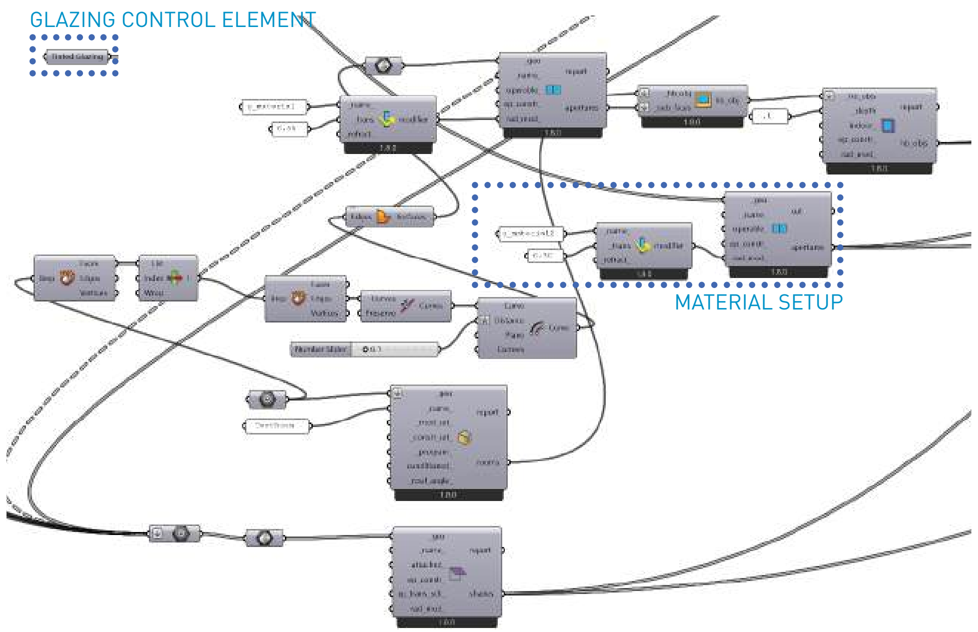
ROOM GEOMETRY SET UP

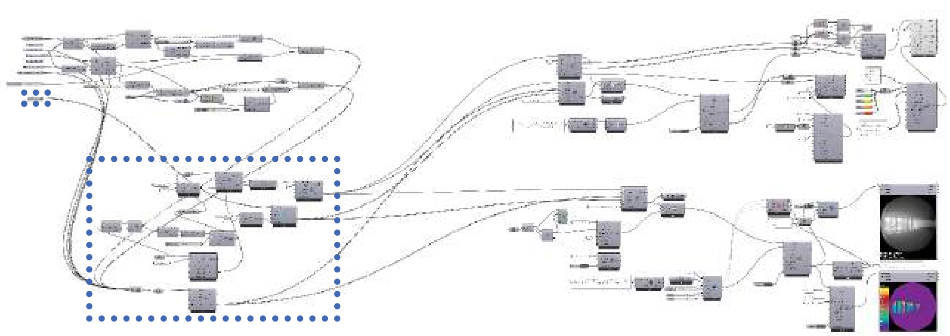
1) Set room to have opening facing facade area only



ROOM BOUNDARY

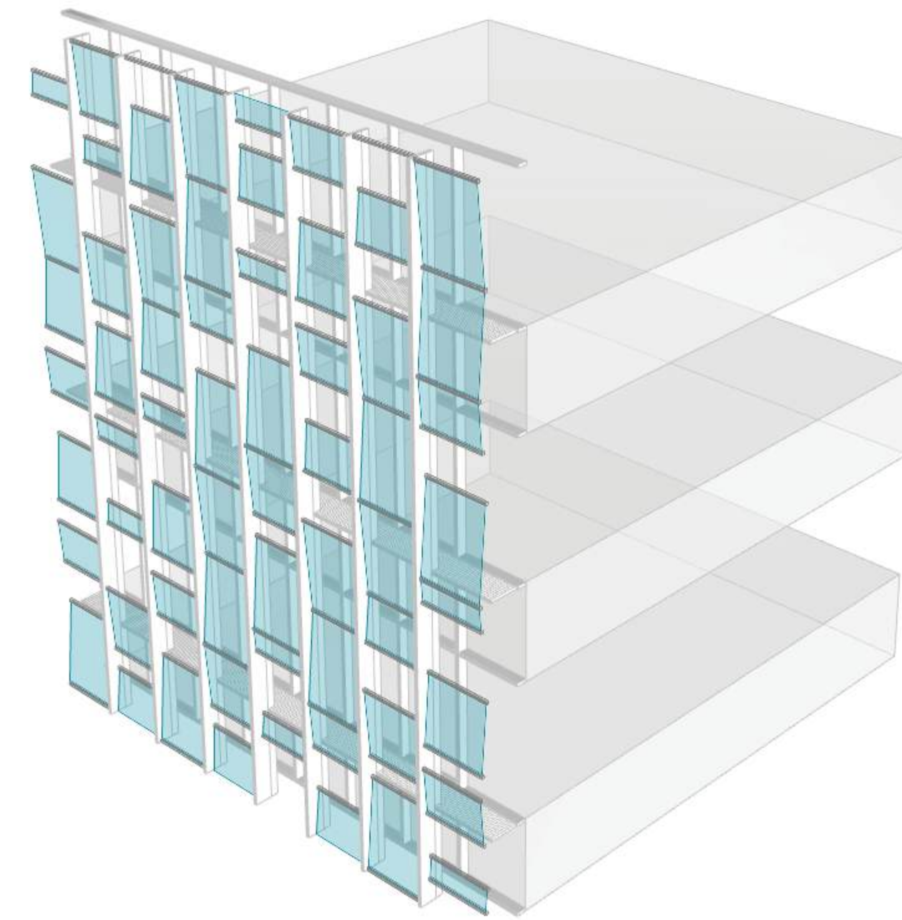
The simulation only need one floor as a typical floor. Room geometry to be completely closed except facade area for better observation during simulation process





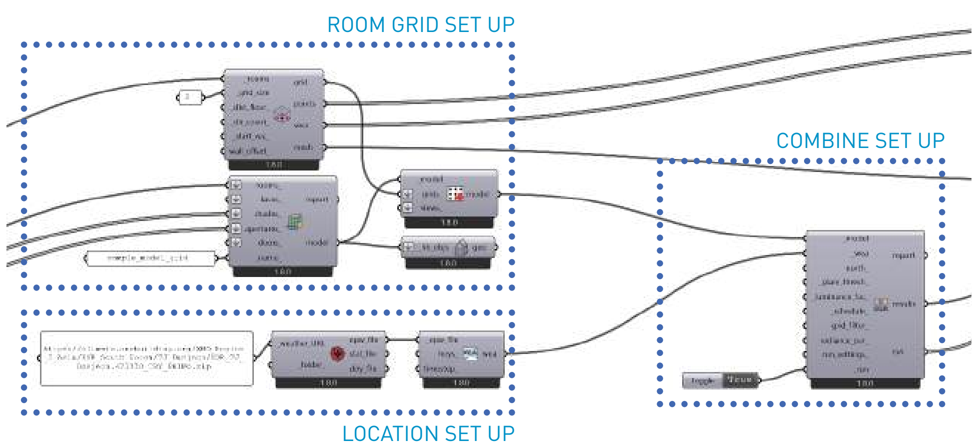
MATERIAL PROPERTY SET UP

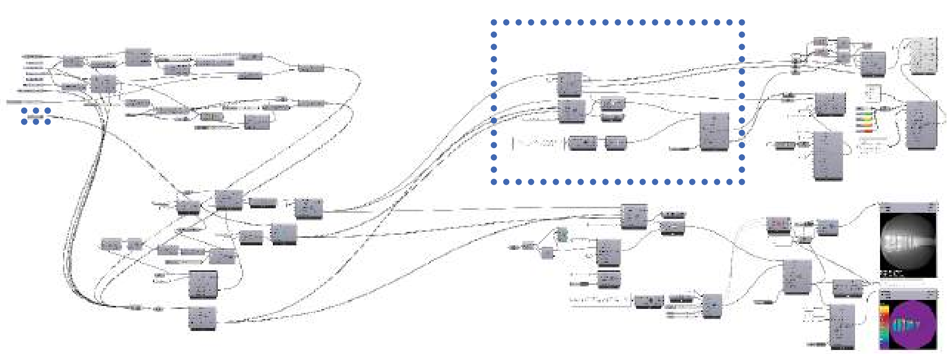
1) Connect Glazing goemetry to geo input of HB Aperture component
2) With using HB glass modifier, set name and transparency of the glazing material
3) Connect it to the rad_mod input of HB Aperture component

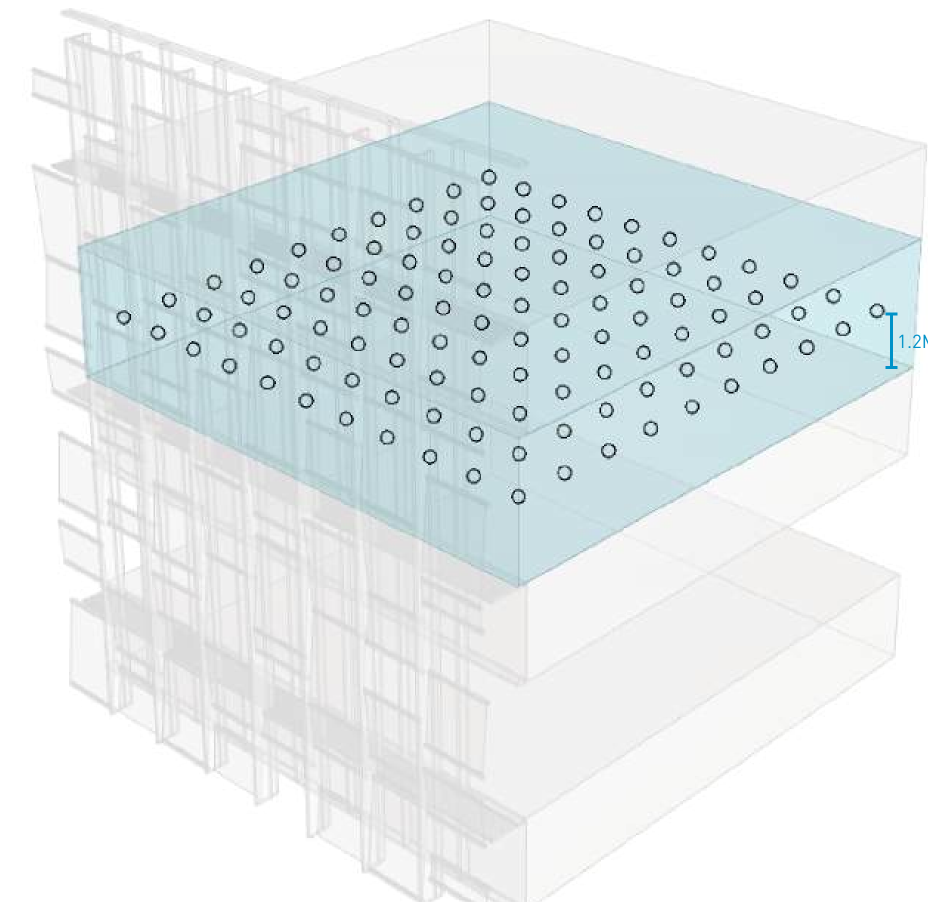


Material property

Transparency of the aperture mimics the effect of tinted glazing. By modifying this parameter, design of the glazing material can be compared and evaluated





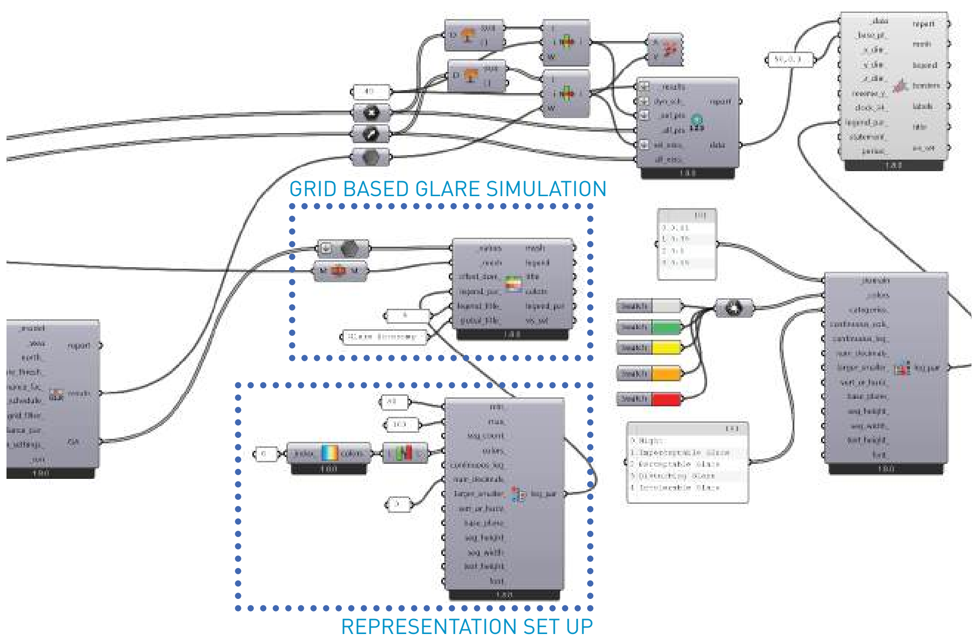


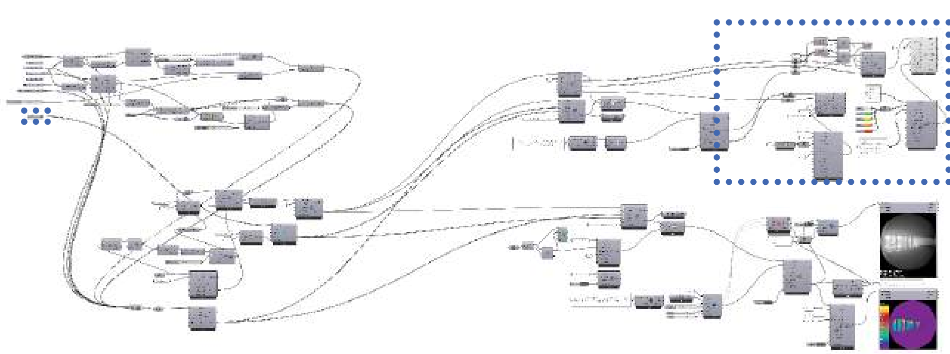
SIMULATION SET UP

1) Set room grid as numerical value in metric (e.g. 1 = 1m)
2) Collect room, aperture and context geometries via HB model component
3) Create grid in room through HB assign grids and views component
4) import EPW weather data and combine every information in HB imageless annual glare component

GRID BASED REPRESENTATION

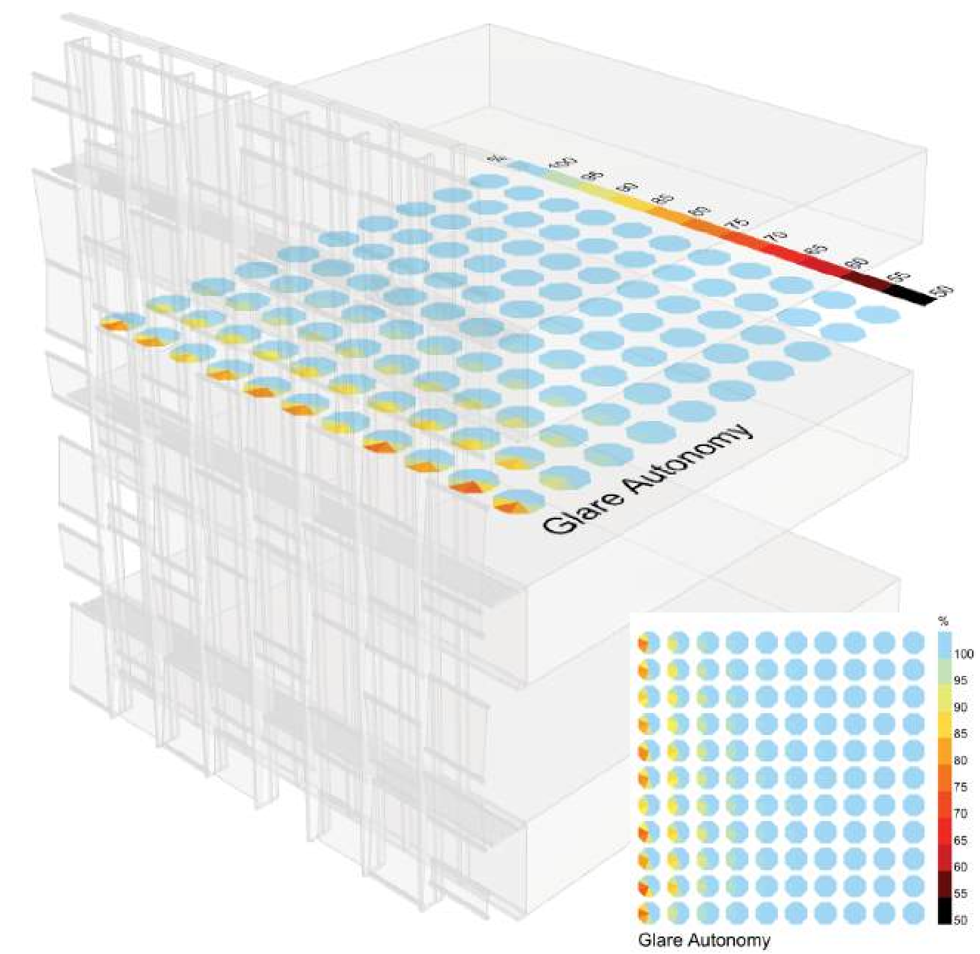
Grid based glare autonomy representation is very simple form of the glare effect analysis. This simulation is faster, easier, and better to be explained with plan of 3d image of the project. Although this simulation is showing the probability of the glare effect in specific spot, this will not give a quantitative data set with eligible standard in indoor environment





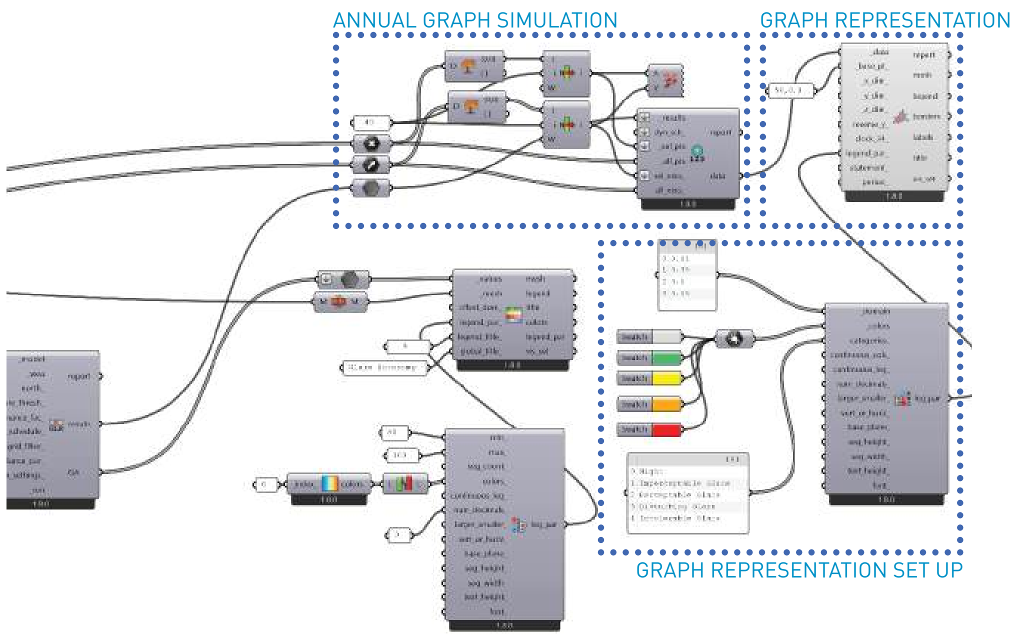
SIMULATION REPRESENTATION

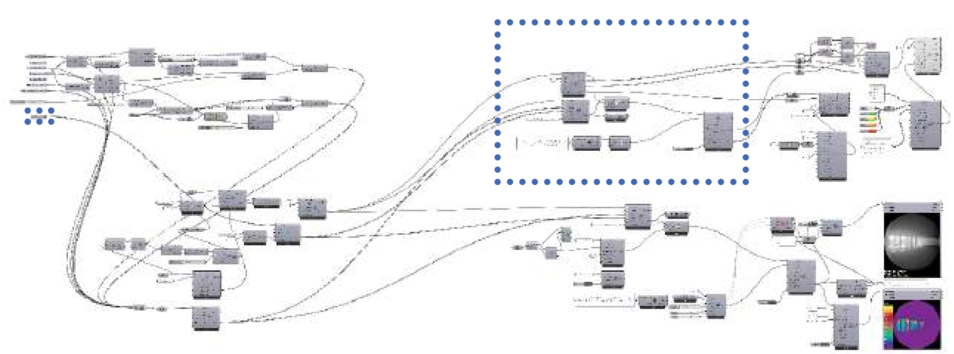
1) Connect GA(Glare Autonomy) output to the LB spatial Heatmap
2) Set up the title and legend
3) Put legend parameter with domain of 50 to 100 and with designated color option



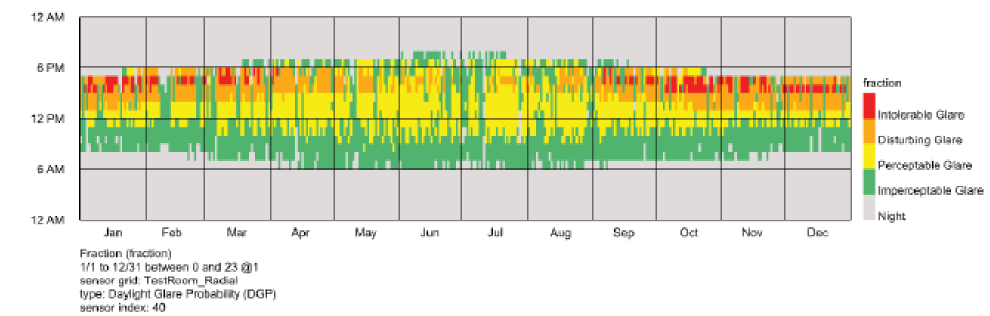
GLARE AUTONOMY

HB Glare autonomy shows only a percentage of the possible glare effect. This is effective as a representation tool with status information, but not a quantitative representation with specific standard.

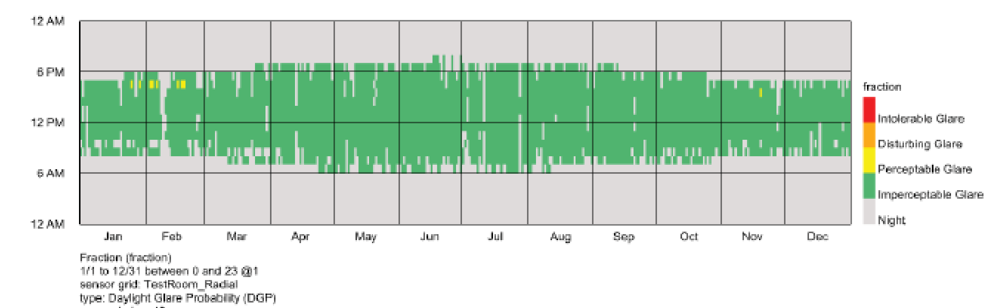




ANNUAL GLARE EFFECT GRAPH BEFORE SECONDARY GLAZING



ANNUAL GLARE EFFECT GRAPH AFTER SECONDARY GLAZING

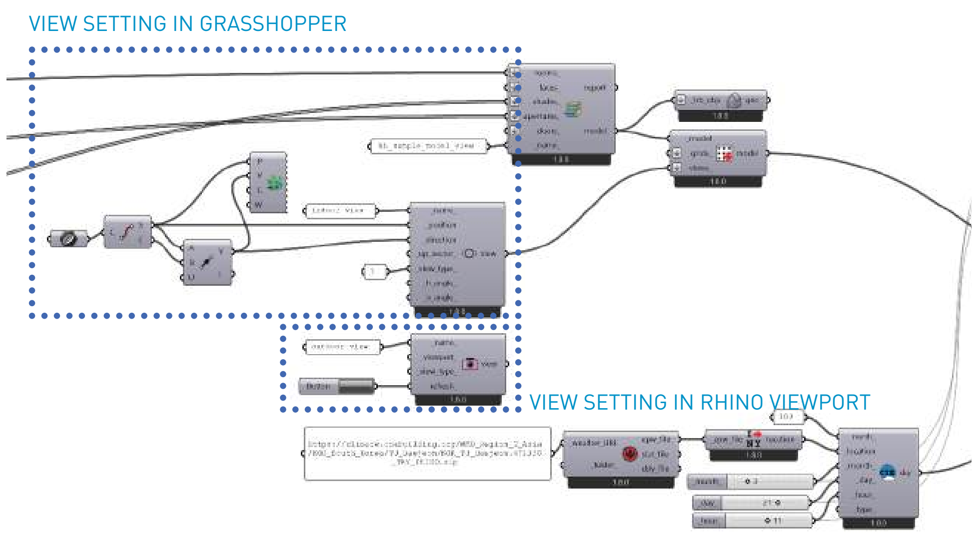


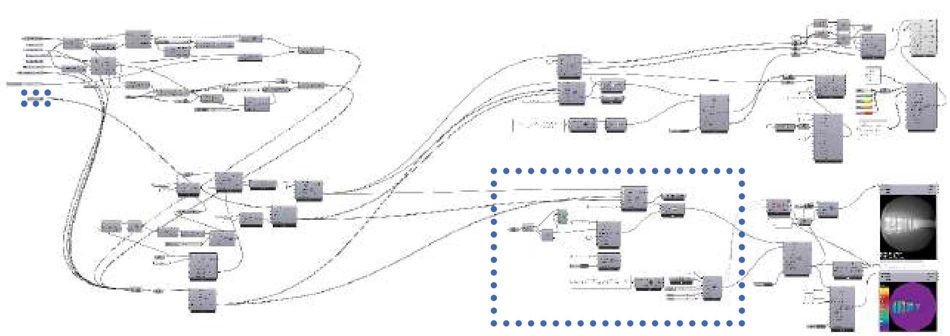
GRAPH REPRESENTATION

1) Parsing the simulation result to HB annual result to data
2) Set colors and domain numbers with proper text categories
3) Connect legend parameter and annual data to LB hourly plot

GRAPH REPRESENTATION AND DGP VALUE

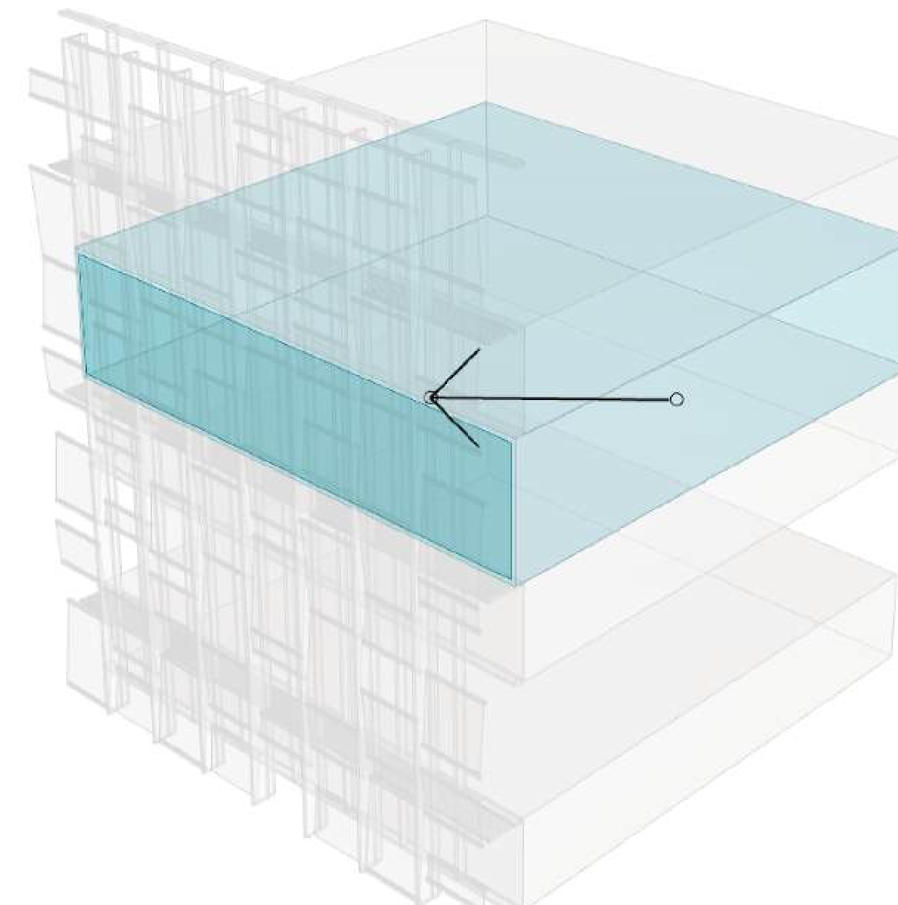
HB have DGP standard in 5 stages - Night/ Imperceptible Glare/ Perceptible Glare/ Disturbing Glare/ Intolerable Glare. These stages divided in accordance with percentile boundary of 1%, 35%, 40% and 45%. with Glare autonomy, these information should brought together for better understanding of the simulation result





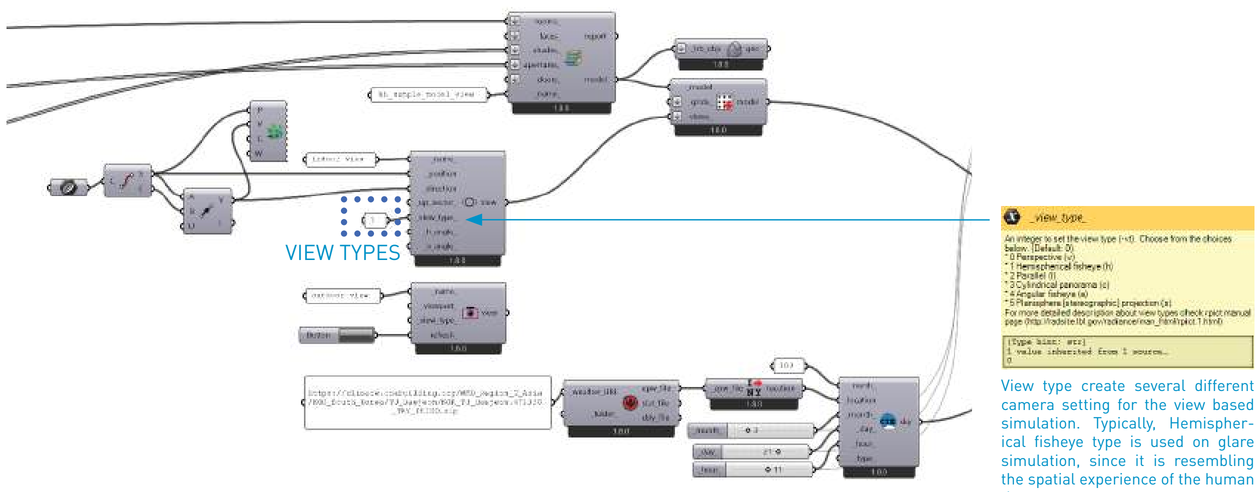
VIEW BASED SIMULATION SET UP

1) Create HB model with same resources for the previous grid based simulation model
2) Set point and direction of the view through HB view component
3) Connect view output to the Assign grid and view component

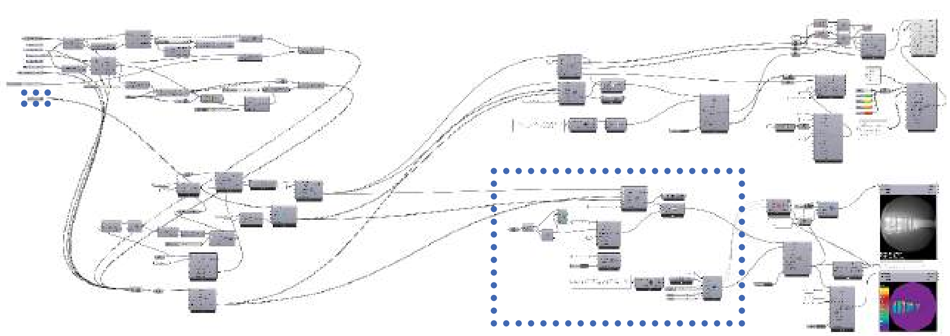


VIEW BASED SIMULATION

This type of simulation is representing the simulated indoor environment via 3 dimensional image. Projection type may vary depending on camera setting for the simulation



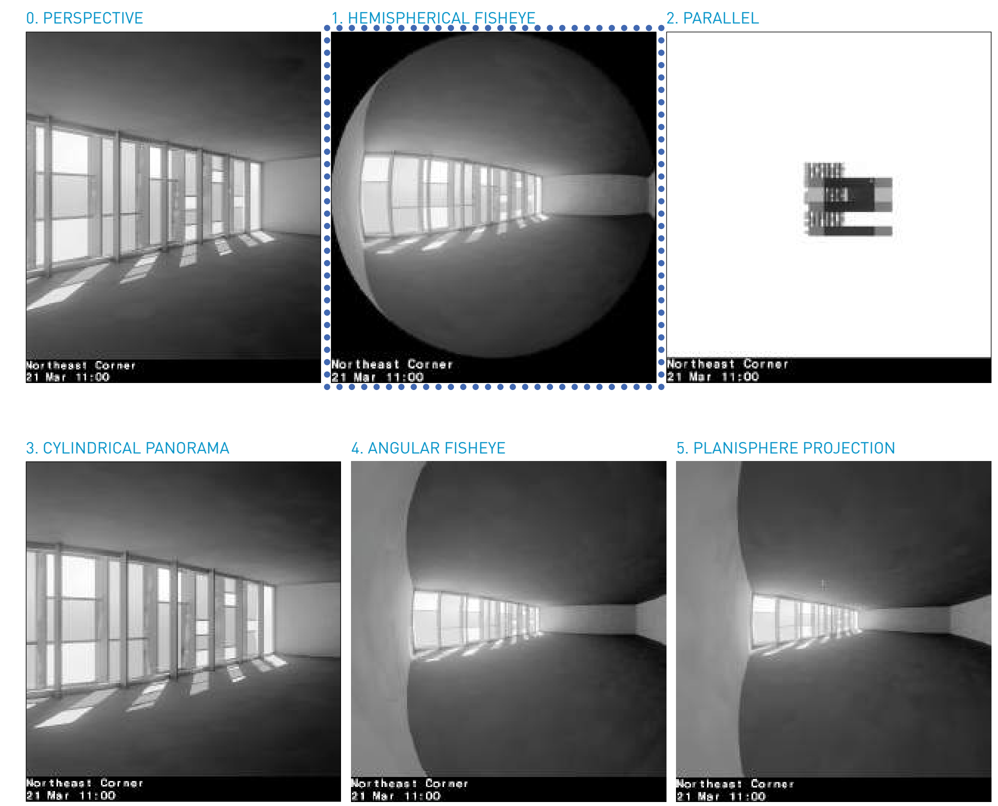
View type create several different camera setting for the view based simulation. Typically, Hemispherical fisheye type is used on glare simulation, since it is resembling the spatial experience of the human the most



VIEW SET UP

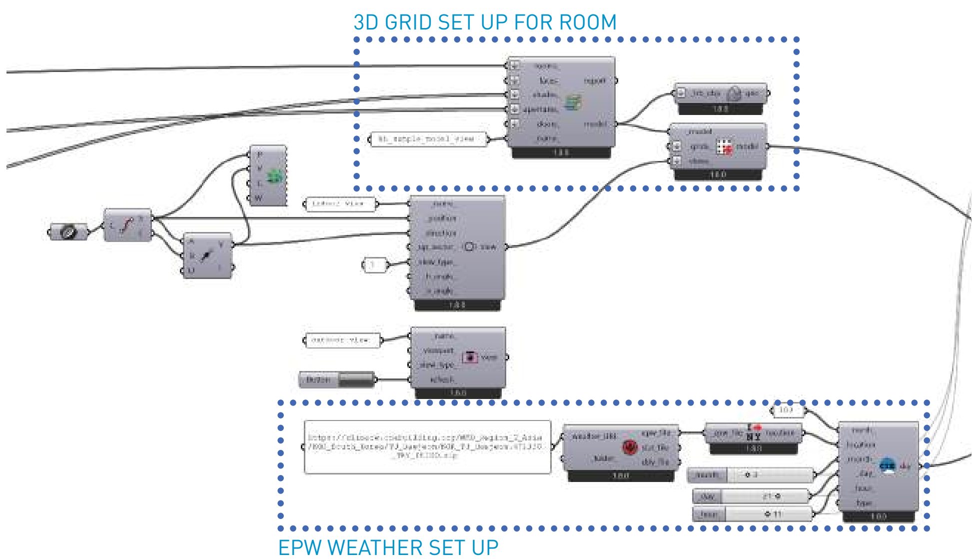
1) Set the proper view types based on usage of the final image

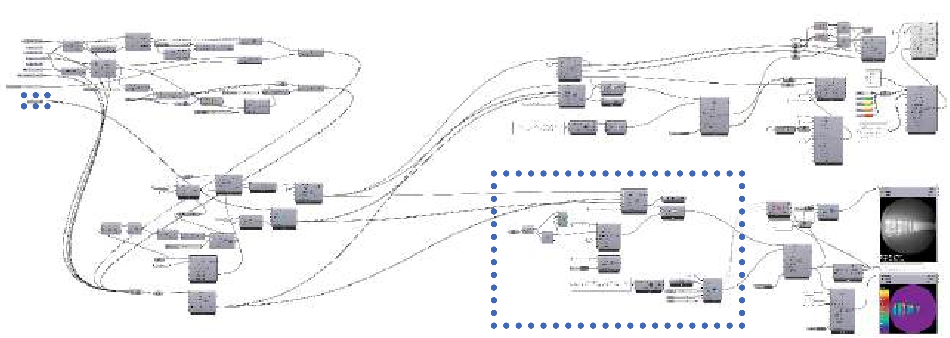
VIEW TYPES IN IMAGE



VIEW TYPES

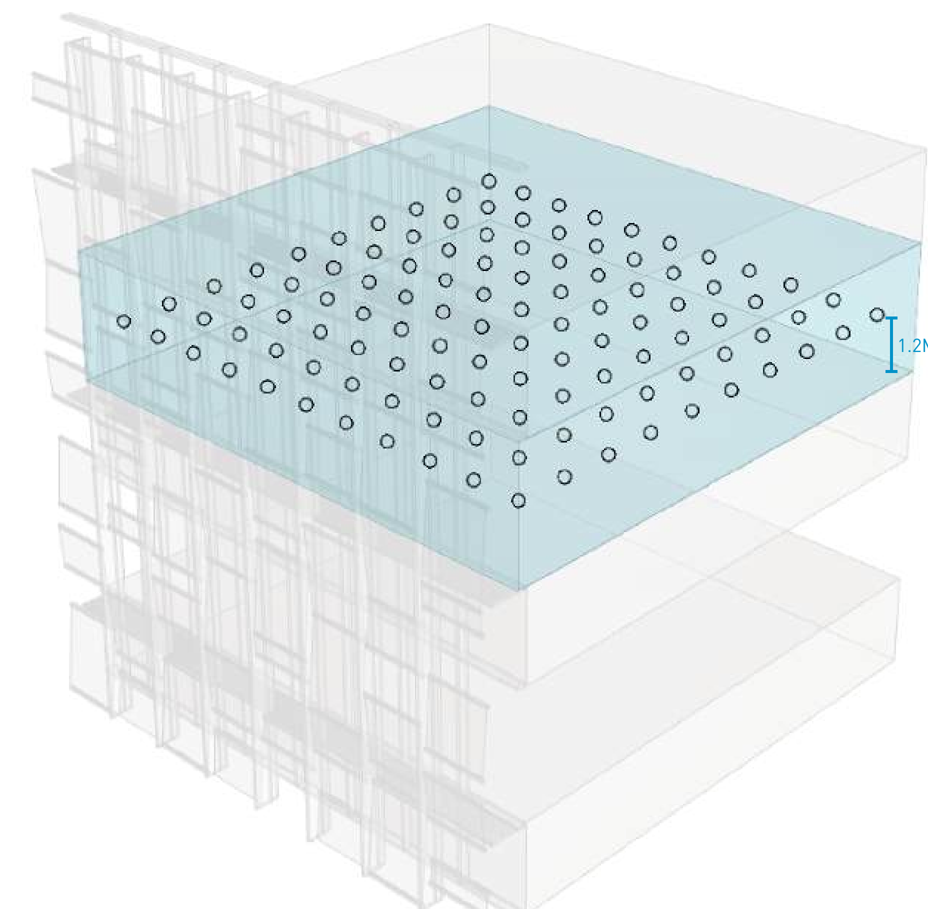
Several view types are provided based on the usage of the image. Usually perspective style is used for the representation, but for specific use of the image, other projections are also used. For example, hemispherical fish eye type can be used to show maximum information in one shot, while planisphere projection can be used for VR devices





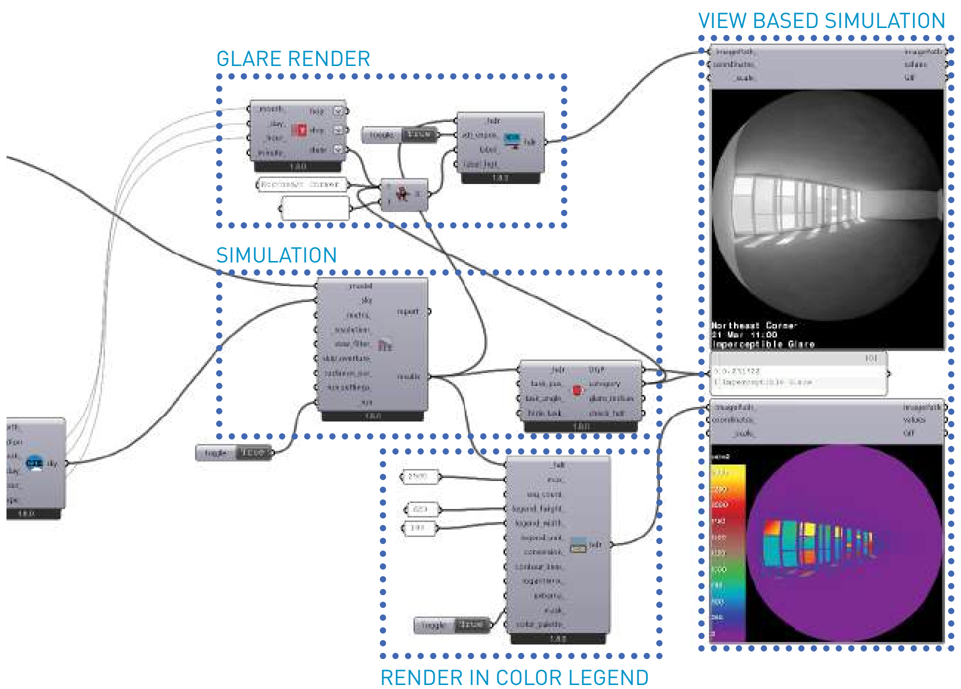
SIMULATION SET UP

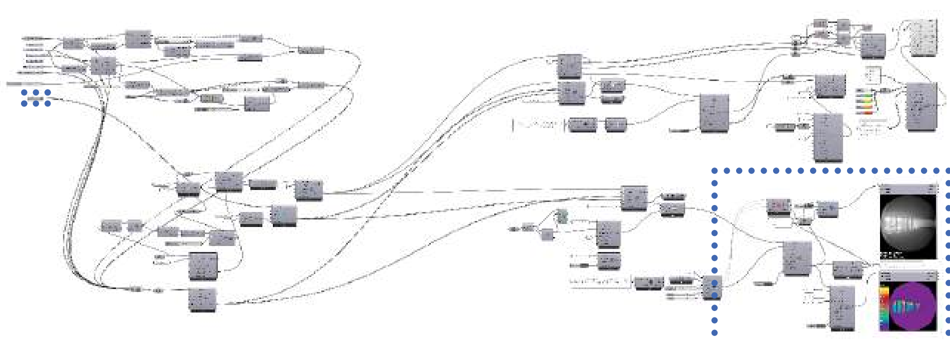
1) Set room grid as numerical value in metric (e.g. 1 = 1m)
2) Collect room, aperture and context geometries via HB model component
3) Create grid in room through HB assign grids and views component
4) import EPW weather data and combine every information in HB imageless annual glare component



ROOM GRID

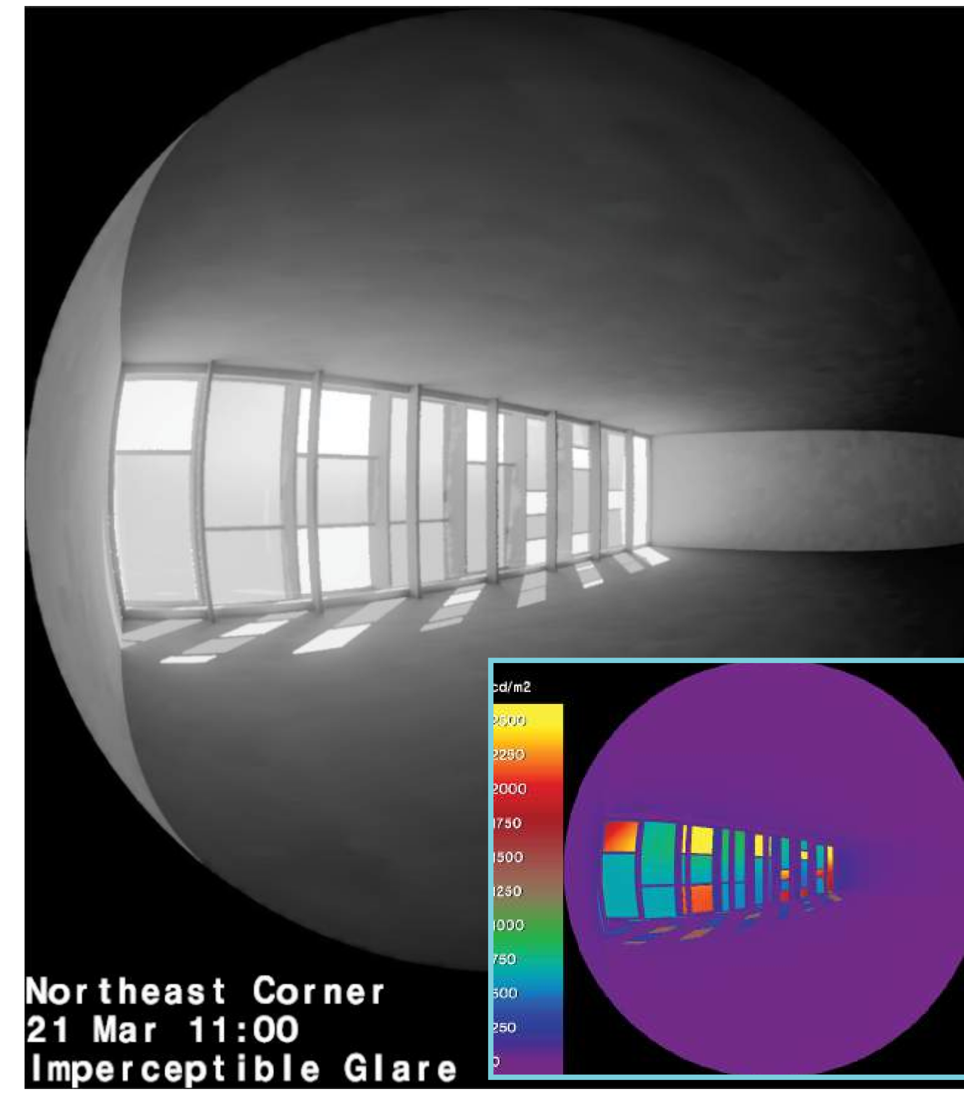
When HB room is created with geometric input, it creates populated particles in the space with regular designated spacing in between them. The standard point of the room is 1.2 meter from the surface to consider real social settings





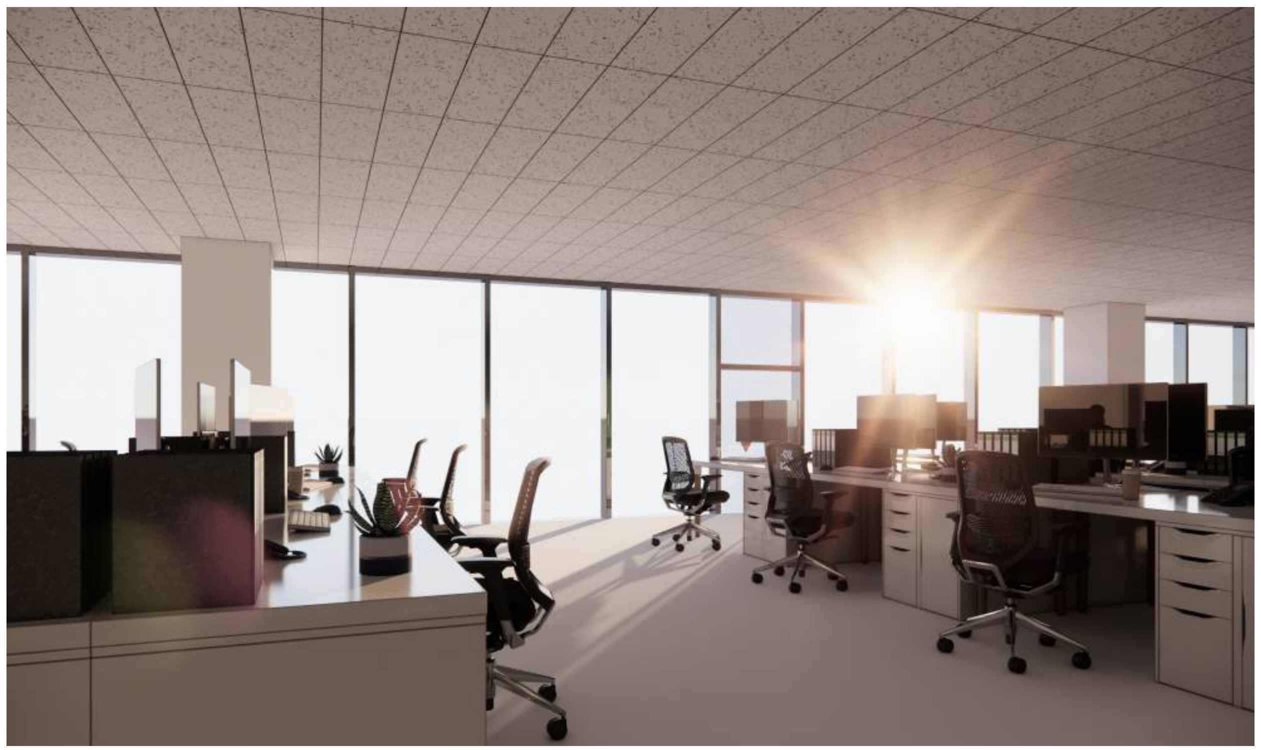
RENDER SET UP

1) Connect CIE sky and HB model to HB PIT view component
2) Connect result through HB adjust HDR to LB imageviewer
3) Check imagepath output

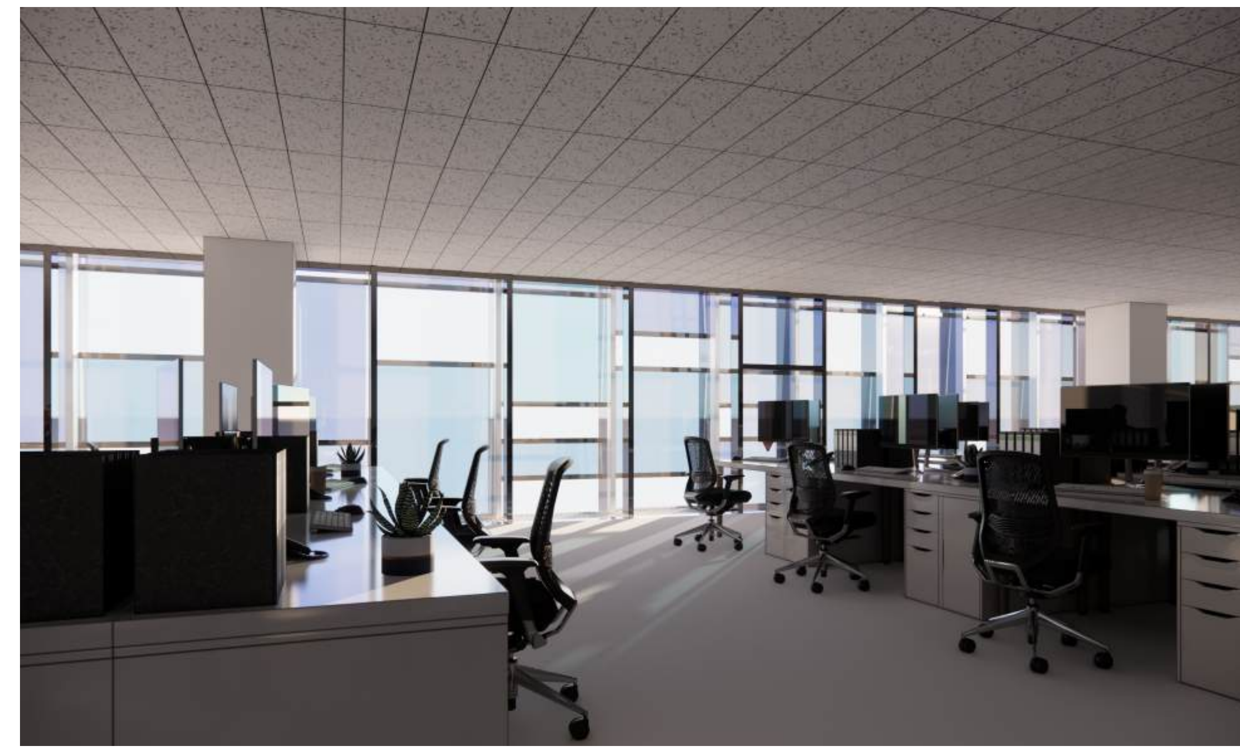


HDR IMAGE AND FALSE COLOR VERSION

False color version amplifying the color differences. Thus, infrared like image can be used as a legend or diagram image of the original HDR (High Dynamic Range) image file.



Office space view before applying glare control layer

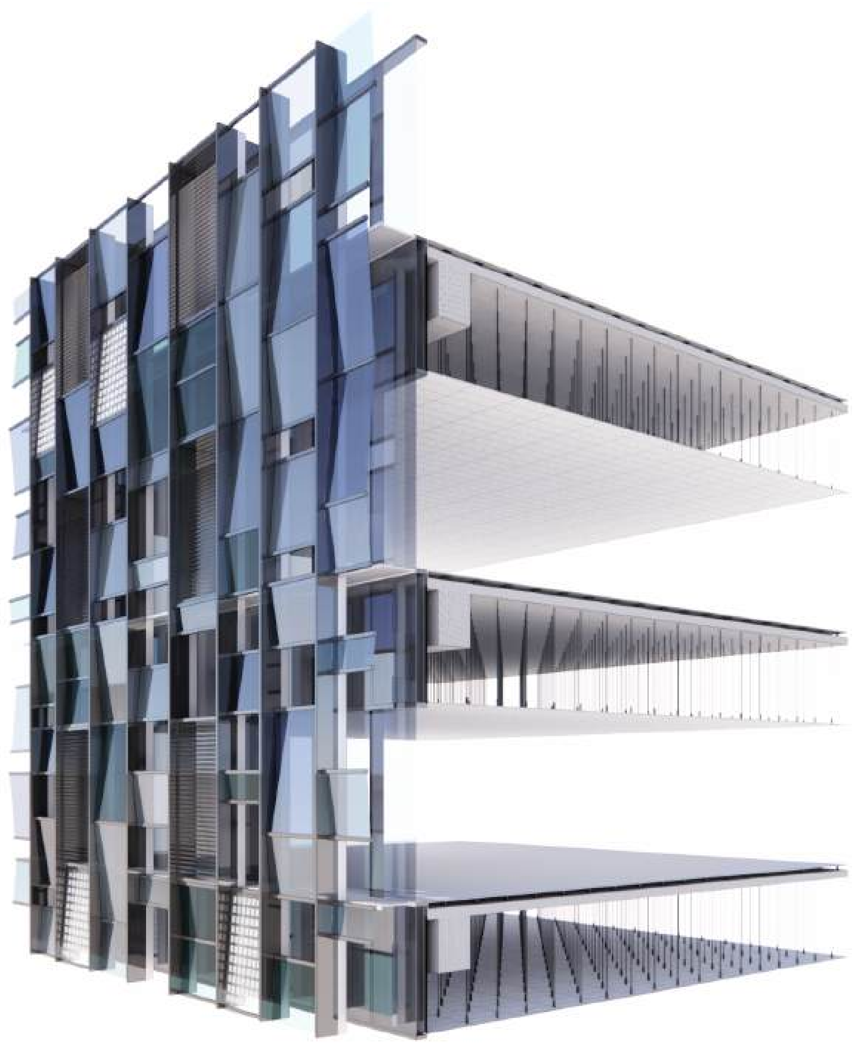


Office space view after applying glare control layer

GLARE EFFECT CONTROL

Although, double skin facade usually used for ventilation benefits, it creates several additional benefits, as represented in this chapter. By using this simulation tool, architect can take advantage of utilizing the solution for glare effect, which was fall in gray area between architect/designer and lighting consultant.

CONCLUSION



Conclusion & Future Study

This research highlights the integration of cutting-edge environmental energy analysis technologies into the architectural decision-making process. By incorporating these advanced tools into their skill sets, architects and designers are empowered to offer persuasive and evidence-based design solutions that align with both functional and environmental goals.

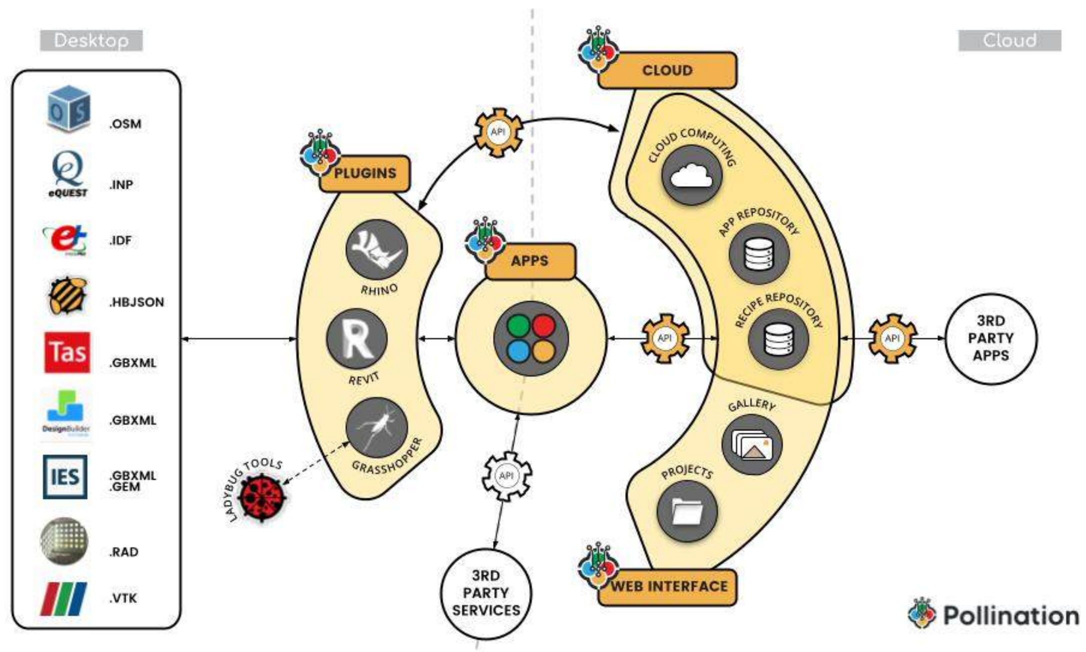
Both parametric and predefined geometries can be simulated and evaluated during the schematic design phase using these techniques. However, it is strongly recommended to adopt parametric modeling for design development. This approach is particularly advantageous due to the intricate interactions among simulation elements in natural environmental contexts. These interactions often produce outcomes that surpass human intuition, making parametric modeling an essential tool for fine-tuning and micro-adjustments during the iterative design process.

While these techniques provide significant benefits to architectural practice, achieving precise and reliable results requires validation through specialized consultants, particularly during later project phases. These experts, who are often not involved in the schematic design stage, play a critical role in confirming the accuracy of energy-related metrics. Consequently, establishing standardized benchmarks and protocols for measuring energy performance milestones is essential to ensure consistency and reliability throughout the design and construction process.

By leveraging the potential of parametric tools alongside expert consultation, architects can achieve a harmonious balance between innovation, sustainability, and practicality in their designs, ultimately contributing to a more energy-conscious built environment.

The future scope of this research will focus on **energy modeling**, a fully energy-driven design process that leverages energy simulation features. This includes not only external environmental factors such as solar orientation, weather data, shading, and glare but also artificial human-engineered systems like HVAC design, aperture optimization, and CFD analysis.

Pollination, Energy simulation Platform for AEC,
https://www.pollination.solutions/



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PT II PREVIEW

Night facade view, Sejong Center II Competition

Kinetic, meta-material bending study. Sejong Center II Competition

PHYSICS DATA

Physical data in architectural design refers to the tangible, measurable characteristics of a building and its components. This data encompasses a variety of aspects that are critical to the design, construction, and performance of architectural projects. Key components of architectural physical data include Geometric information, Structural Data, Material Properties, Constructability, etc

Kangaroo Physics is an interactive physics engine for simulation, optimization, and form-finding in architectural design and engineering. Developed by Daniel Piker, Kangaroo Physics operates within the Grasshopper environment, a visual programming language integrated with Rhinoceros 3D (Rhino). Kangaroo Physics is widely used by architects, engineers, and designers to explore complex geometries and structural systems through real-time simulations.
It is a powerful tool for integrating the principles of physics into the design process, allowing for the creation of innovative and efficient structures. Its versatility and interactive capabilities make it a valuable resource for designers seeking to push the boundaries of architectural and engineering design.

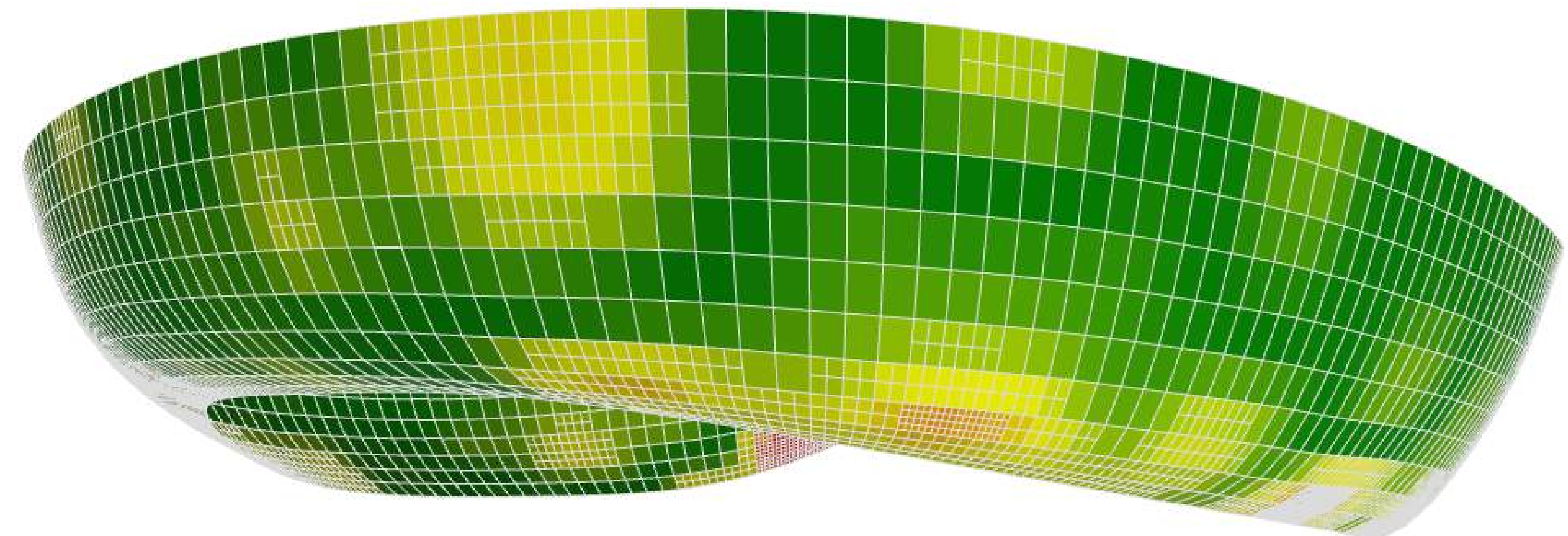
Karamba 3D is a parametric structural engineering tool that integrates seamlessly with Grasshopper and Rhinoceros 3D (Rhino). Developed by Clemens Preisinger, Karamba 3D enables architects, engineers, and designers to perform accurate and interactive structural analysis within the familiar environment of Grasshopper.
Karamba empowers designers to seamlessly integrate structural considerations into their design workflows, bridging the gap between architecture and engineering. Its parametric and interactive nature makes it an invaluable tool for creating innovative, efficient, and structurally sound designs.

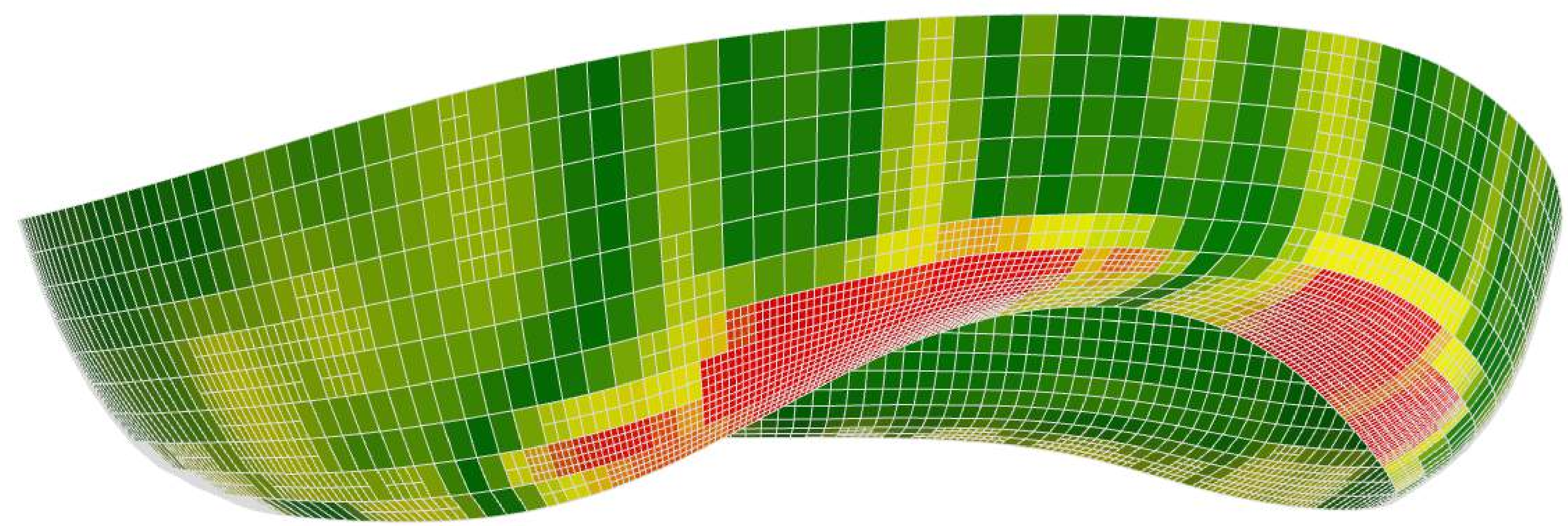
FEATURED TECHNICAL IMPROVEMENT

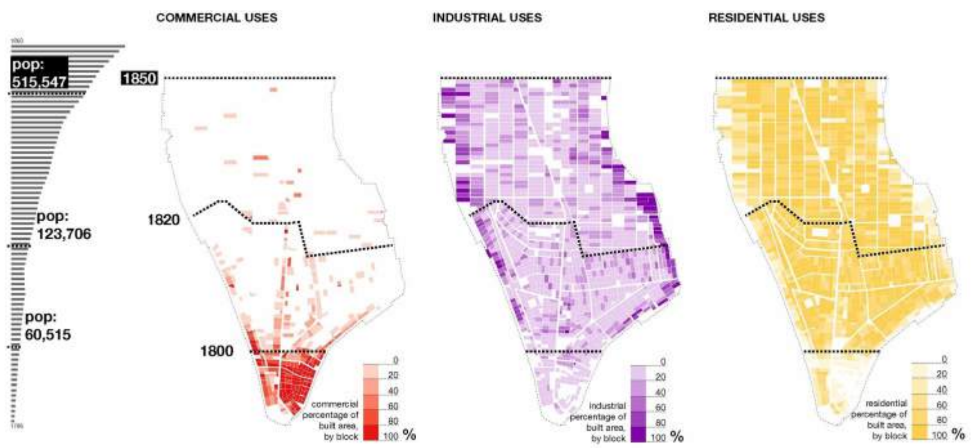
Kangaroo Physics, which originally started as a plug-in for Grasshopper, has now evolved into a fundamental component of the program, offering a range of advanced simulation capabilities that greatly enhance its functionality and versatility in design processes.

Initially, Kangaroo used a method known as 'Dynamic Relaxation,' which is a traditional approach to physics simulation. However, with the introduction of the more advanced 'Projective Dynamics' method, which allows for more direct and real-time simulation results, there have been significant improvements in stability and convergence speed. Additionally, the results now provide not only geometric information but also other numerical data sets such as collinearity, coplanarity, and plasticity.

With these enhanced features, Kangaroo Physics has become an exceptionally powerful tool in architectural design practice. It now plays a crucial role in form-finding, geometric optimization, and constructability improvement, providing designers with sophisticated tools to tackle complex challenges and achieve more refined and innovative solutions.







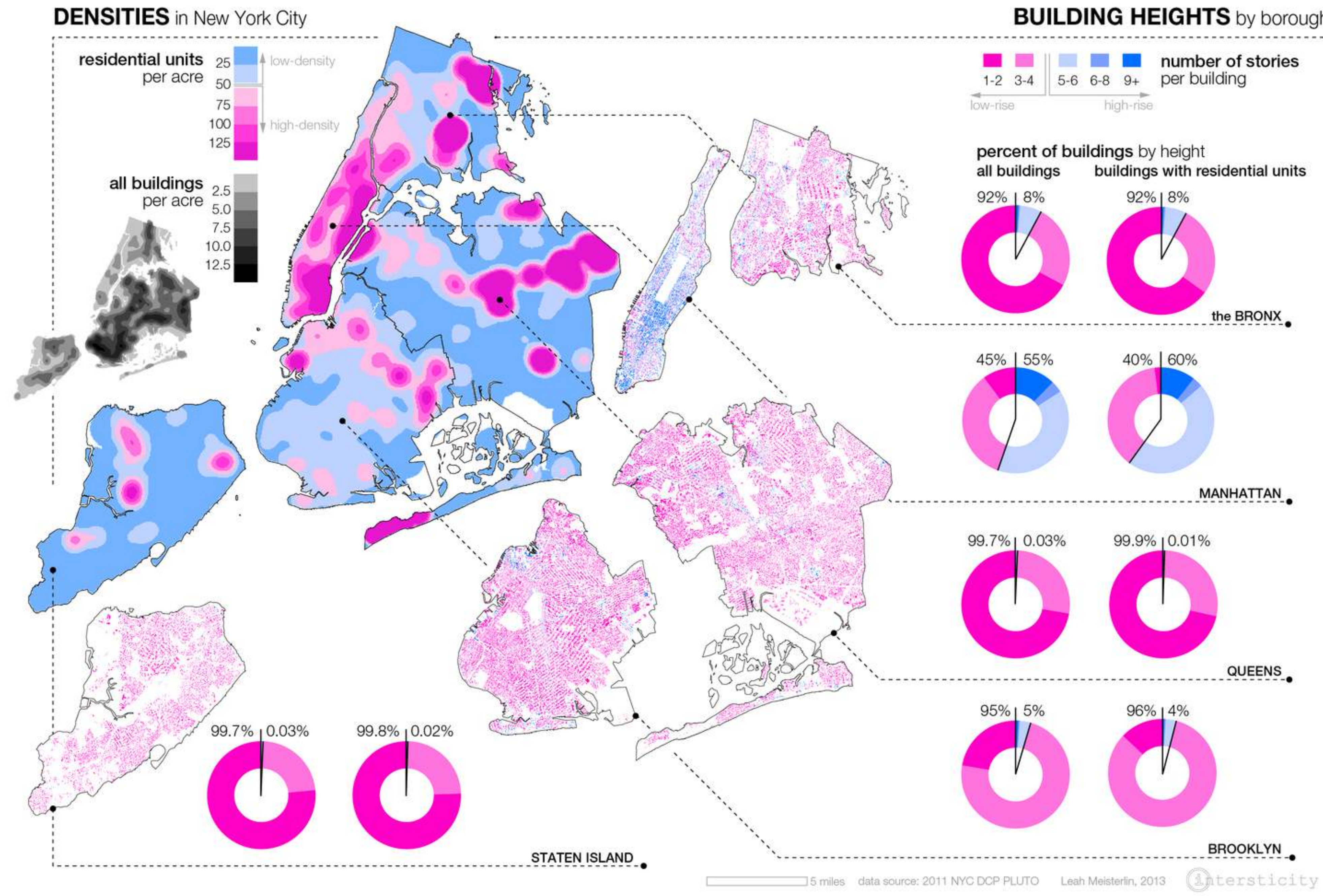
GIS DATA

Geographic Information System data in architectural design refers to spatially referenced information that provides insights into the physical and environmental context of a site. This data is essential for understanding the geographic, demographic, ecological, and infrastructural characteristics of a location, which can significantly influence architectural and urban planning decisions. Key components of GIS data in architectural design include Topography, Zoning or other regulation, Environmental conditions (specifically, such as flood zone or soil contamination), Infrastructure, Demographics, Historic or Cultural sites, Urban Morphology, natural ecosystems.

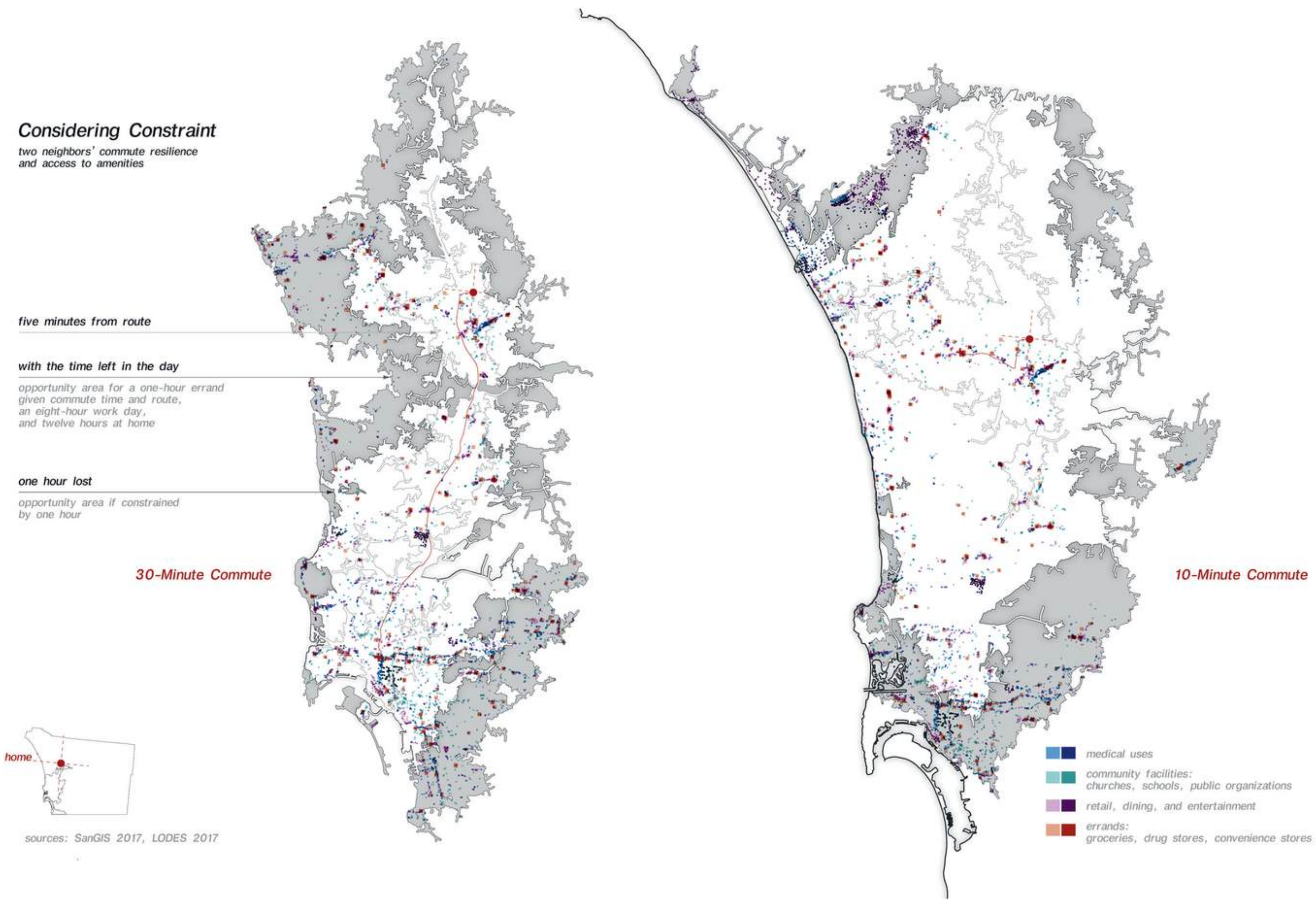
By integrating GIS data into the design process, architects and urban planners can create more informed, context-sensitive, and sustainable designs. GIS data provides a comprehensive understanding of the site and its surroundings, enabling better decision-making and enhancing the overall quality and resilience of architectural and urban projects.

In New York City area, a wealth of GIS data is readily accessible to the public, providing valuable resources for architects, urban planners, researchers, and other stakeholders. Some of the most commonly used and easily accessible GIS data sources in NYC include NYC Open Data, NYC Planning Department, NYC Department of City Planning, Metropolitan Transportation Authority, NYC Department of Building, etc.

These sources offer a wide range of GIS data that can be leveraged to support architectural and urban design projects, ensuring they are well-informed, contextually appropriate, and sustainable.



Cartographies of Distance, in L. Kurgan and D. Brawley, Eds. (2019) Ways of Knowing Cities. pp 250-72.



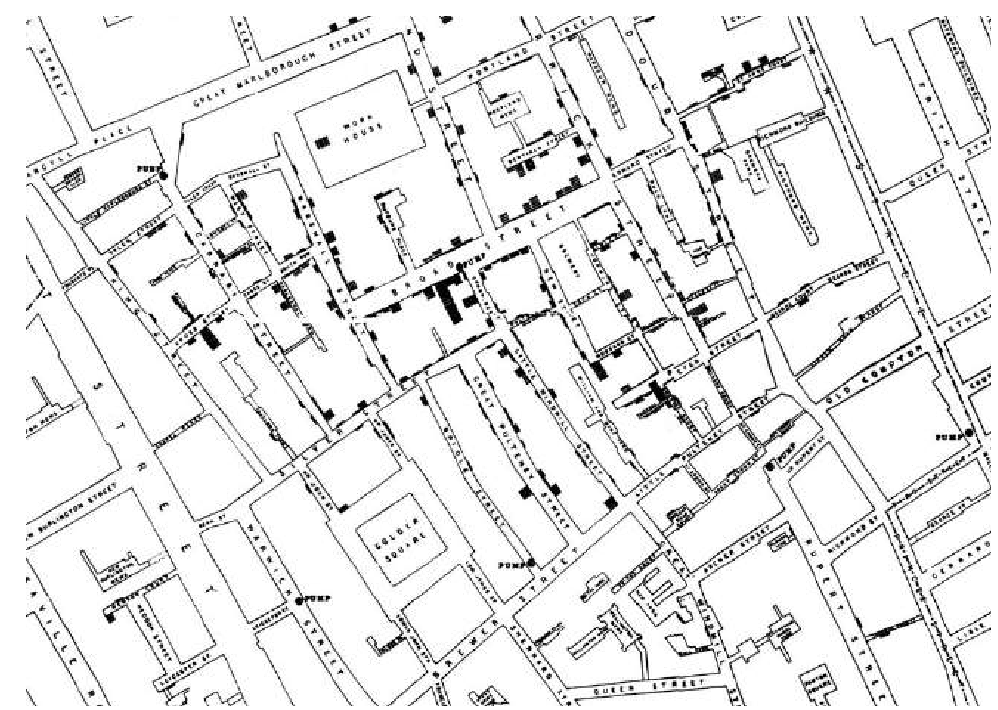
John Snow's map of cholera deaths in London's SoHo neighborhood in 1854.

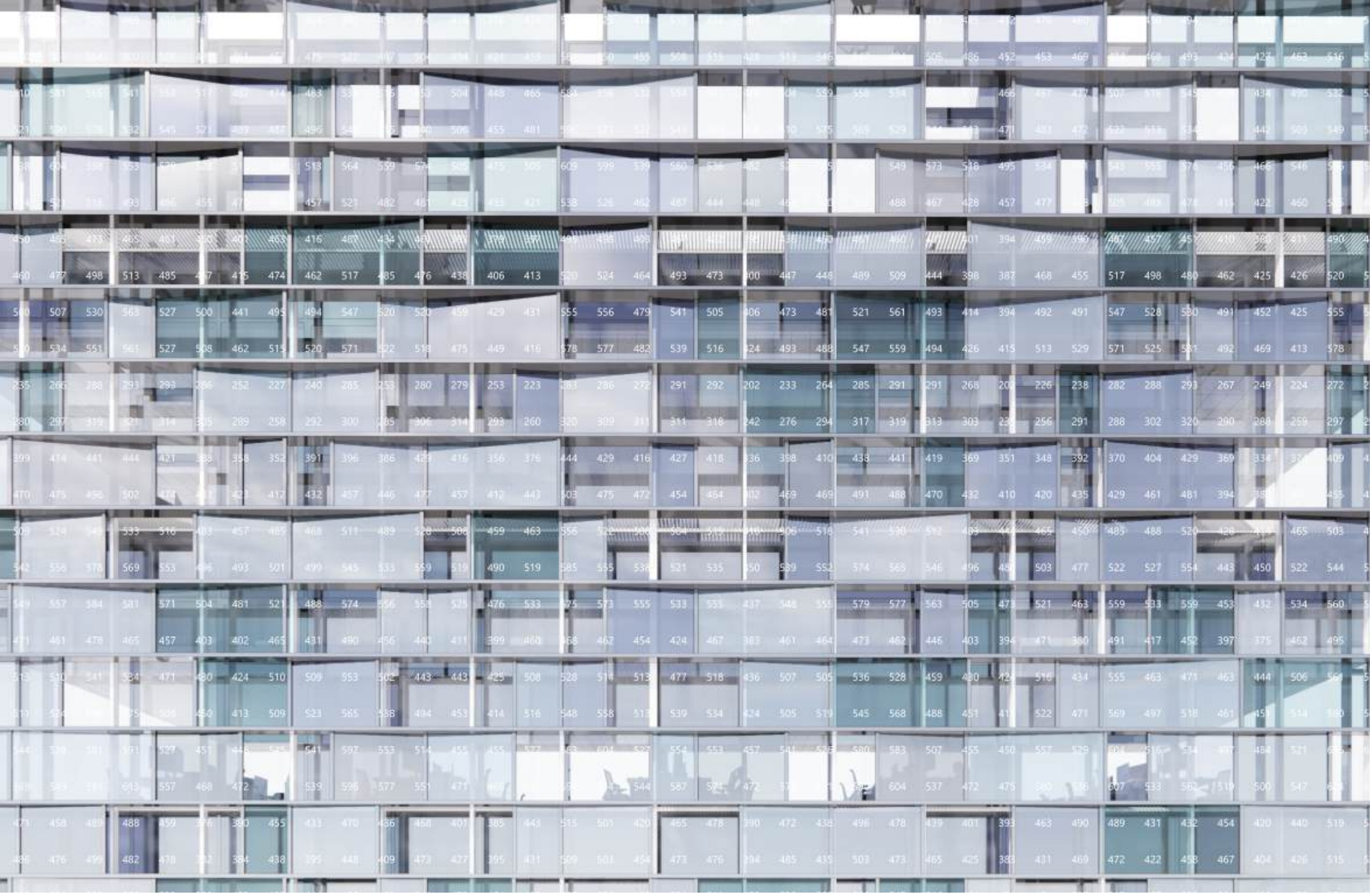
CARTOGRAPHIC EVOLUTION IN THE ERA OF BIG DATA

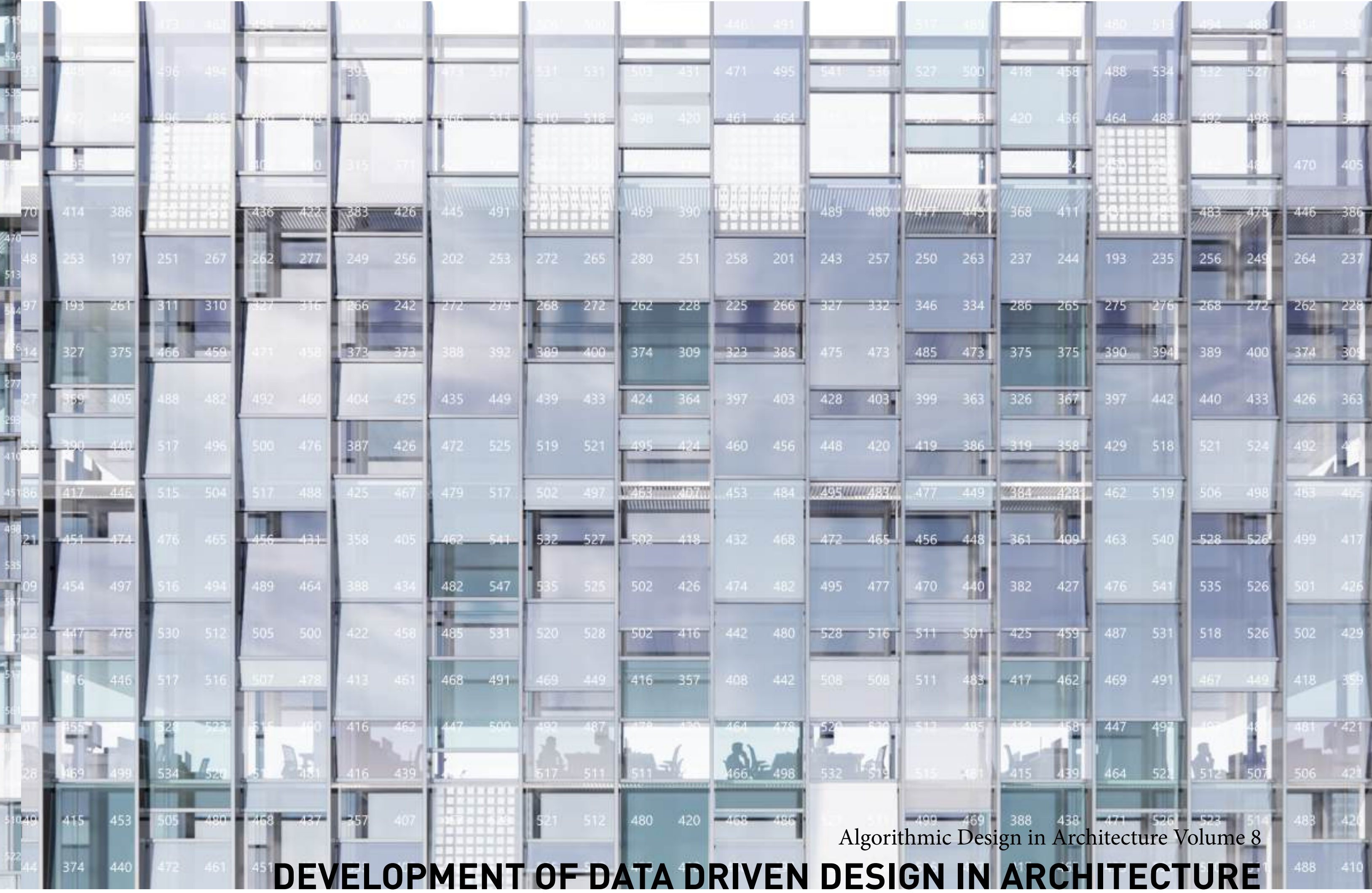
Cartography, the craft of creating maps to represent geographical spaces, has always been an essential tool for understanding and navigating the architectural context. As the discipline evolves in response to technological advancements, its application in urban contexts has grown increasingly sophisticated.

This art and science of map-making, has undergone a significant transformation with the advent of Geographic Information Systems (GIS), particularly in the realm of urban mapping. In the context of modern urban planning, cartography is no longer limited to static representations of geographical spaces; it now involves the creation of dynamic, data-driven maps that convey complex spatial information in an intuitive and accessible manner.

By harnessing the power of GIS data, modern cartographers can produce highly detailed urban maps that serve as essential tools for analyzing spatial relationships, understanding urban growth, and guiding sustainable development. This research delves into the role of cartography in contemporary urban mapping, emphasizing the synergy between traditional map-making techniques and advanced GIS technology.







Algorithmic Design in Architecture Volume 8

DEVELOPMENT OF DATA DRIVEN DESIGN IN ARCHITECTURE

PART - I

H Architecture

DEVELOPMENT OF DATA DRIVEN DESIGN IN ARCHITECTURE PT.I

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