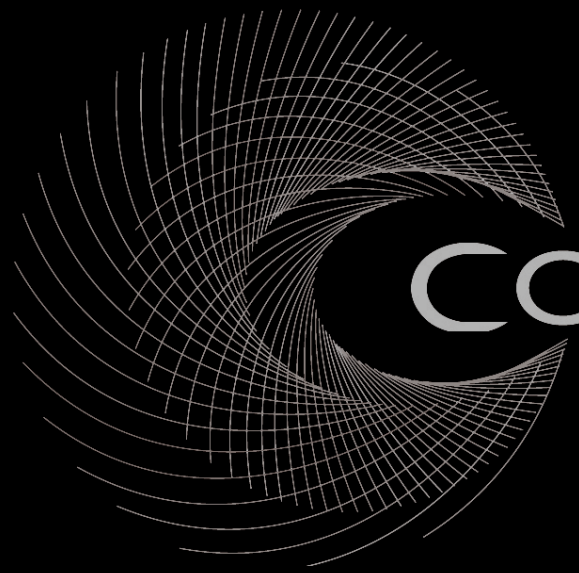


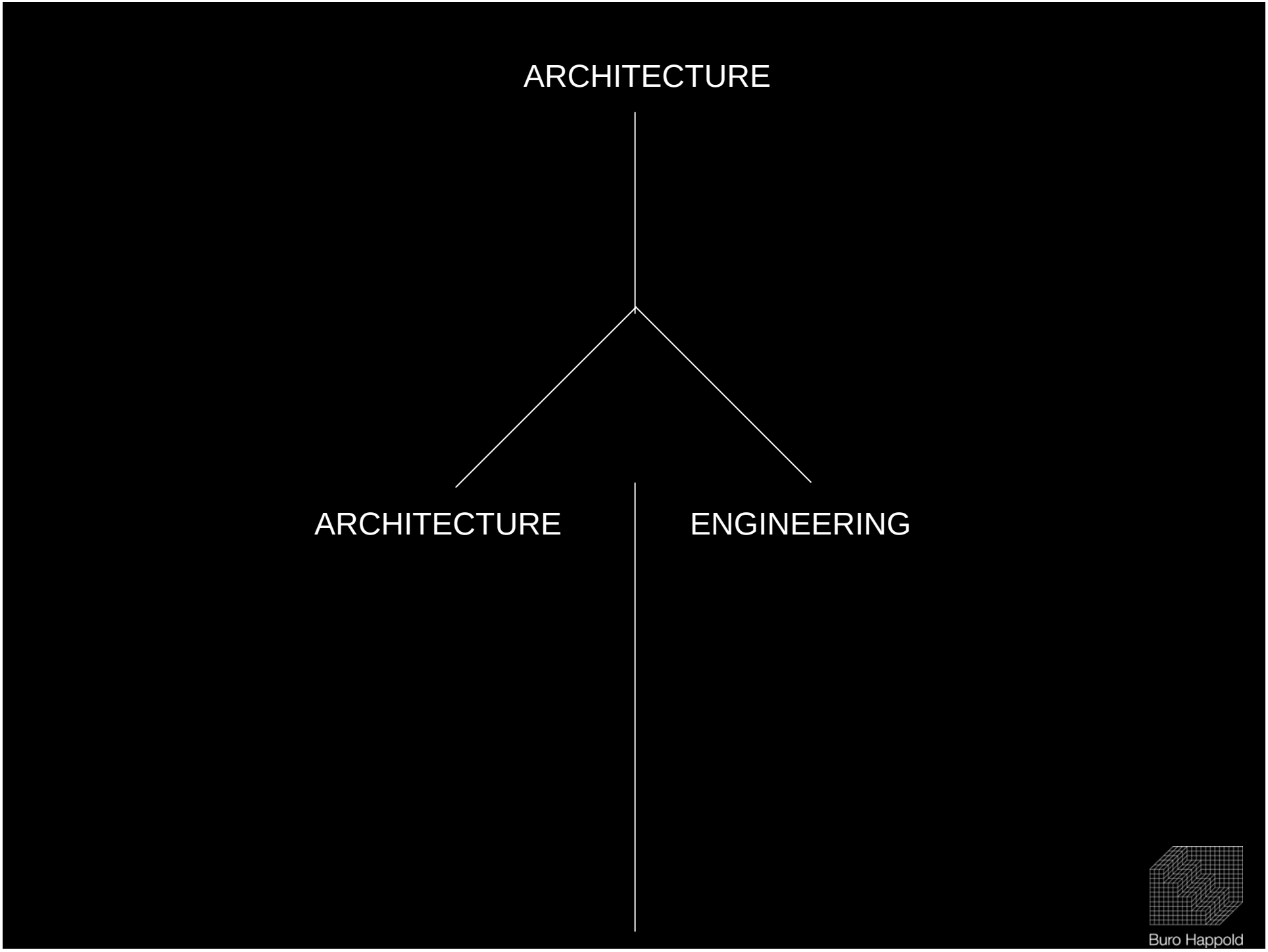
CoSA SOLUTIONS

Computational Simulation and Analysis

Buro Happold

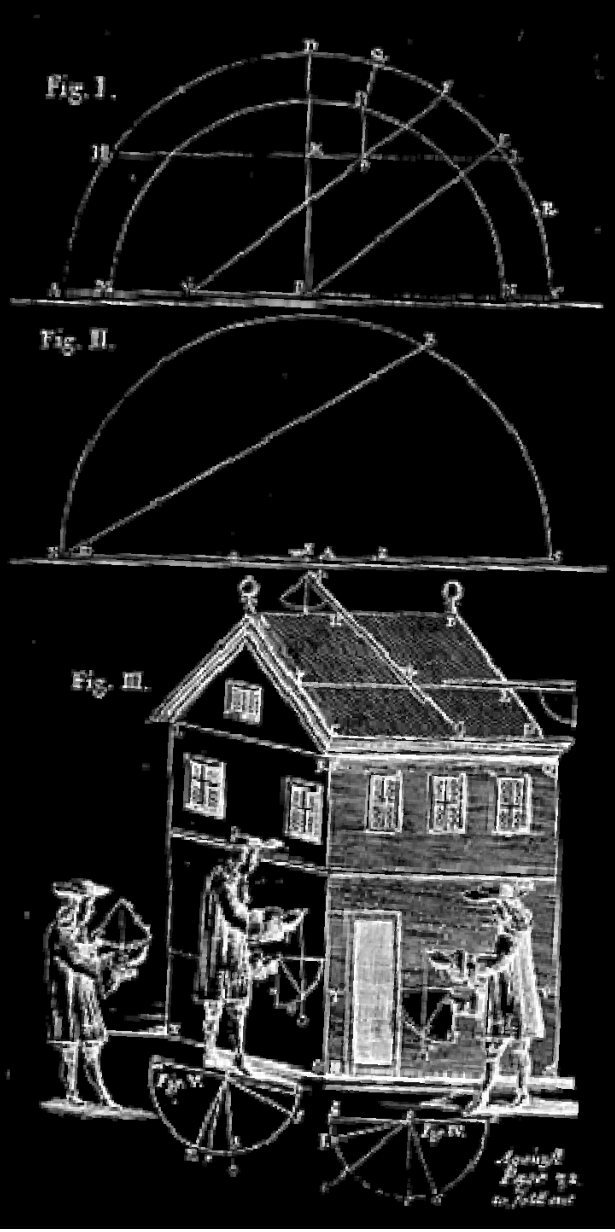
ARCHITECTURE

Buro Happold


ARCHITECTURE
ARCHITECTURE
ENGINEERING
Buro Happold

ARCHITECTURE

ENGINEERING



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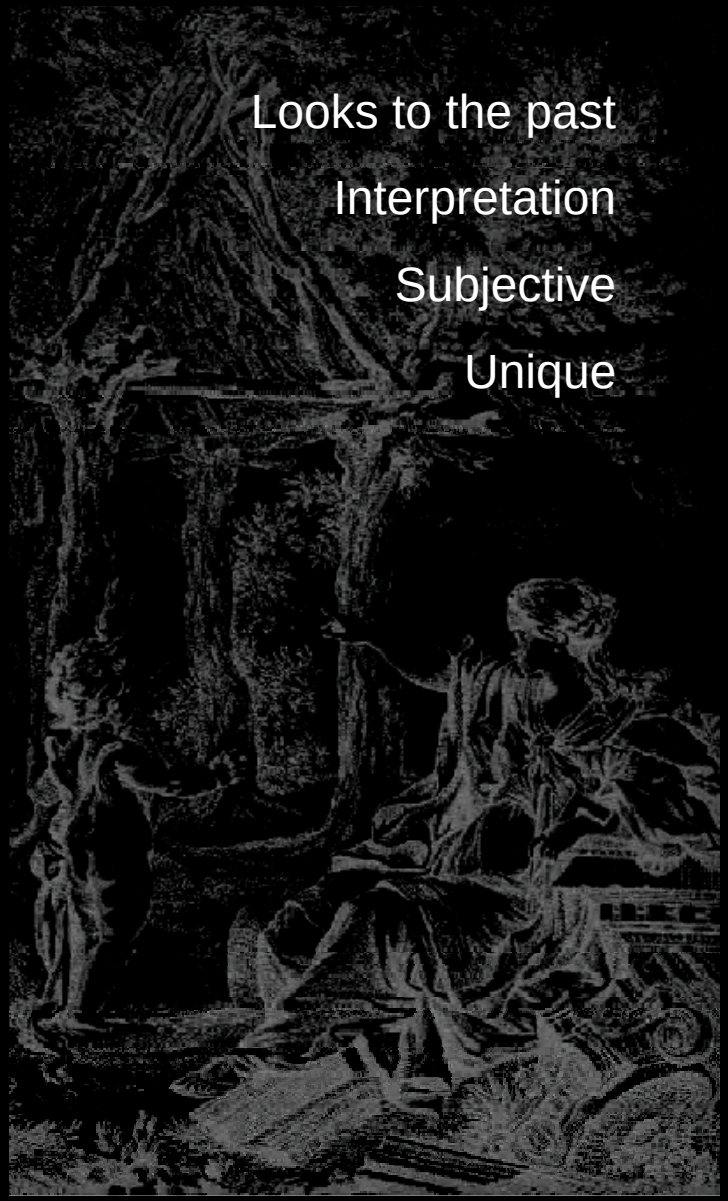
ARCHITECTURE



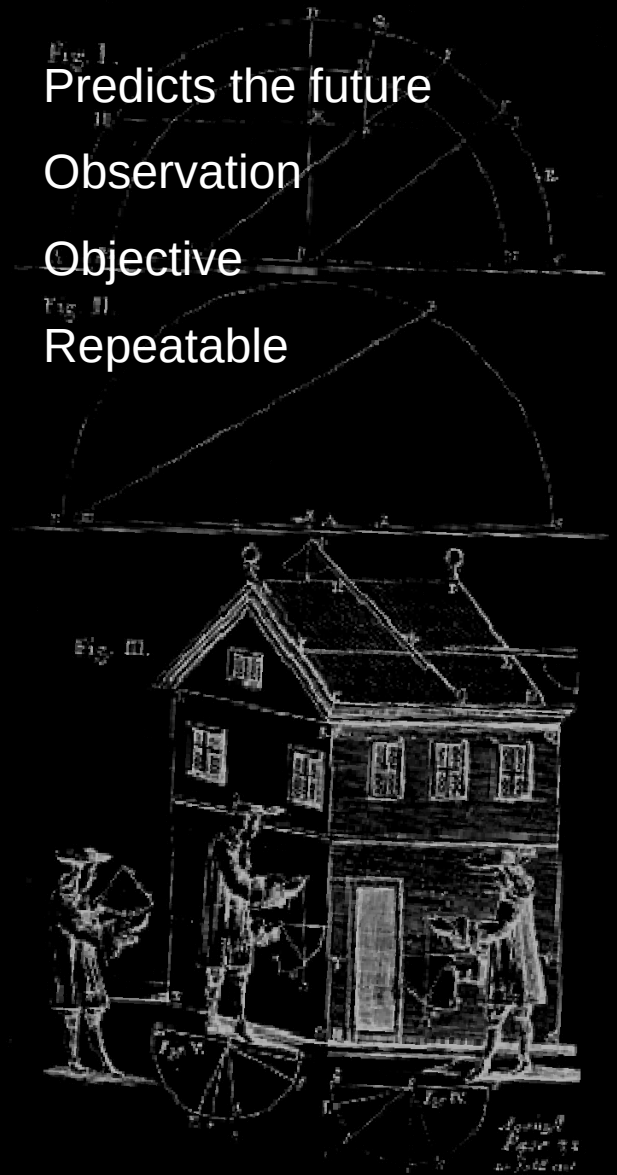
Looks to the past

Interpretation

Subjective

Unique

ENGINEERING



Predicts the future

Observation

Objective

Repeatable

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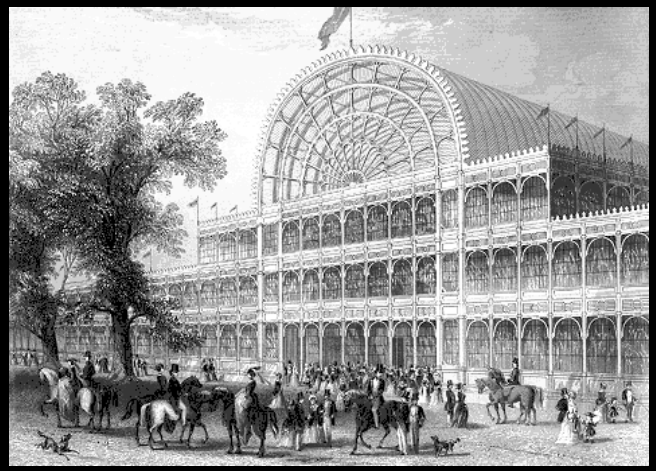
ARCHITECTURE

Qualitative design drivers based on interpretation of clients needs.

Subjective feedback loop based on aesthetics and poetics.

Subject to codes but not evaluated by them.

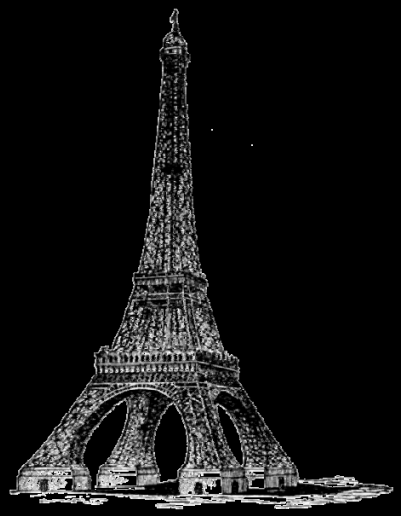


ENGINEERING

Quantitative performance drivers based on prescribed design criteria.

Immediate feedback loop built into equations.

Standard interpretation through codes.



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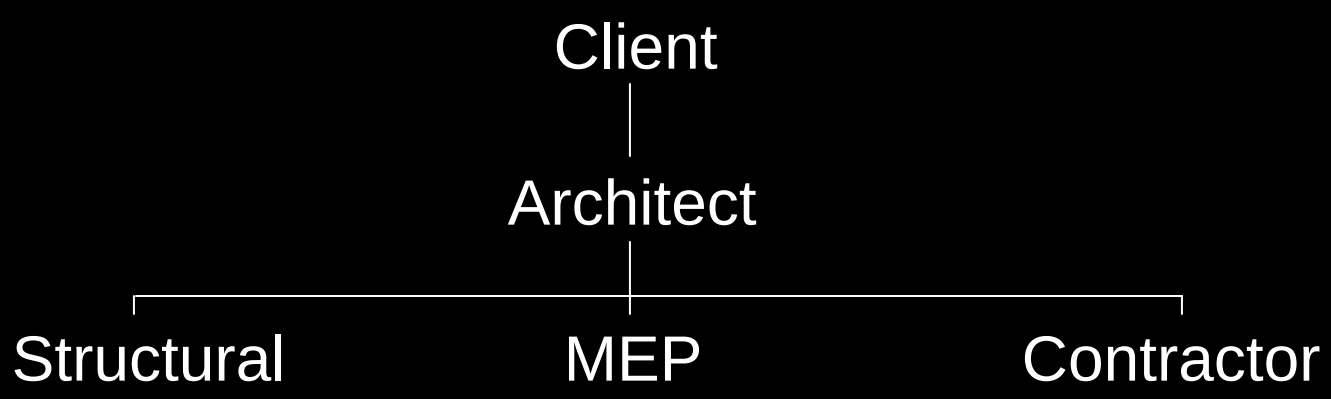
ARCHITECTURE

I want it to look this way

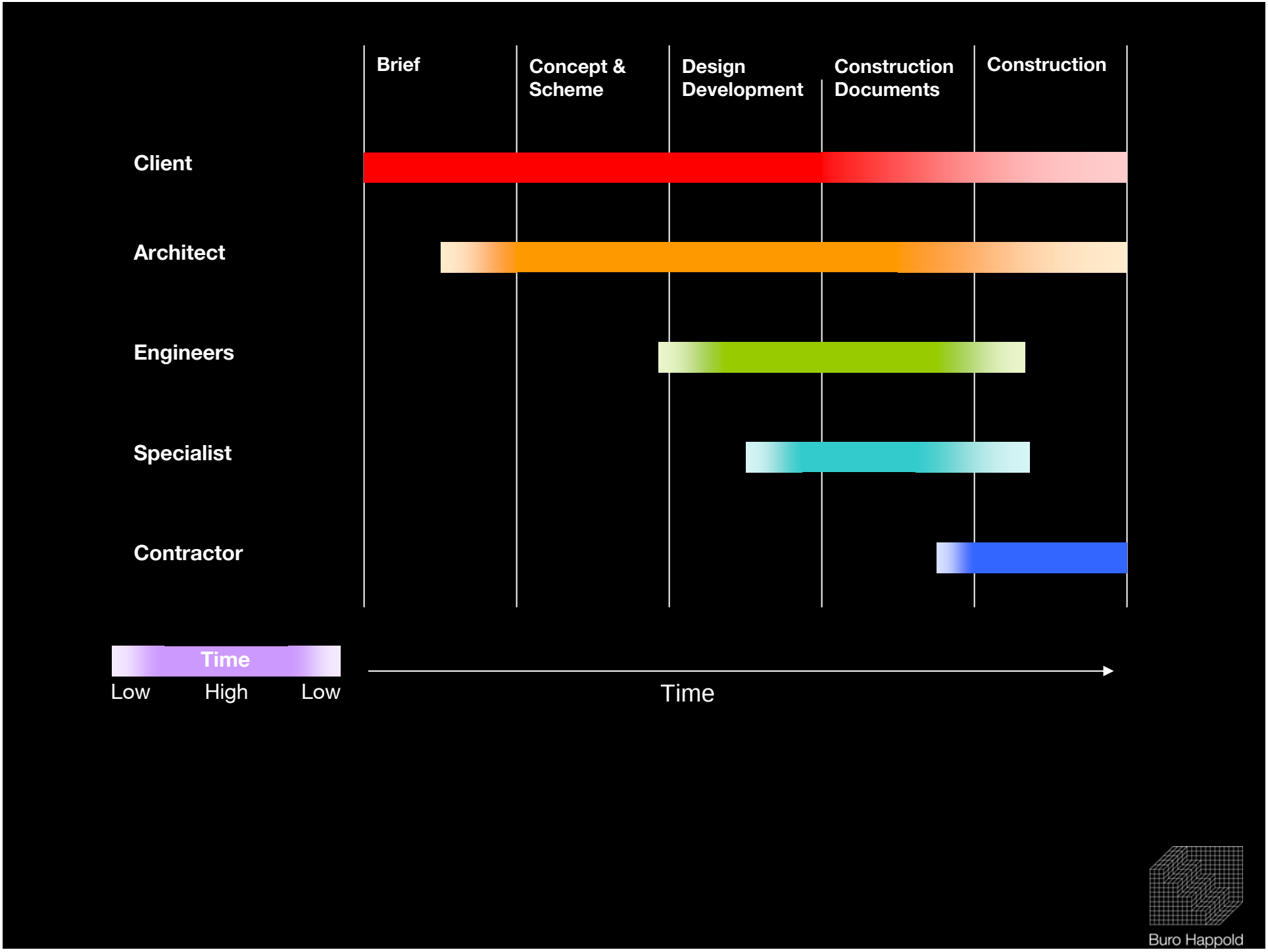
ENGINEERING

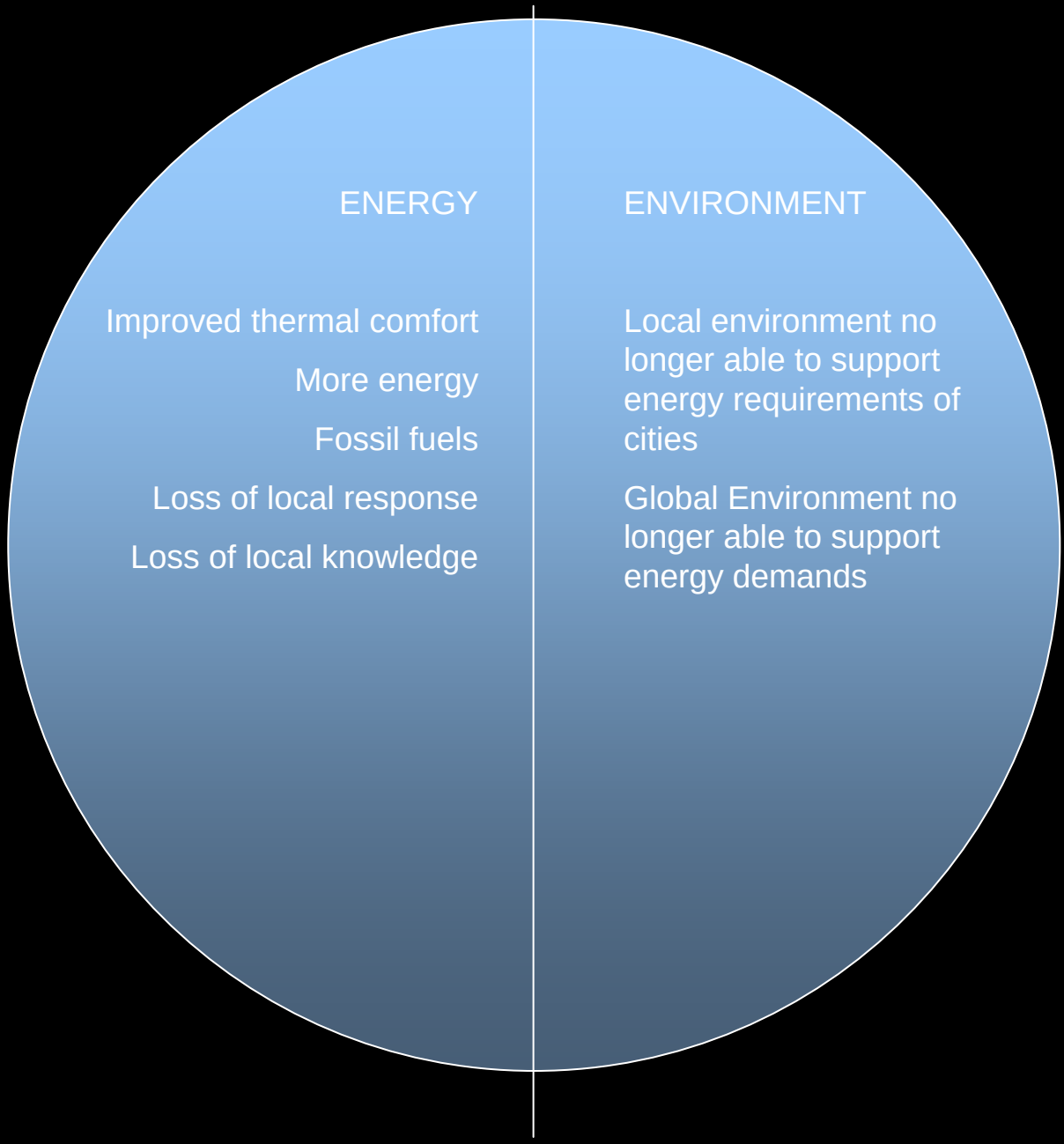
Just add energy

$$Q = U * A * \Delta T$$

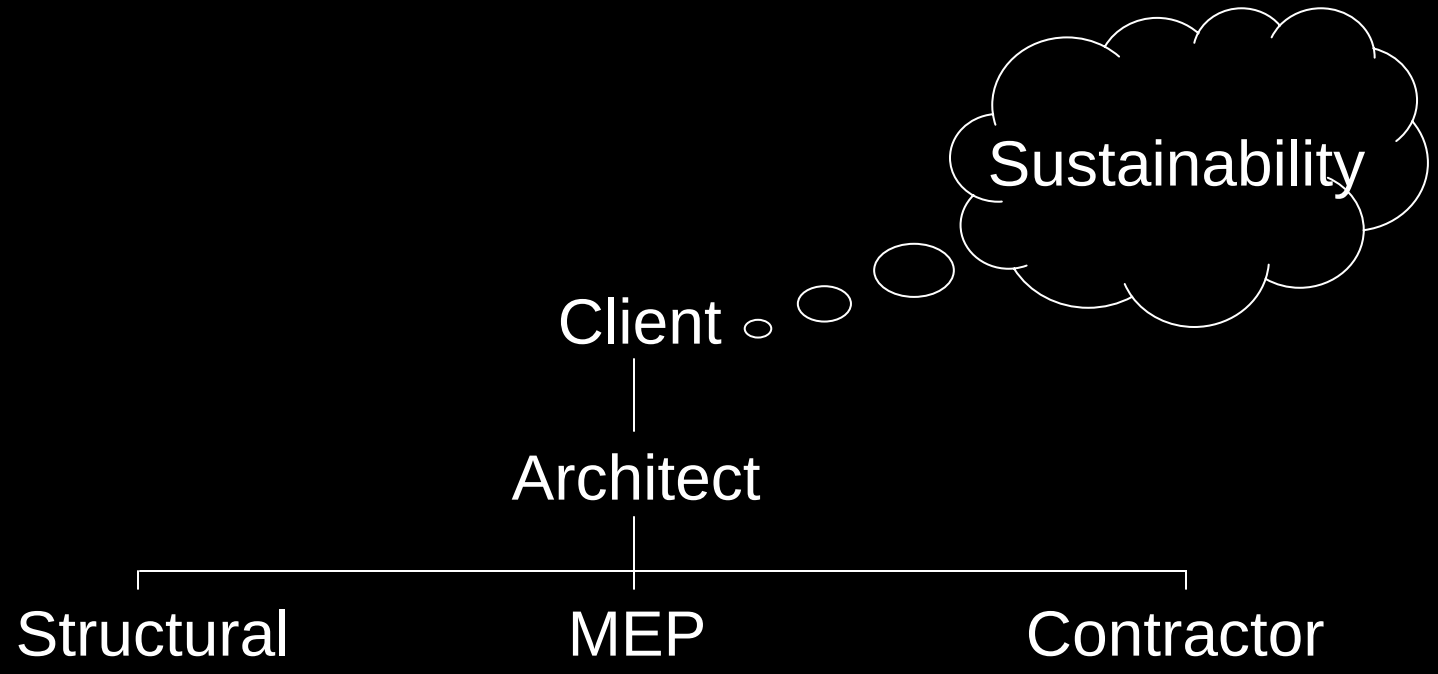


Buro Happold


Brief
Concept & Scheme
Design Development
Construction Documents
Construction
Client
Architect
Engineers
Specialist
Contractor
Time
Low
High
Low
Time
Buro Happold

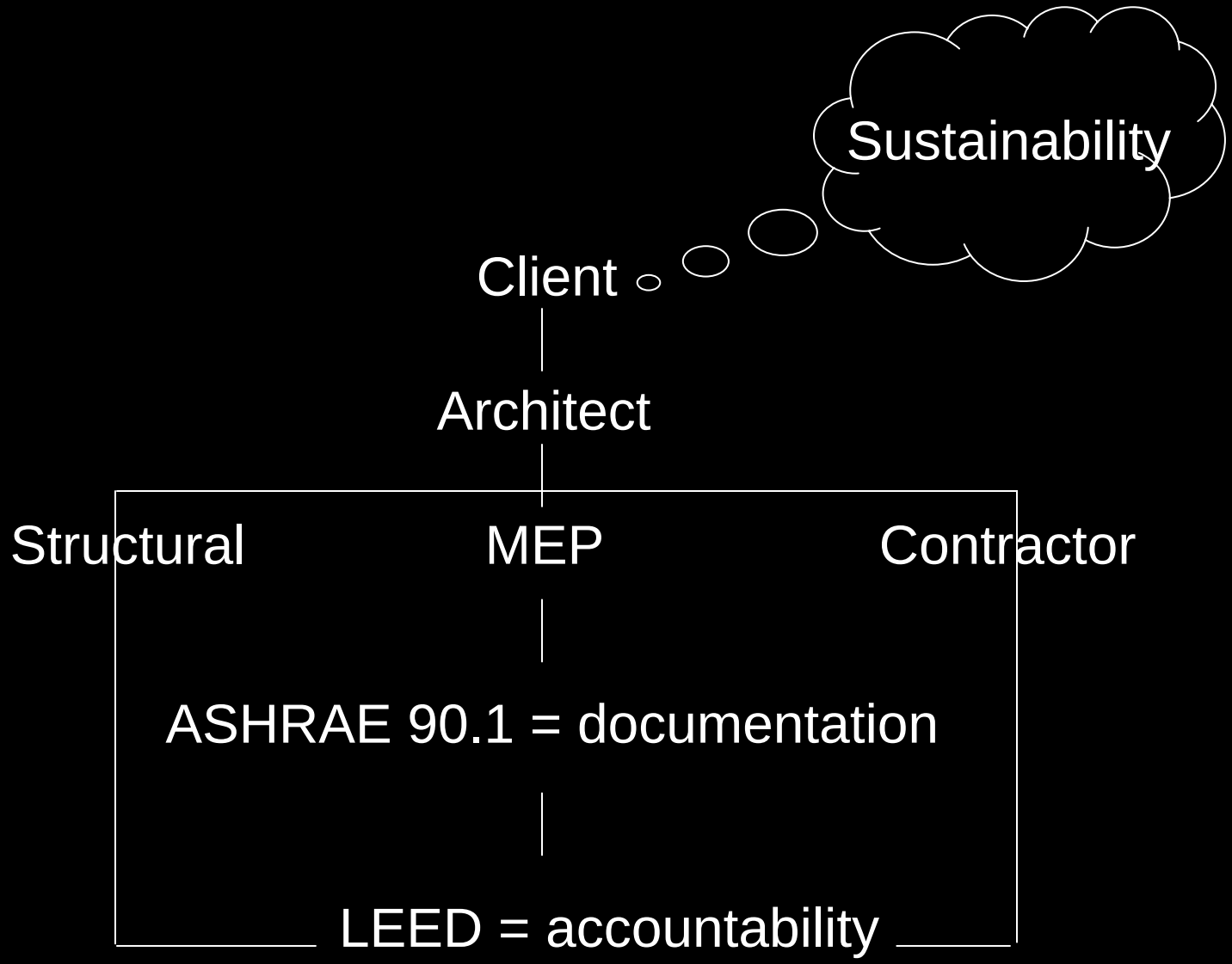


Buro Happold



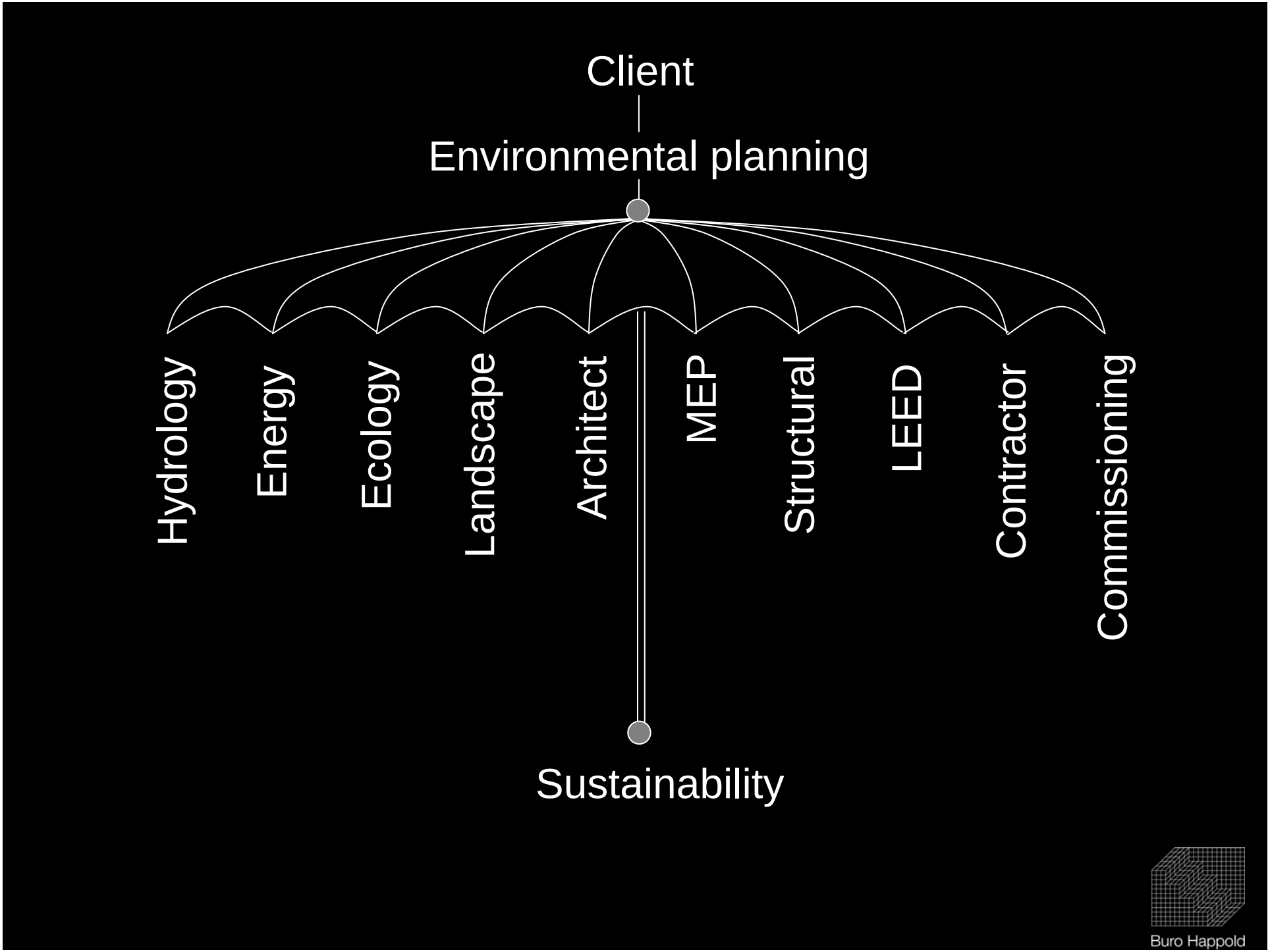
Who is responsible for delivering sustainability ?
How is sustainability delivered?
How do we know when it has been achieved?

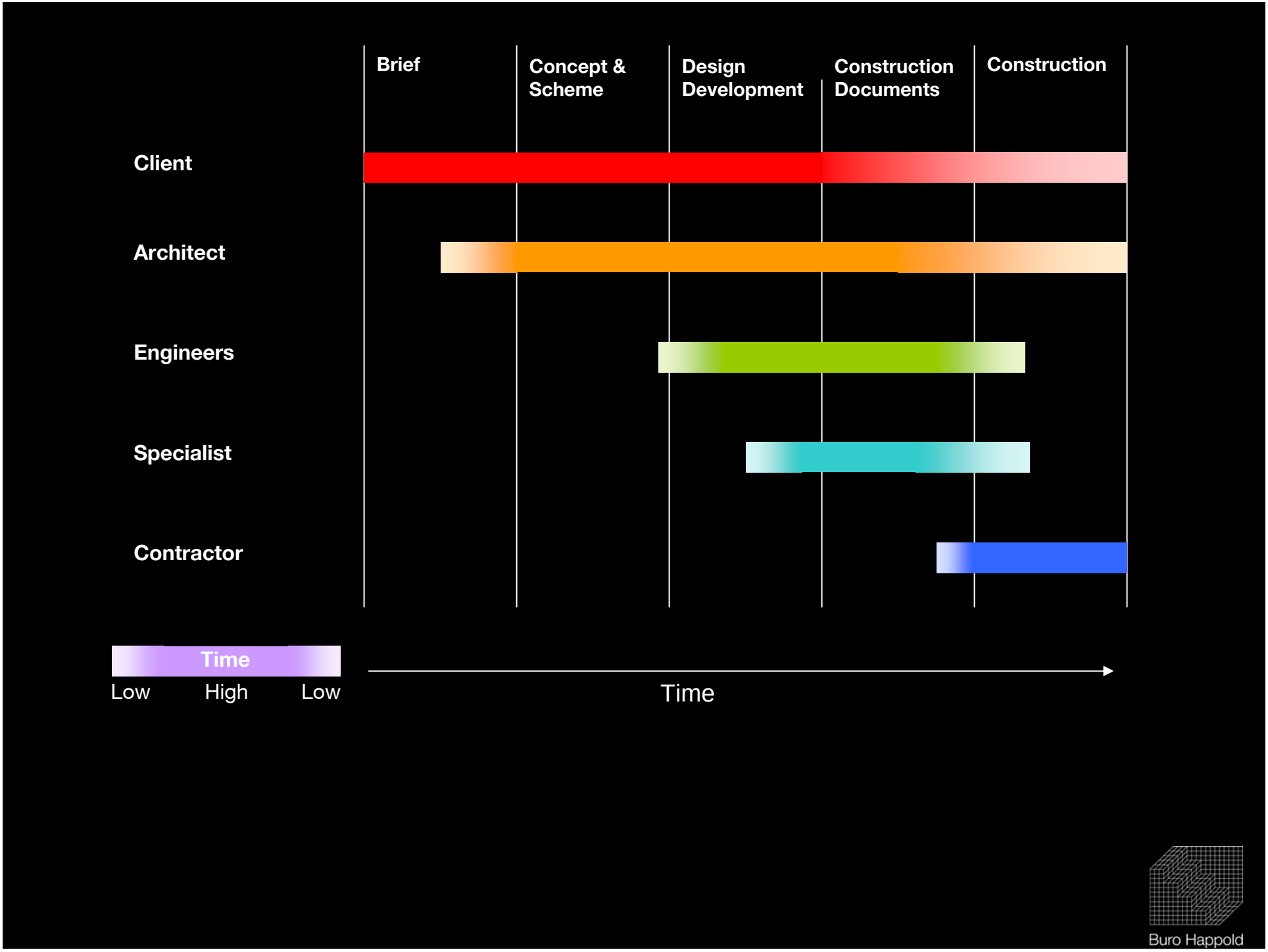
Buro Happold



Buro Happold

The Illusive Mystery


Client
Environmental planning
Hydrology
Energy
Ecology
Landscape
Architect
MEP
Structural
LEED
Contractor
Commissioning
Sustainability
Buro Happold


Brief
Concept & Scheme
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Architect
Engineers
Specialist
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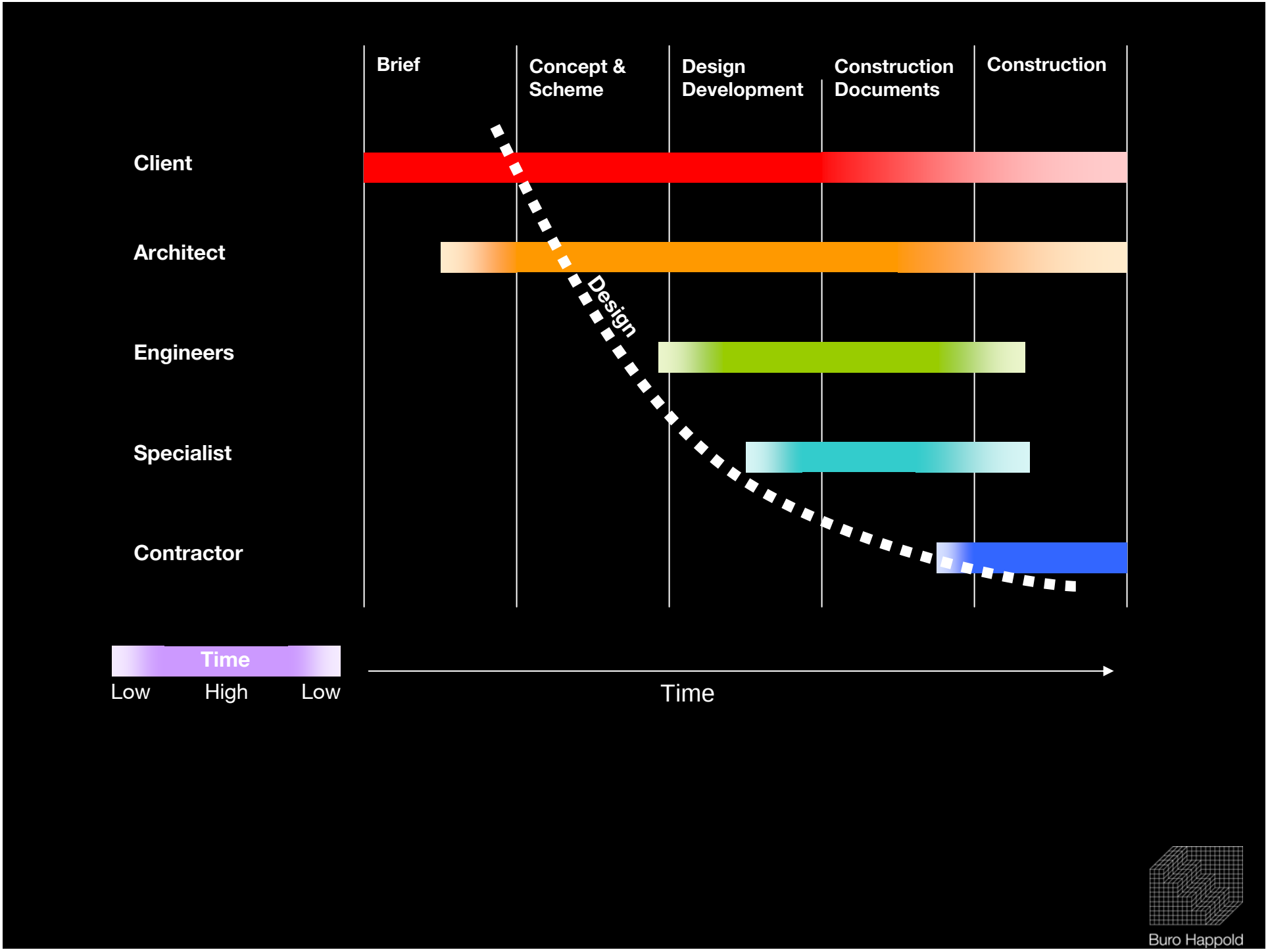
High
Low
Time
Buro Happold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Construction Documents
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Design
Time
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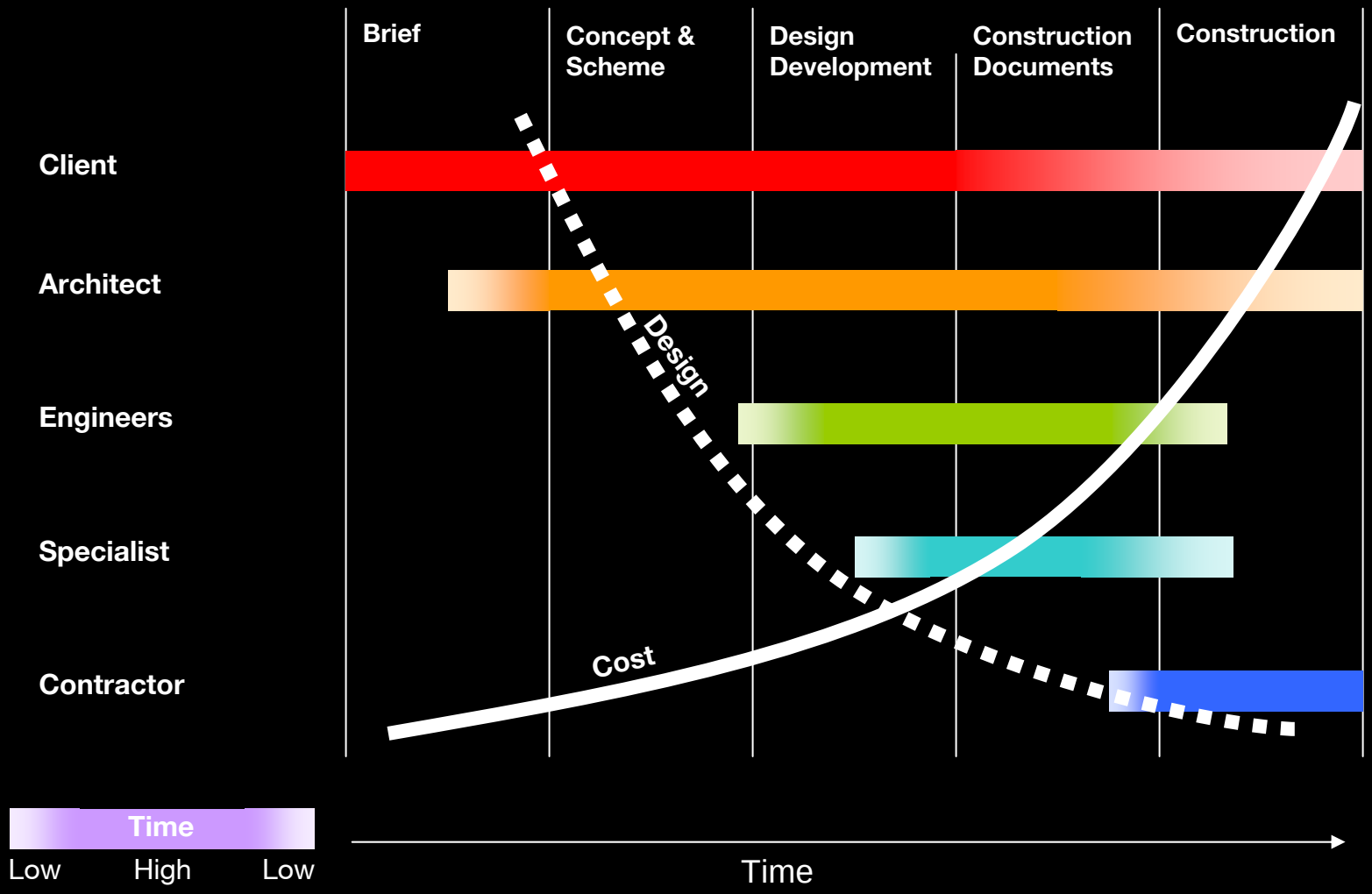
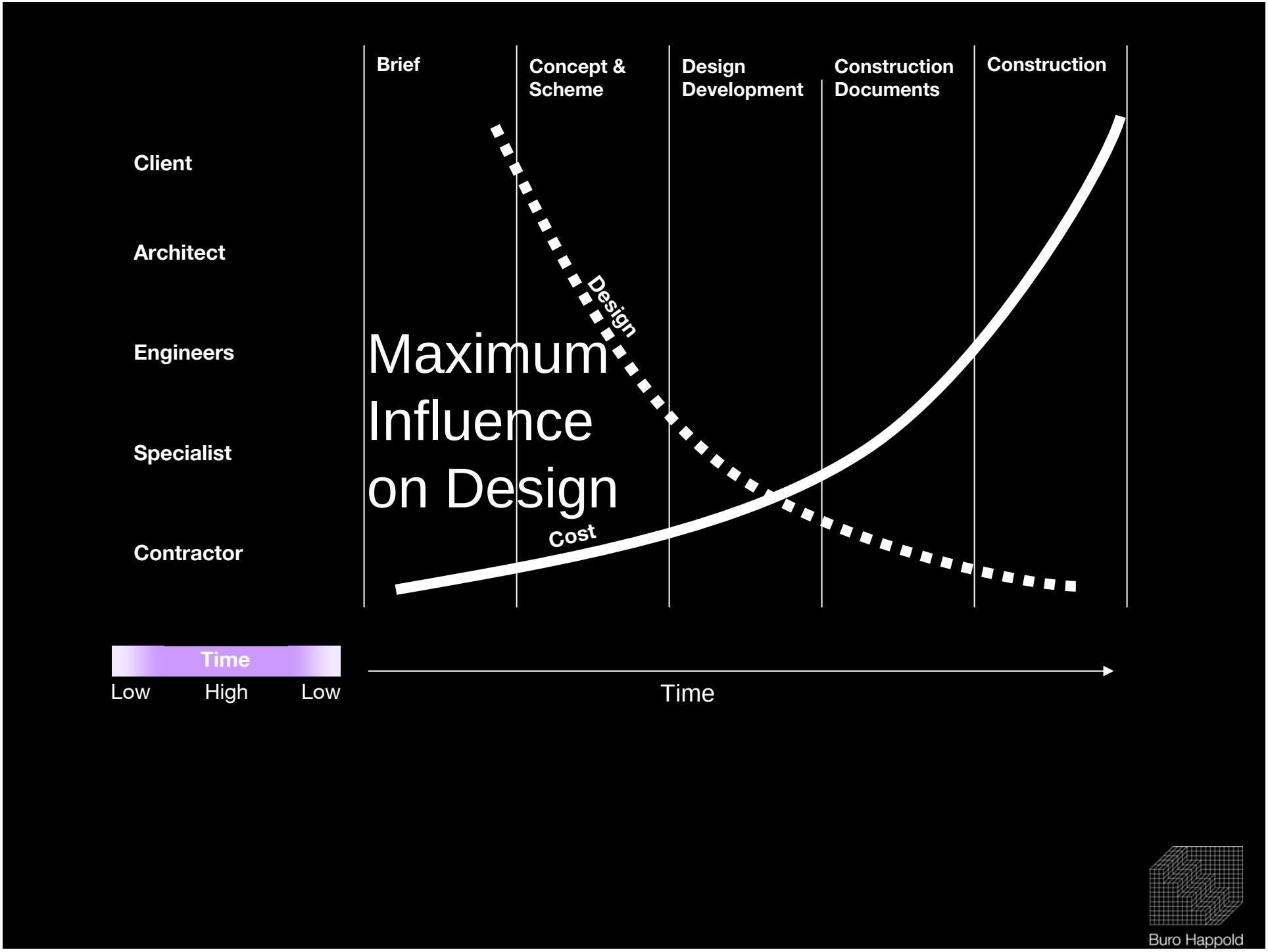
Time
Buro Happold



Buro Happold



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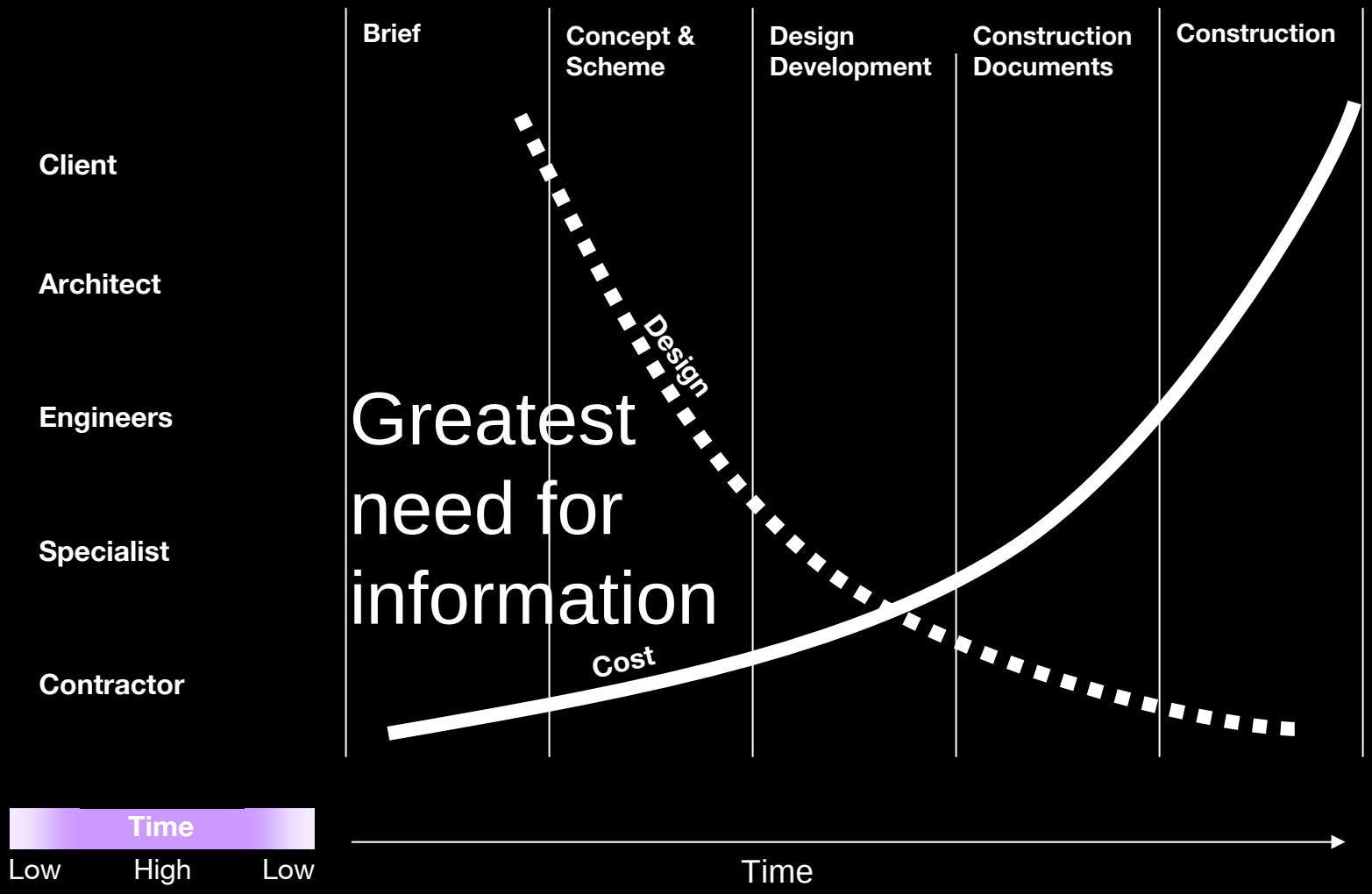

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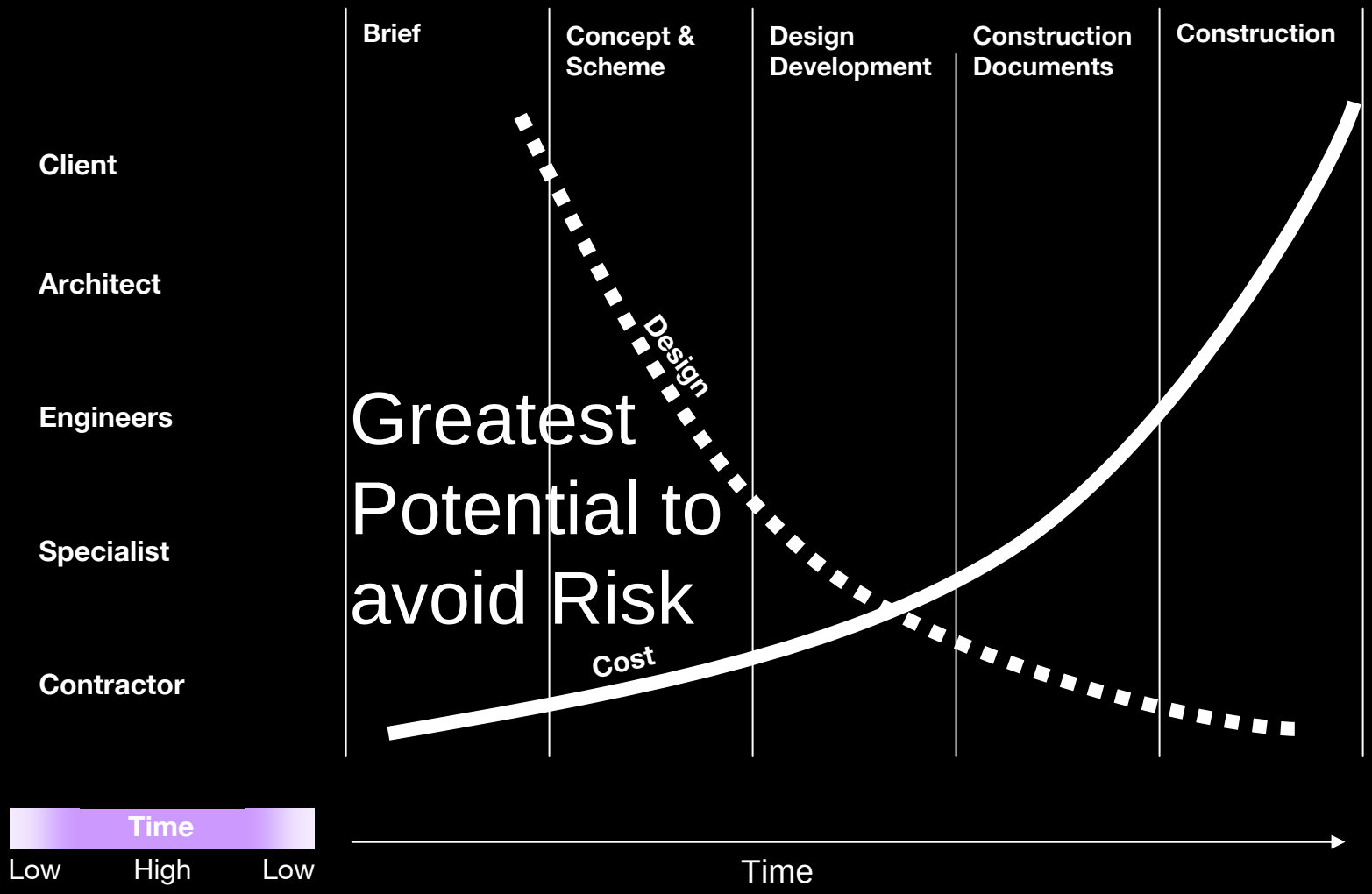

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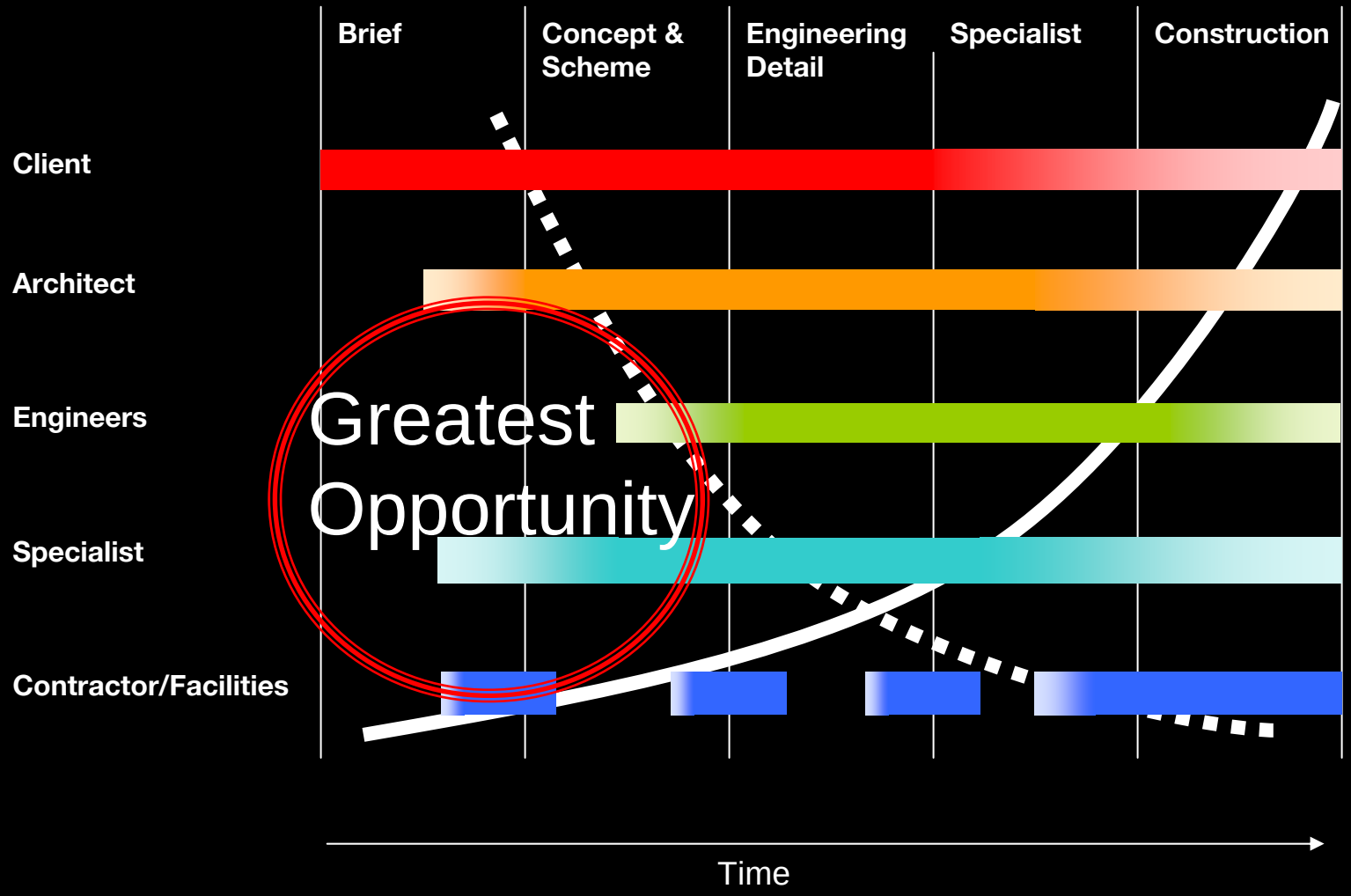
Brief
Concept & Scheme
Design Development
Construction Documents
Construction
Client
Architect
Engineers
Specialist
Contractor
Design
Greatest Potential to avoid Risk
Time
Low
High
Low
Time
Buro Happold



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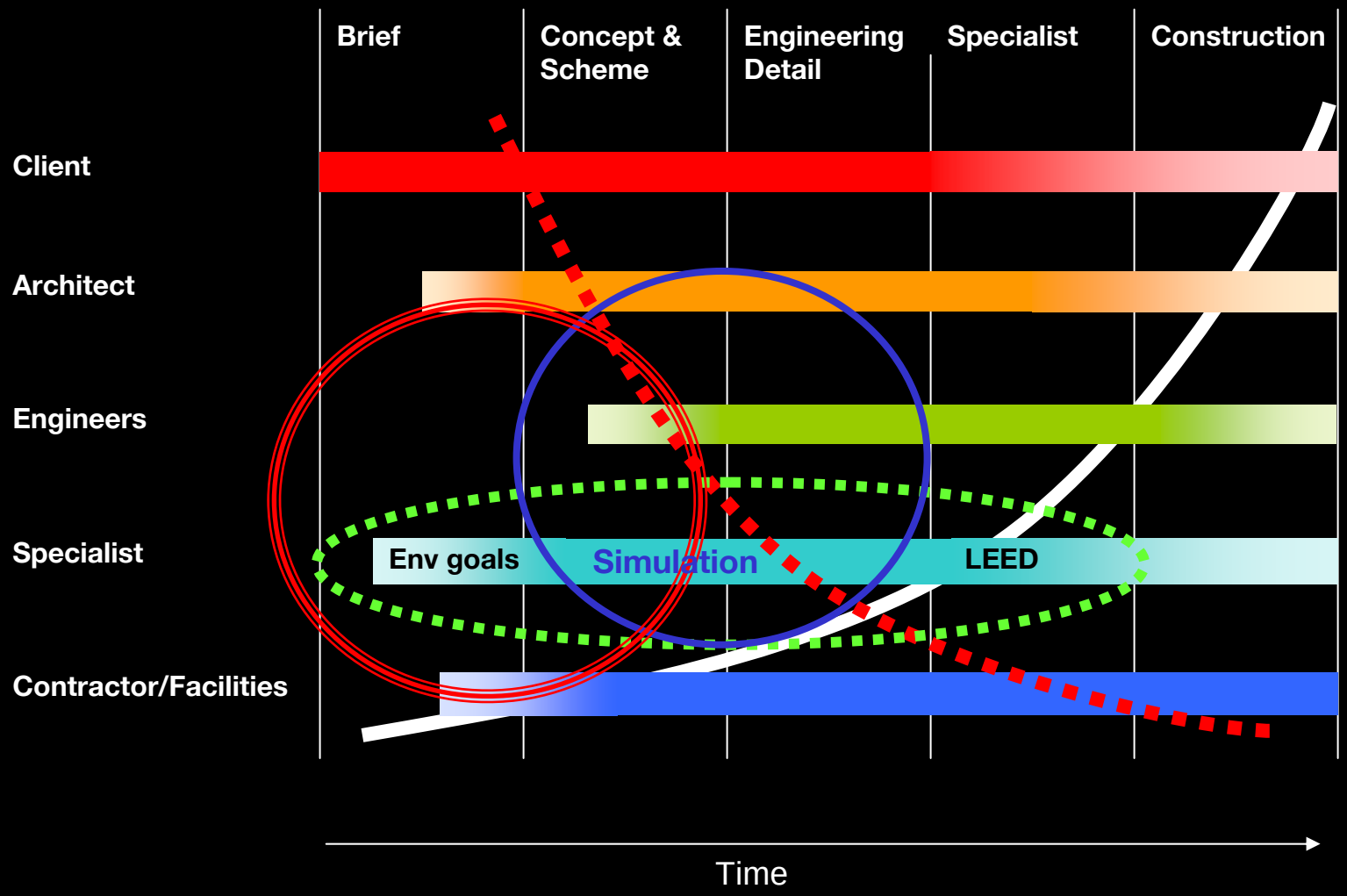
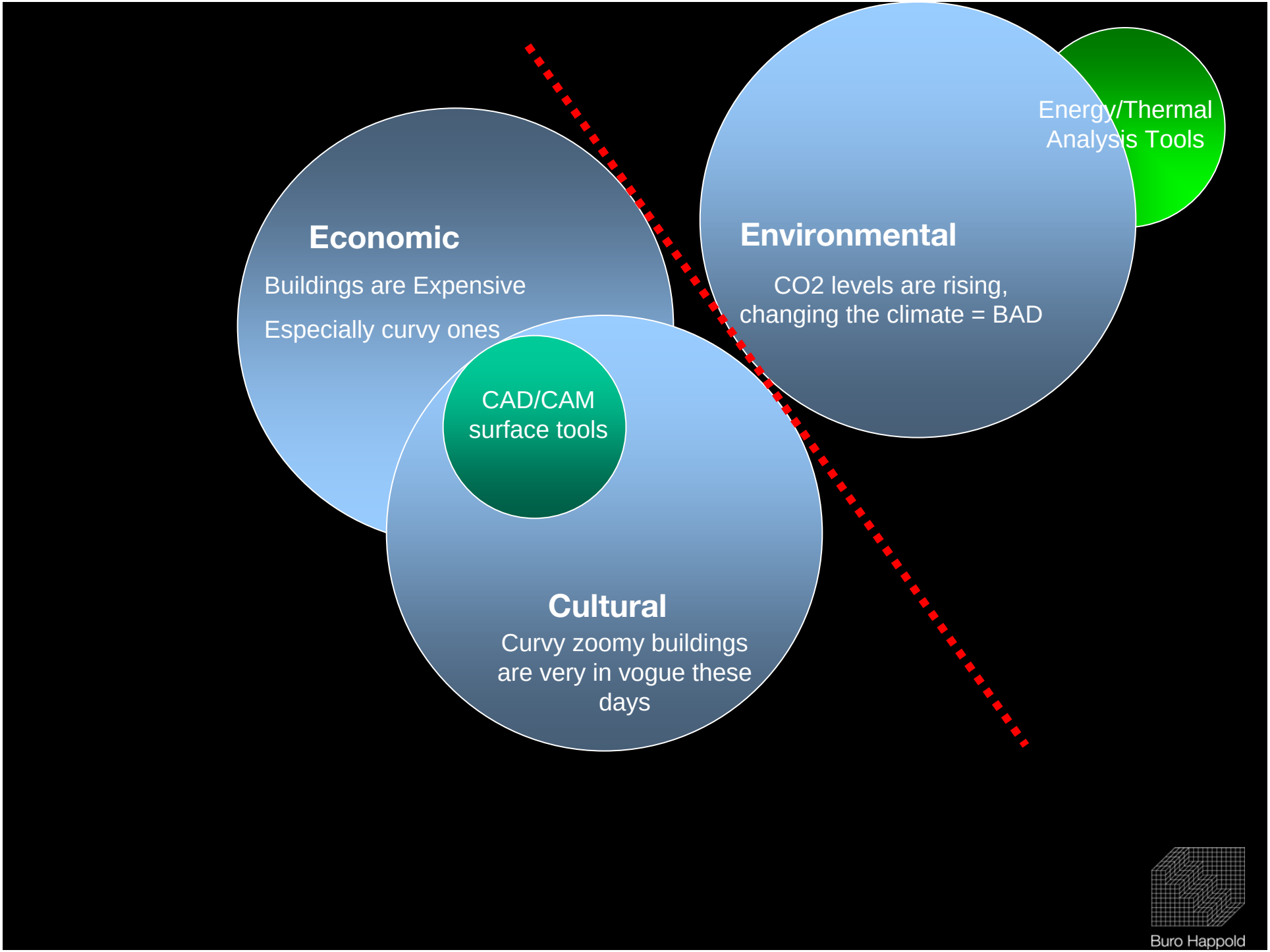
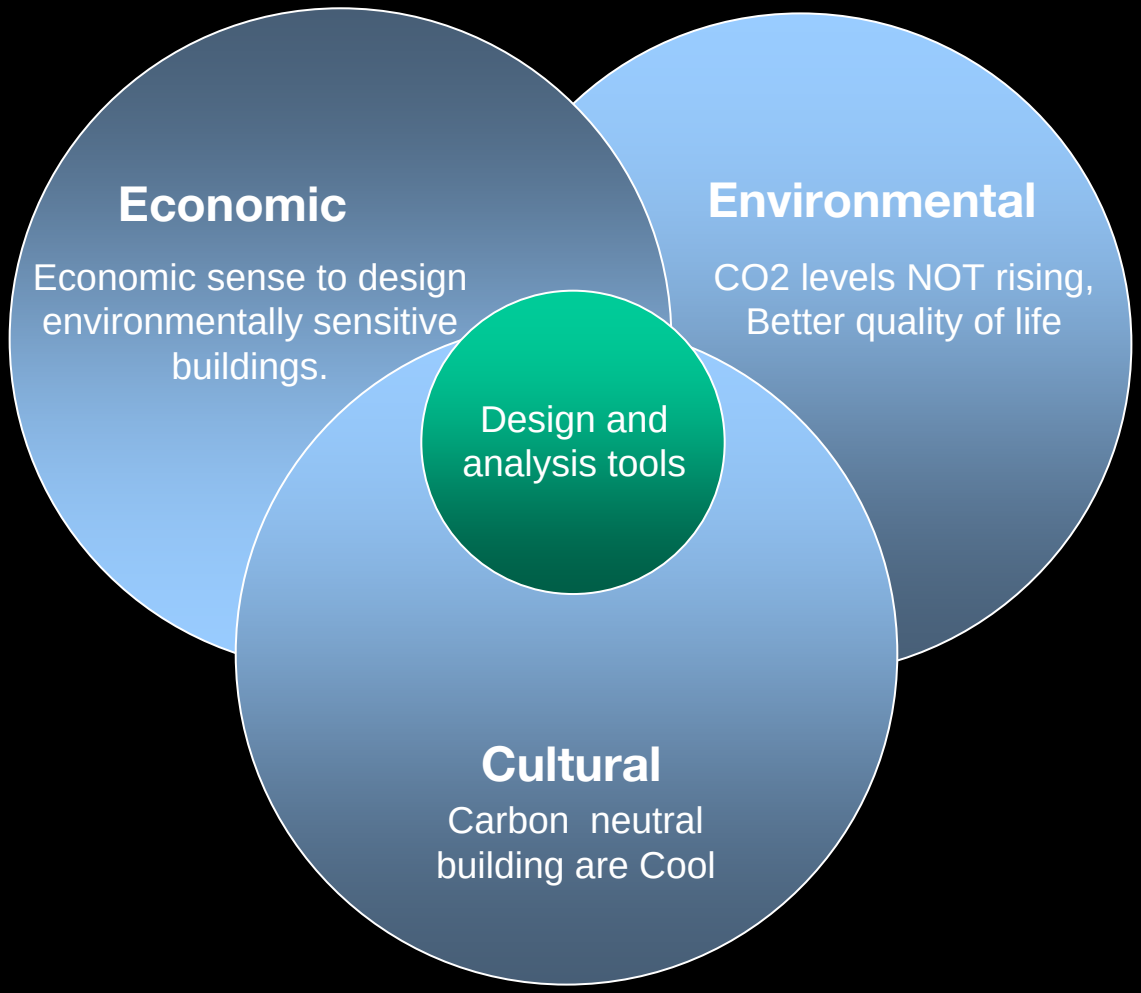


Buro Happold

Buro Happold


Energy/Thermal
Analysis Tools
Economic
Buildings are Expensive
Especially curvy ones
Environmental
CO2 levels are rising,
changing the climate = BAD
CAD/CAM
surface tools
Cultural
Curvy zoomy buildings
are very in vogue these
days
Buro Happold



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A mindset shift

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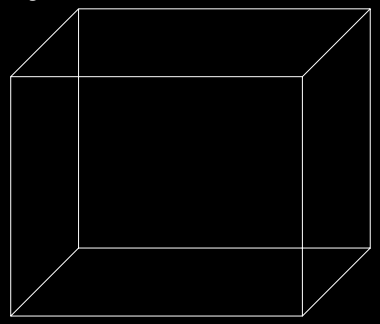
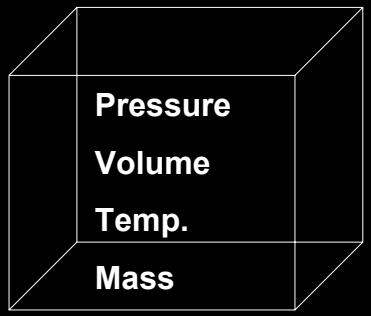
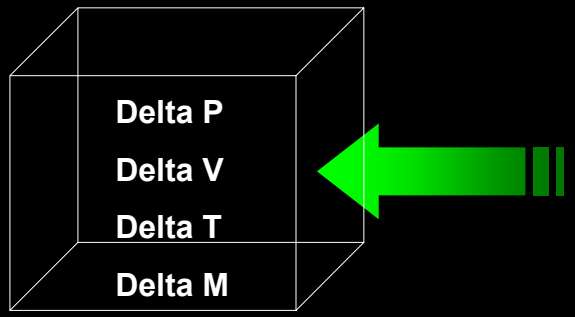
System Boundaries



System State



Change in State



What is a system:

A system is a region of space containing a quantity of matter whose behavior is being investigated. This quantity of matter is separated from its surroundings by a boundary, which may be physical such as walls, or some imaginary surface enveloping a defined region.

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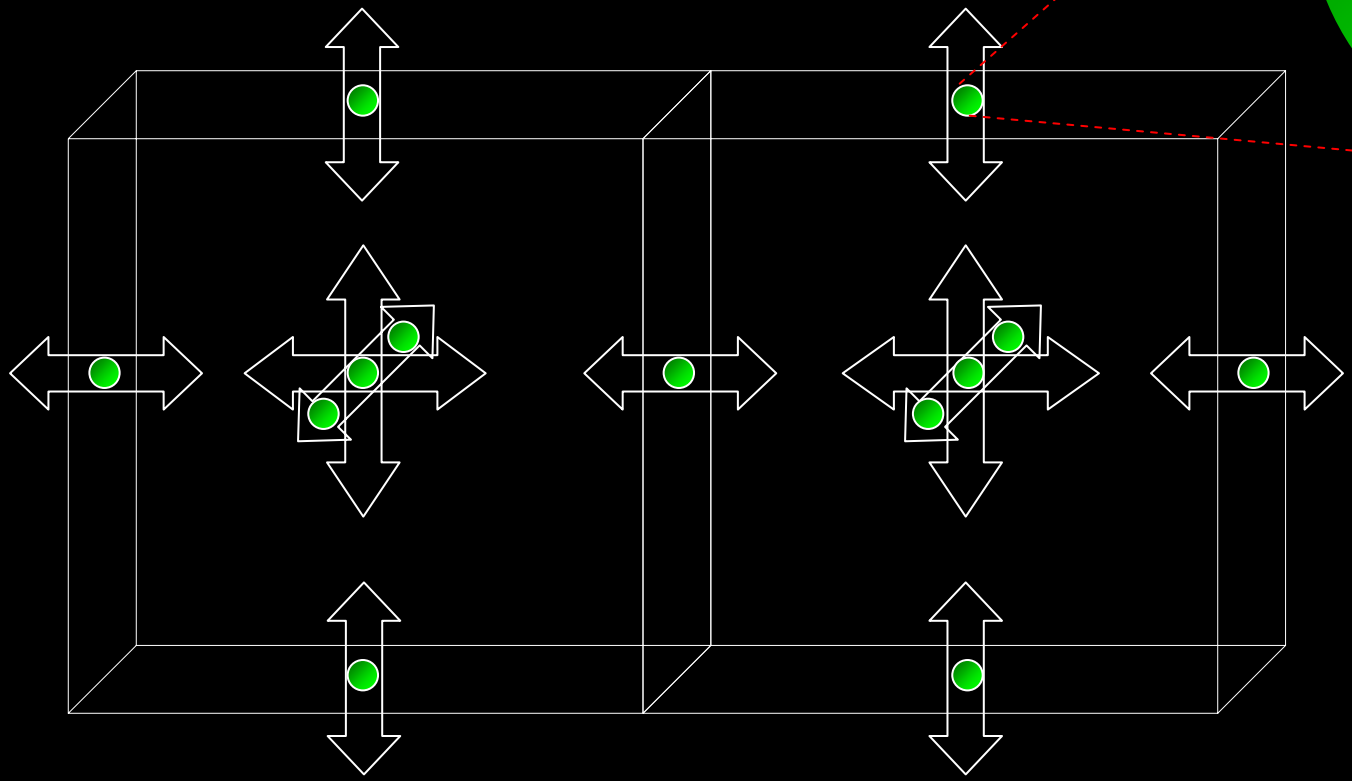
Nodal network is a collection of nodes that contain a defined set of equations that represent the physical phenomena that are being studied at a certain point in a system



Node

- Geometric Location
- Material properties
- Boundary conditions
- Links with other nodes
- Defined equation sets
- Defined moment in time

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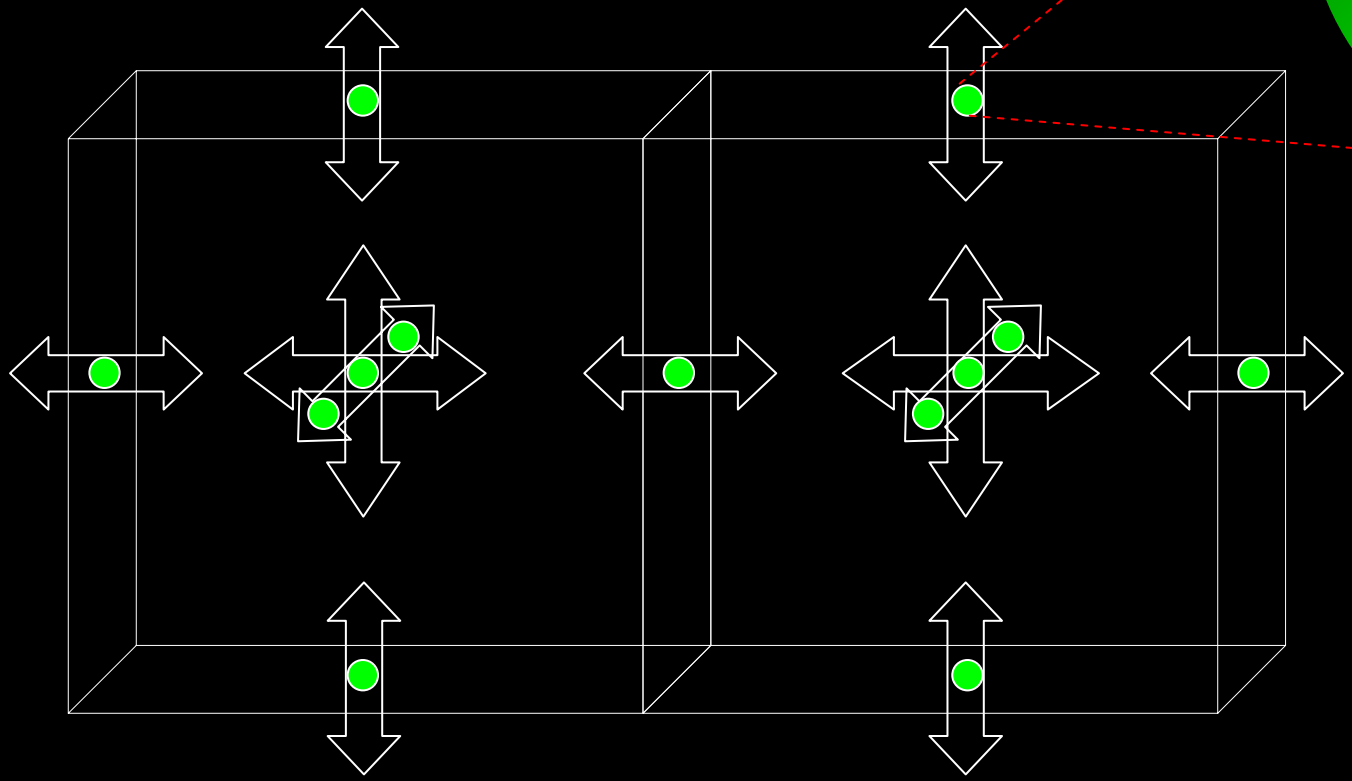
A node could represent a room, part of a room, an opening, a wall, a window, a crack in a window, a mechanical system, a fan, a duct, etc.



Solve for

- Conservation of mass
- Conservation of momentum
- Conservation of Energy

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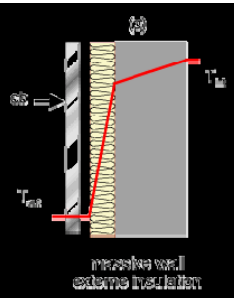

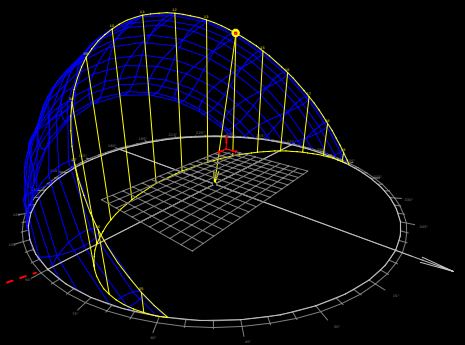

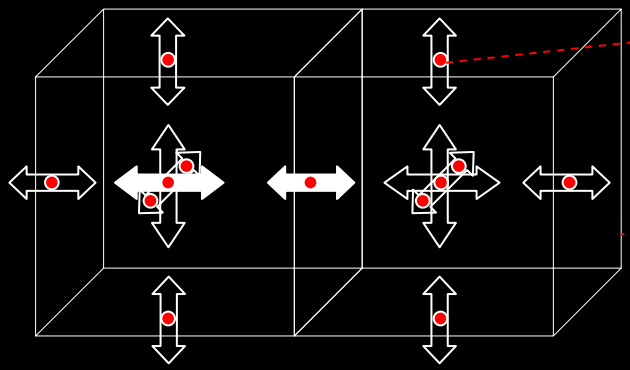

Solve for

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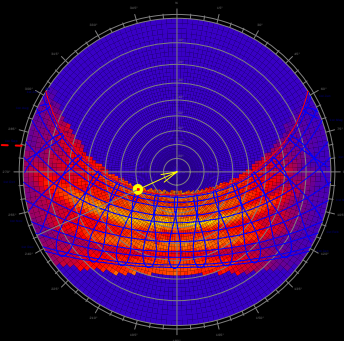

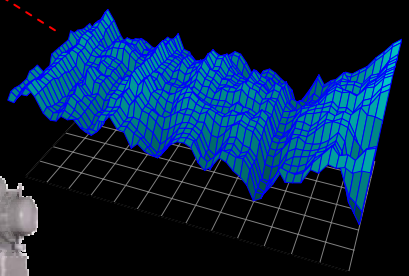

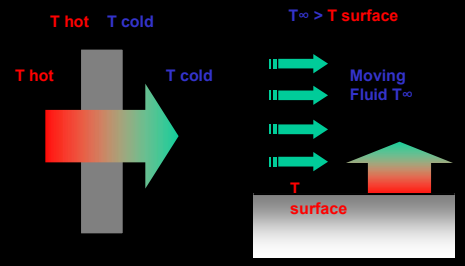

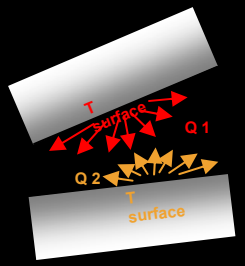

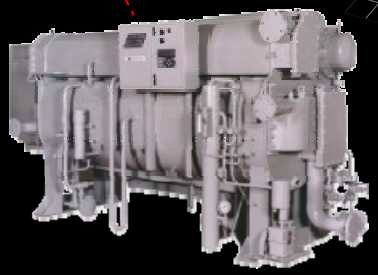

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How do we Simulate

Thermal Sim — Light/Shade Sim — Air Flow Sim

Site Planning →

Envelope Design →

Component Selection →

Systems Optimization →

Costs and Payback →

DESIGN SPACE

Each tool we have addresses different aspects of a design problem. These tools range from Rules of Thumb, to Computational Fluid Dynamics. No tool should be seen as the "Truth" because simulations are only representations of assumptions based on observations of previous events.

The visual output of a computational simulation program can provide a way to focus a design team on a problem, explain the problem to them in a visual and intuitive way. Then we can engage the entire design team in problem solving design work shops with each member of the team operating within the same design space moving towards a collective and integrated solution.

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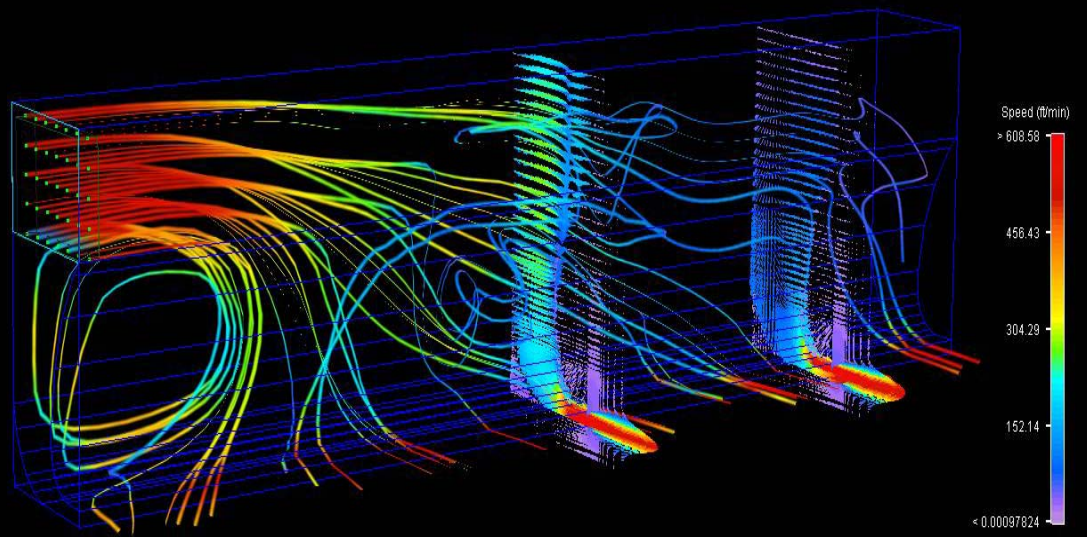

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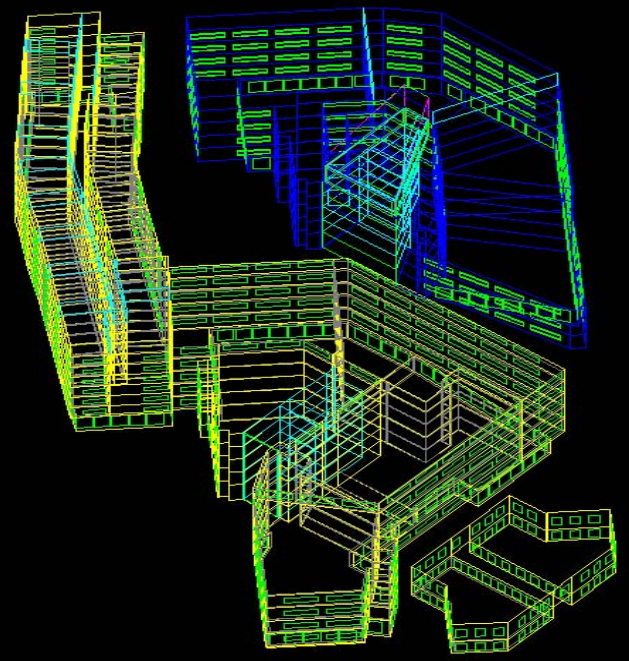

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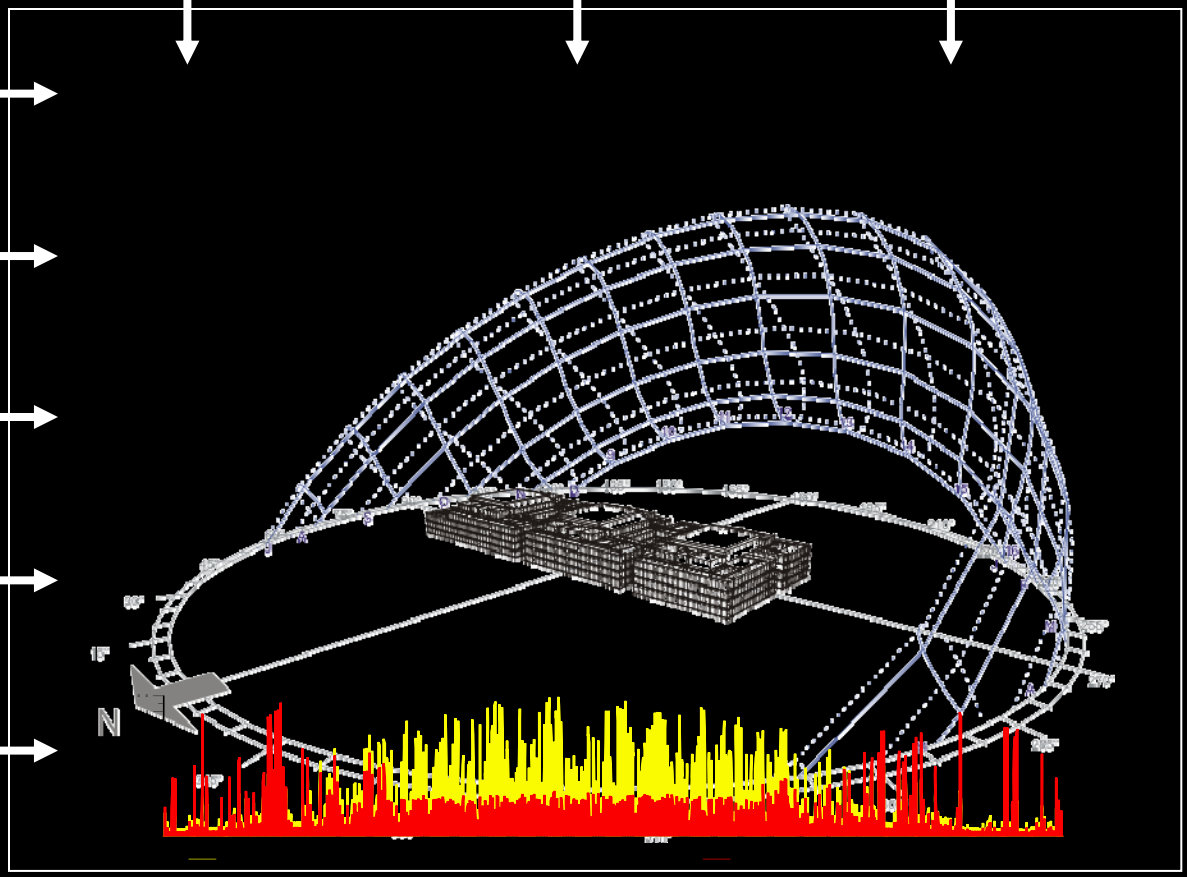

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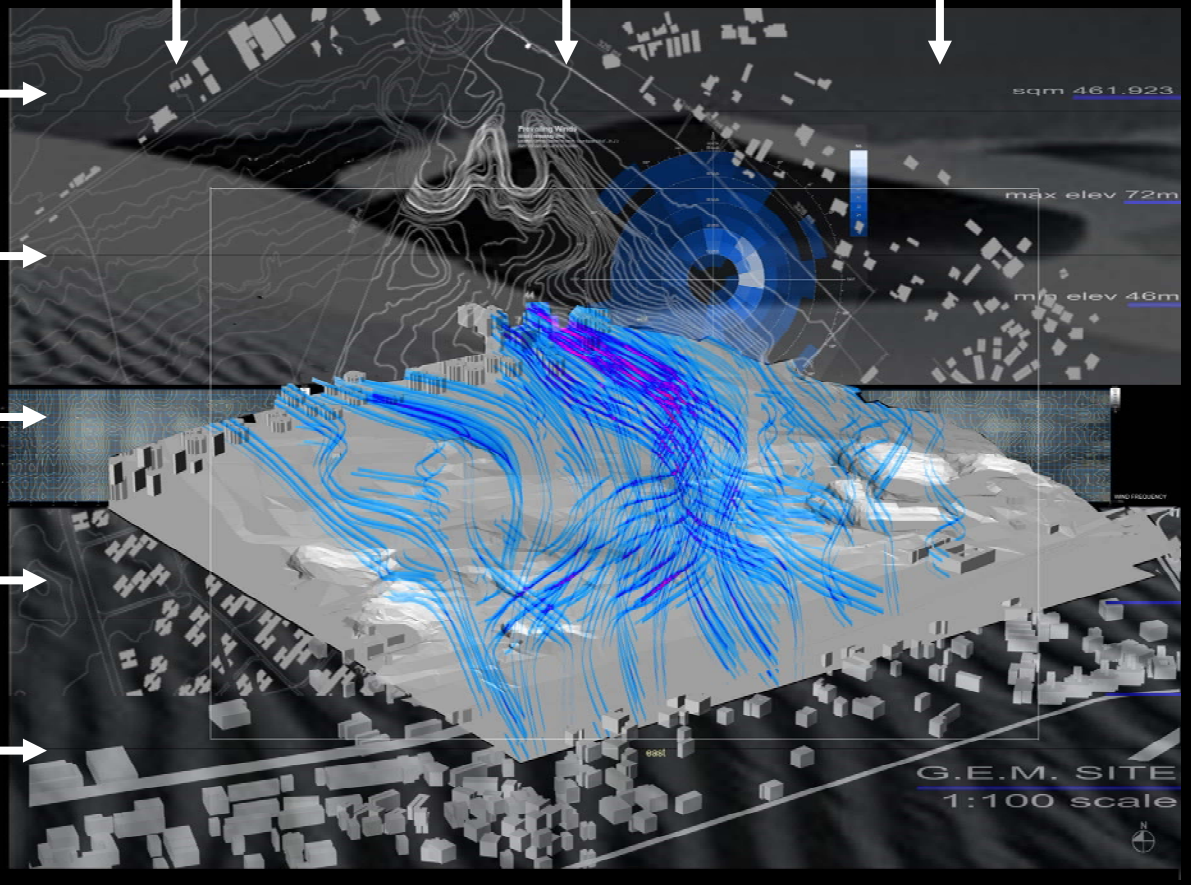

Buro Happold

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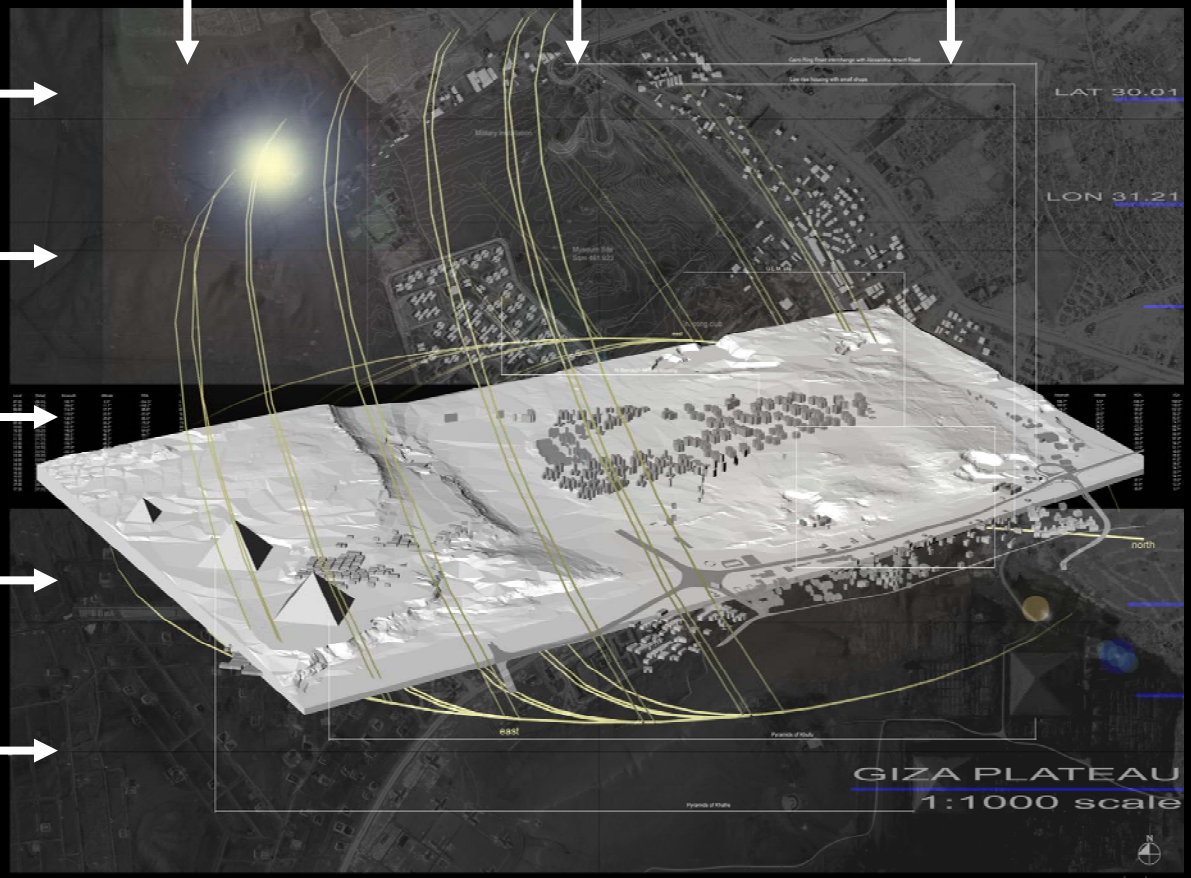

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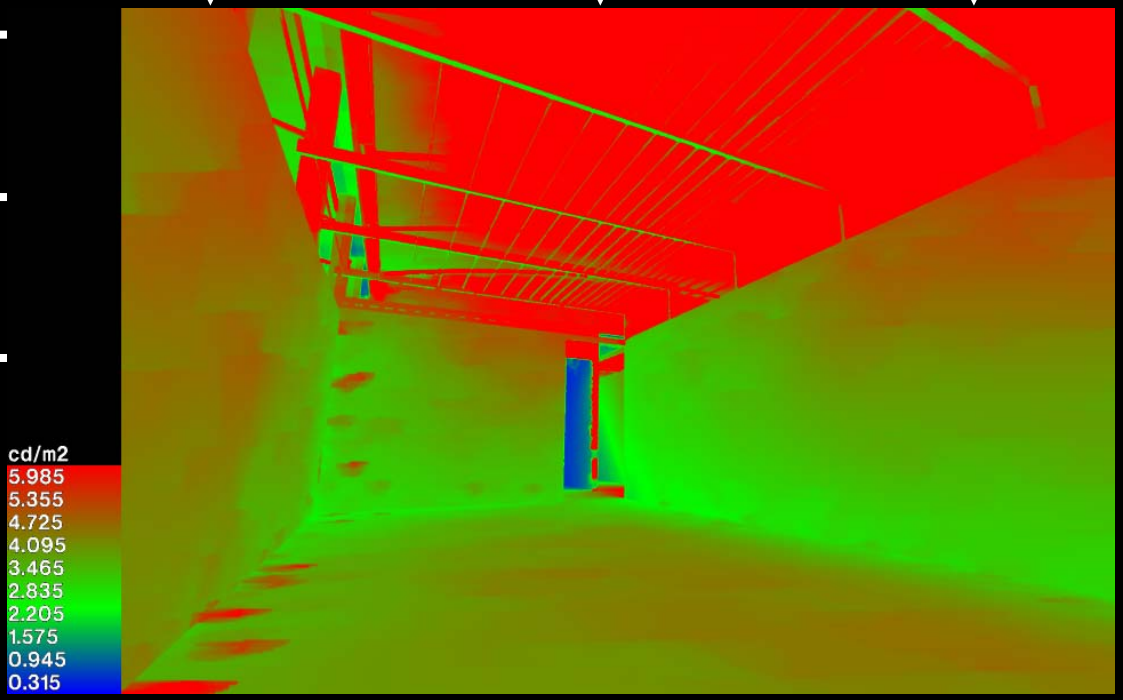

Buro Happold

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Light/Shade Sim

Air Flow Sim

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Buro Happold

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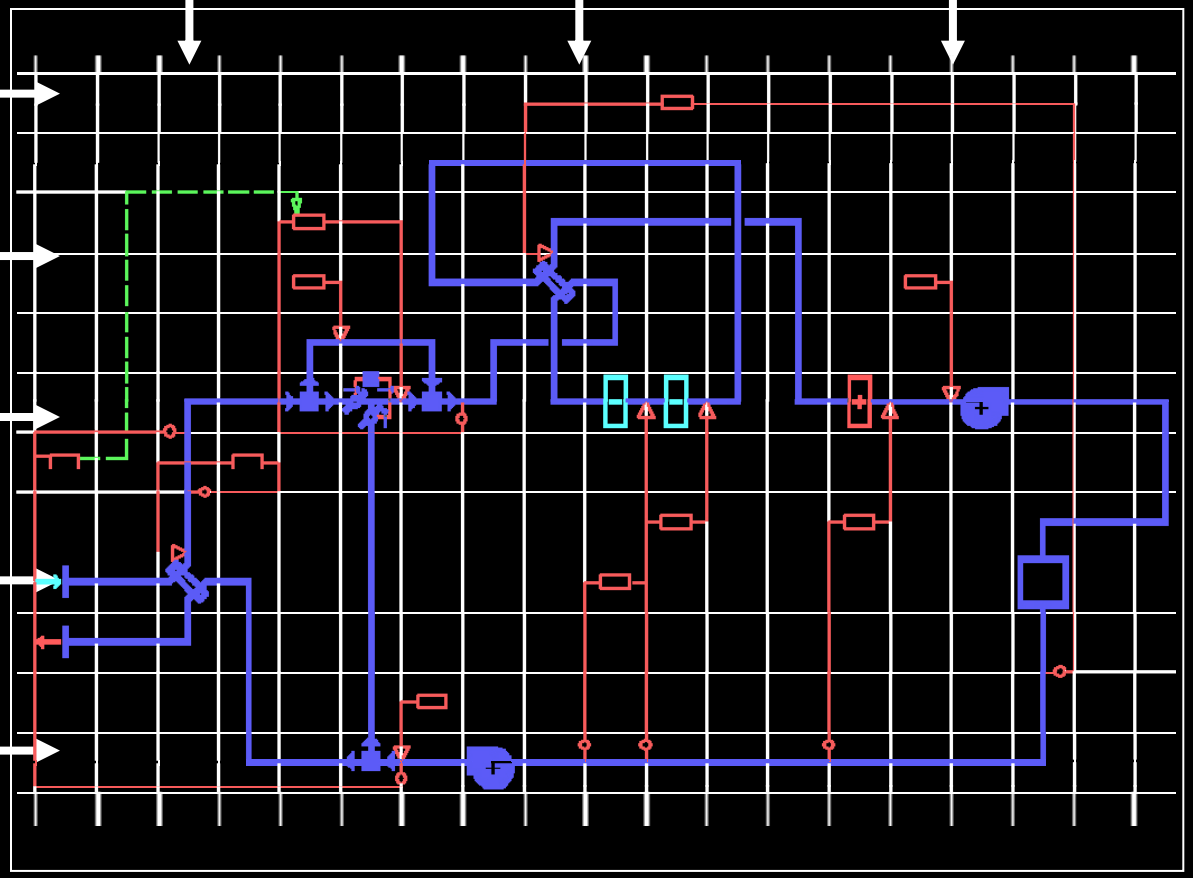


Buro Happold

How do we Simulate — Thermal Sim — Light/Shade Sim — Air Flow Sim

Site Planning →

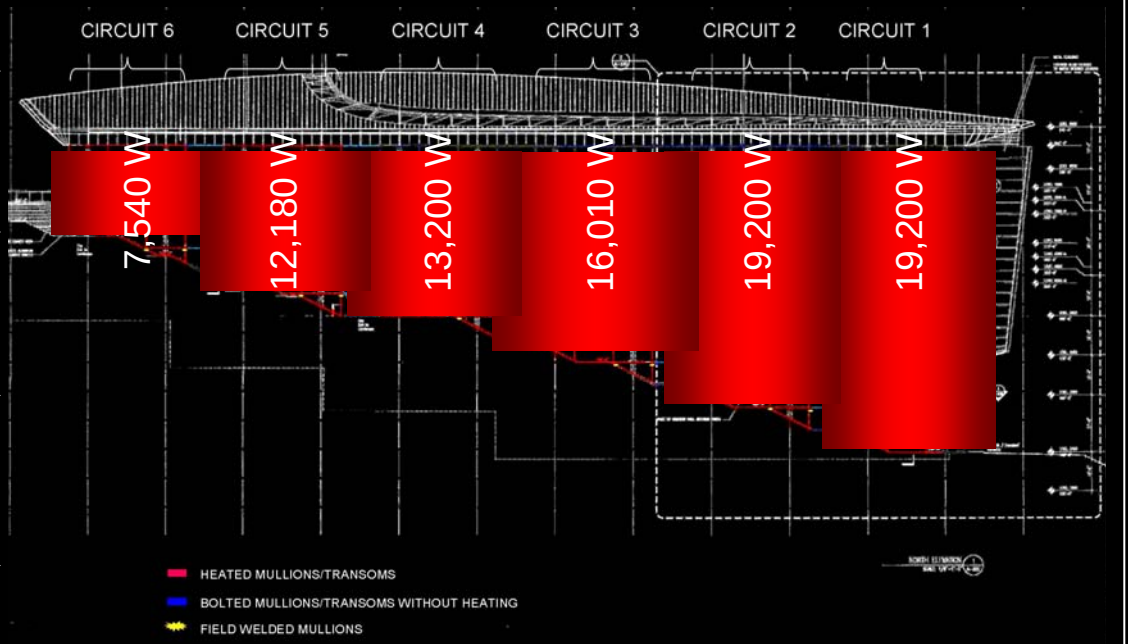
Envelope Design →

Component Selection →

Systems Optimization →

Costs and Payback →

North Façade - Integrated Heating Elements



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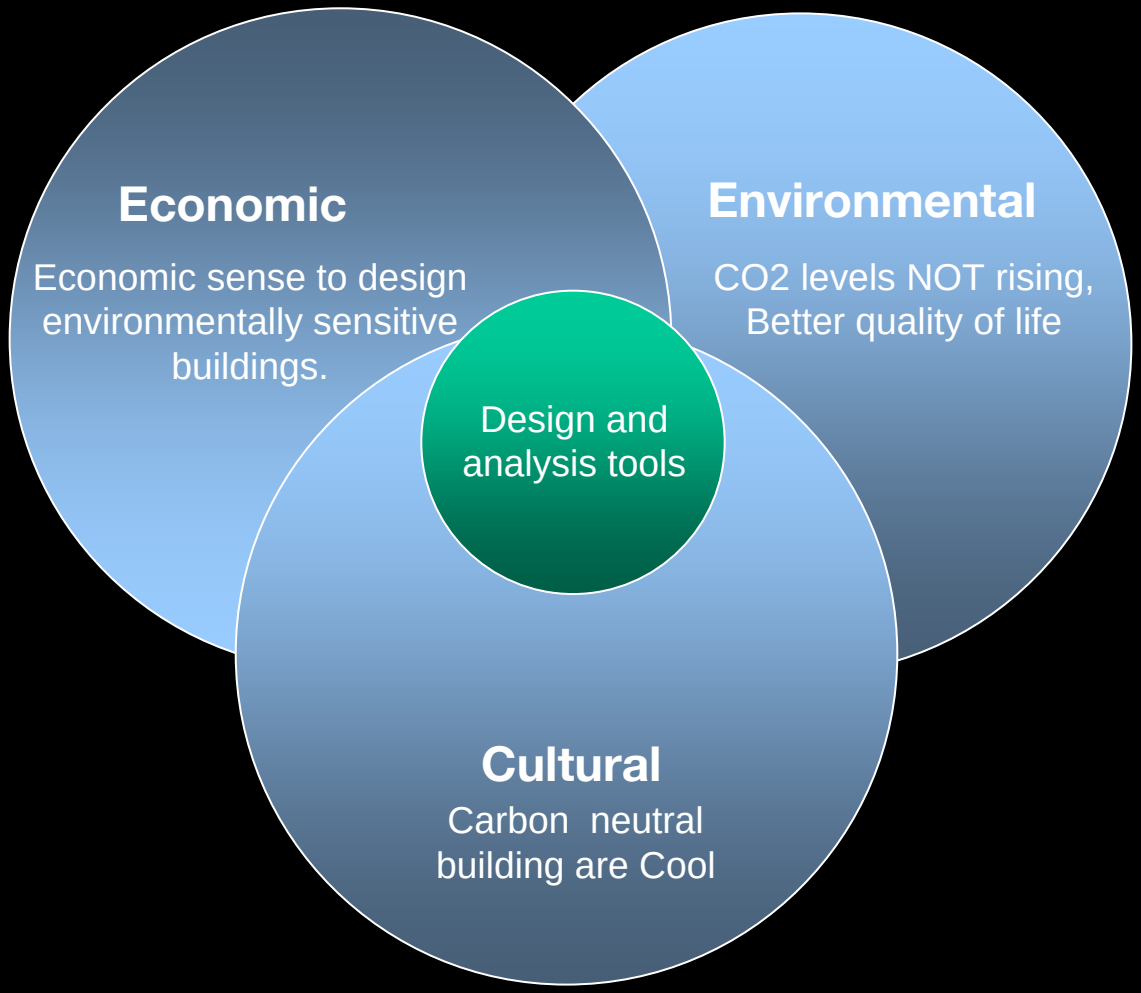
The Confidence to BUILD

Informing Design • Building in Performance

Buro Happold



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USGBC “Guiding Principles”

- Triple Bottom Line: Sustainable development involves the simultaneous pursuit of economic prosperity, environmental quality and social equity.
- Establish Leadership: Champion societal models that achieve a more robust triple line.
- Endeavor to create and restore harmony between human activities & natural systems
- Be guided by the Precautionary Principle in utilizing technical & scientific data to protect, preserve & restore the health of the global environment, ecosystems & species
- Insure inclusive, interdisciplinary, democratic decision-making with the objective of building understanding & shared commitments toward a greater common good
- Strive for honesty, openness & transparency

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LEED
Leadership In Energy & Environmental Design

LEED gives building owners and operators the tools they need to have an immediate and measurable impact on their buildings' performance.

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ASHRAE 90.1 appendix G

ASHRAE/IESNA Standard 90.1-1999

ASHRAE®

STANDARD

Energy Standard for Buildings Except Low-Rise Residential Buildings

I-P Edition

Approved by the ASHRAE Standards Committee June 19, 1999, and by the ASHRAE Board of Directors June 24, 1999.

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AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.

1791 Tullie Circle, NE • Atlanta, GA 30329

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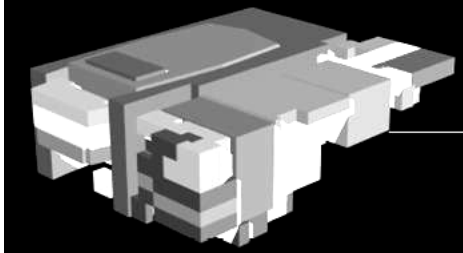
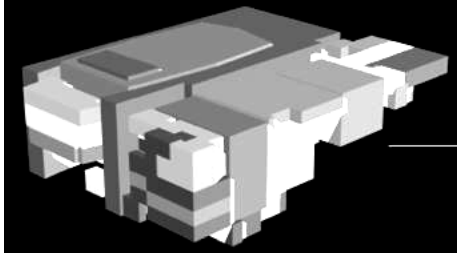
ASHRAE 90.1 appendix G

The ECB method requires the proposed design annual energy cost be less than the annual energy cost of a budget building. The comparison is made possible by modeling the proposed design and budget building with an energy simulation program, in this case POWER DOE. The budget building model is constructed with the same occupancy, schedules, gross floor area, and shape or the proposed design. However the budget building meets the prescriptive requirements of the ASHRAE 90.1 standard. The annual energy consumption of the proposed design must be less than the annual energy budget of the budget building.

In order to obtain building permits in a jurisdiction that has adopted the ASHRAE 90.1 standard, the building designers must demonstrate that the design meets the Standards requirements. Due to the innovative design proposed by the architect, the analysis was performed using the Energy Cost Budget (ECB) Method as defined by ASHRAE 90.1. It is important to understand the ECB method's limitations and intent. The ECB method is intended to provide fair method of comparison between the estimated annual energy cost of the proposed design and the budget building design for purposes of compliance with the Standard. The ECB method is not intended to provide the most accurate prediction of actual energy consumption or costs for the building as it is actually built. (for additional information refer to ASHRAE 90.1 users manual)



Budget Building Simulation



Proposed Design Simulation

Building Geometry

Building Loads

Building Schedules

Weather Data

Wall assembly U values

50% total exterior glazing

5% max area of Skylight

VAV HAVC System

Glass SHGC and U values

Budget Building

Electricity results = kWh per year

Steam results = M lbs per year

Chilled water results = ton-hr per year

TOTAL ENERGY BUDGET= $ per year

ASHRAE 90.1 Compliance Check:
Proposed Design **<** Budget Building

Wall assembly U values

54% total exterior glazing

5% total area skylight

VAV and heat wheels

Glass SHGC and U values

TOTAL ENERGY BUDGET= $ per year

Electricity results = kWh per year

Steam results = M lbs per year

Chilled water results = ton-hr per year

Proposed Design

Results and Comparison

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ASHRAE 90.1 appendix G

PHYSICAL PROPERTIES
Building Description of spaces, floor area, wall area, wall insulation, window properties, ect.

USAGE PROPERTIES
Schedules of spaces, i.e. occupancy, equipment, lighting, task lighting, etc.

WEATHER DATA
Hourly weather data for the site.

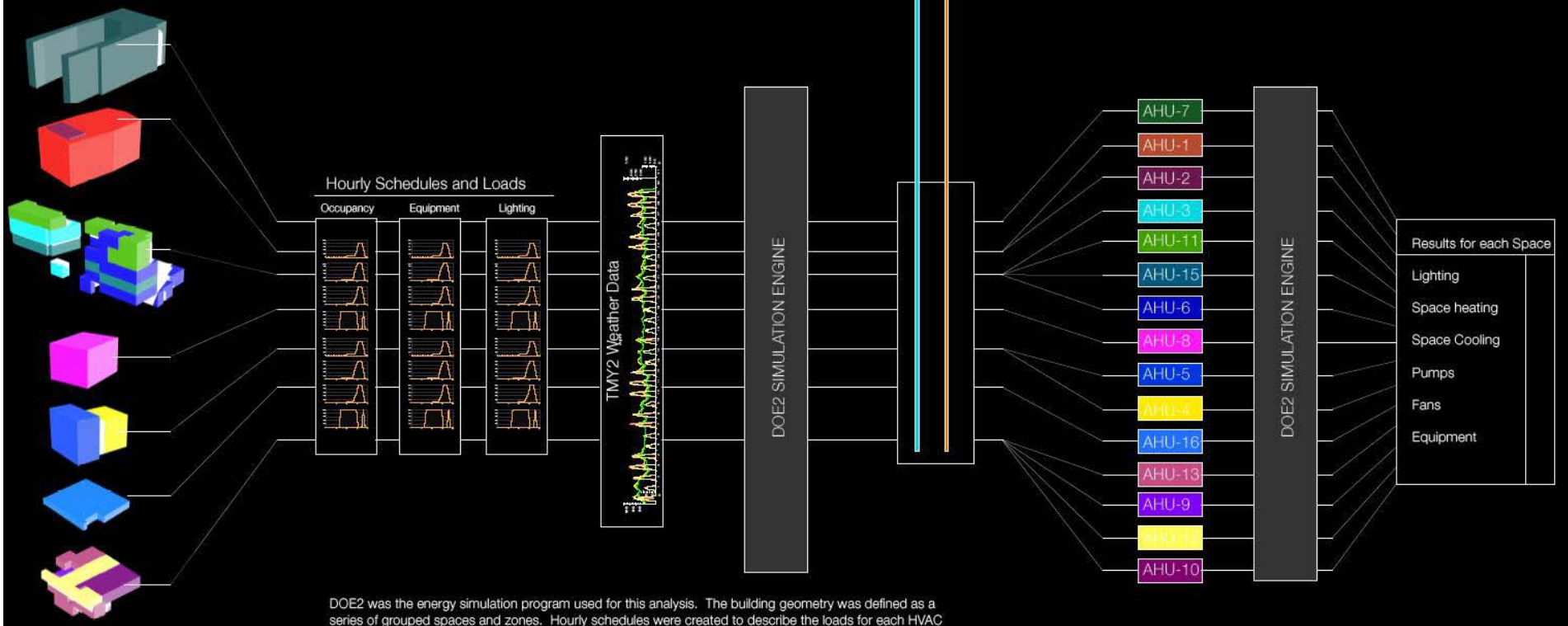
LOADS SIMULATION
Hourly weather data for the site.

CENTRAL PLANT
Properties of Building i.e. chilled water supply, steam supply, pumps, etc.

AIR SYSTEMS
Properties of air building air handling units, fan coil units, radiators, etc.

HVAC SIMULATION
Simulates the building systems to meet the loads of each space for each hour.

RESULTS
Sums energy consumption of central plant by end-use for each space for each hour of the yea



DOE2 was the energy simulation program used for this analysis. The building geometry was defined as a series of grouped spaces and zones. Hourly schedules were created to describe the loads for each HVAC system. Results form the simulations were compared between the proposed design and budget building.

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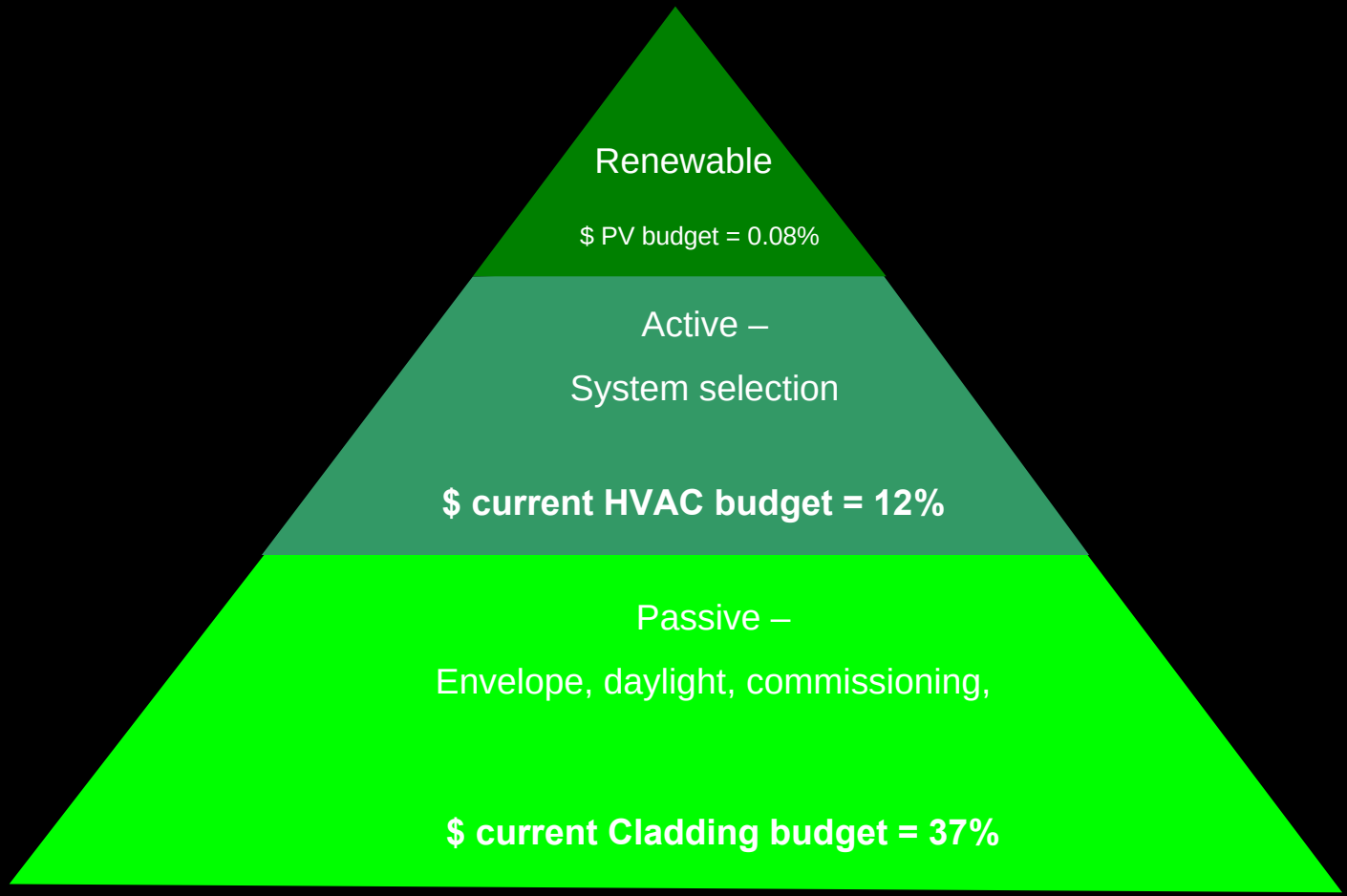

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Energy Conservation Measures		LEED	Capital Cost	Payback	Carbon
			$	yrs	tons CO2
Renewable	Photovoltaic Roof	X			
	Photovoltaic Façade System	X			
Active	High Efficiency Mechanical System	X			
	CHP system with Absorption Cooling	X			
	Variable Speed Pumps and Fans	X			
	Occupancy Sensors	X			
	Building Commissioning	X			
	Advanced BMS	X			
	Groundsource Heat Pumps	X			
Passive	Reduced Glazing Area	X			
	High Performance Glass	X			
	Green Roof	X			
	Increased Insulation	X			
	Solar Shading	X			
	Daylighting	X			

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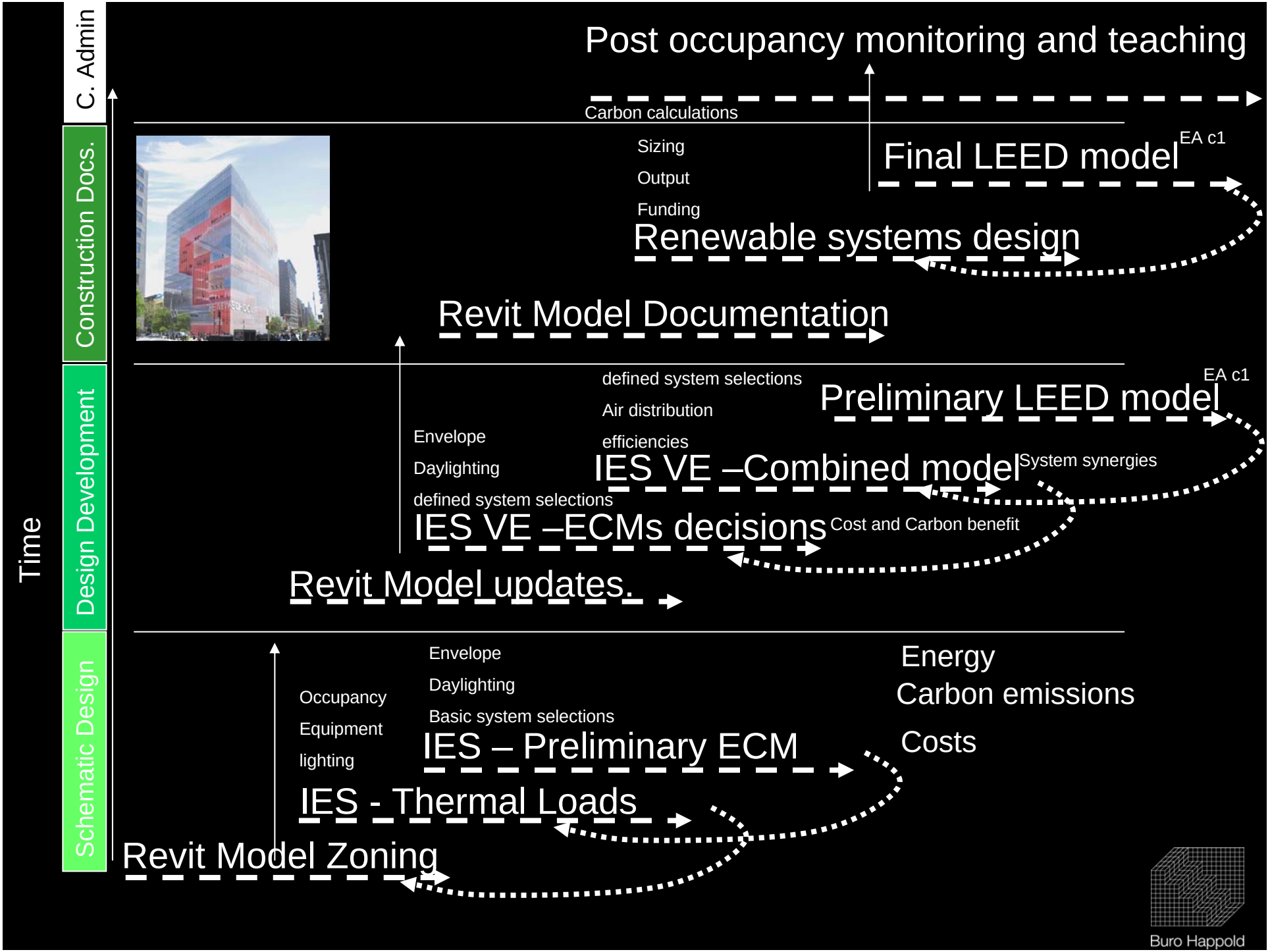
C. Admin
Construction Docs.
Design Development
Schematic Design
Time
Post occupancy monitoring and teaching
Carbon calculations
Sizing
Output
Funding
Final LEED model
EA c1
Renewable systems design
Revit Model Documentation
defined system selections
Air distribution
efficiencies
Preliminary LEED model
EA c1
Envelope
Daylighting
defined system selections
IES VE –Combined model
System synergies
IES VE –ECMs decisions
Cost and Carbon benefit
Revit Model updates.
Occupancy
Equipment
lighting
Envelope
Daylighting
Basic system selections
Energy
Carbon emissions
Costs
IES – Preliminary ECM
IES - Thermal Loads
Revit Model Zoning
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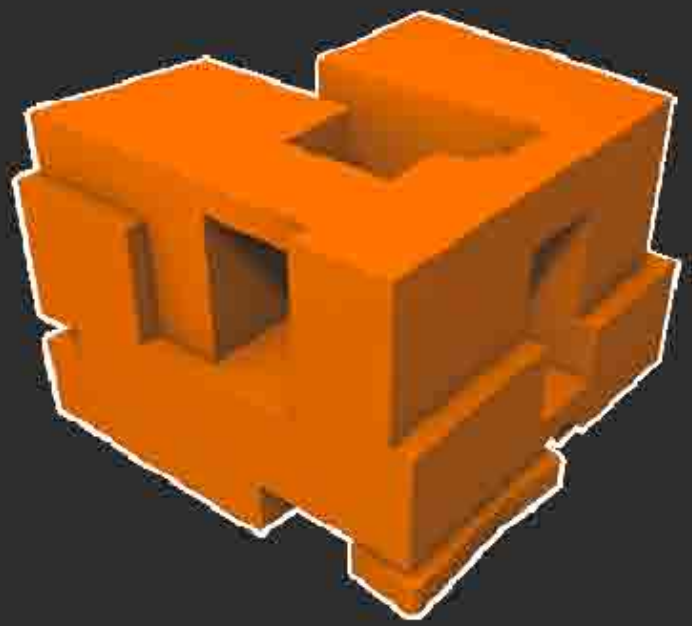

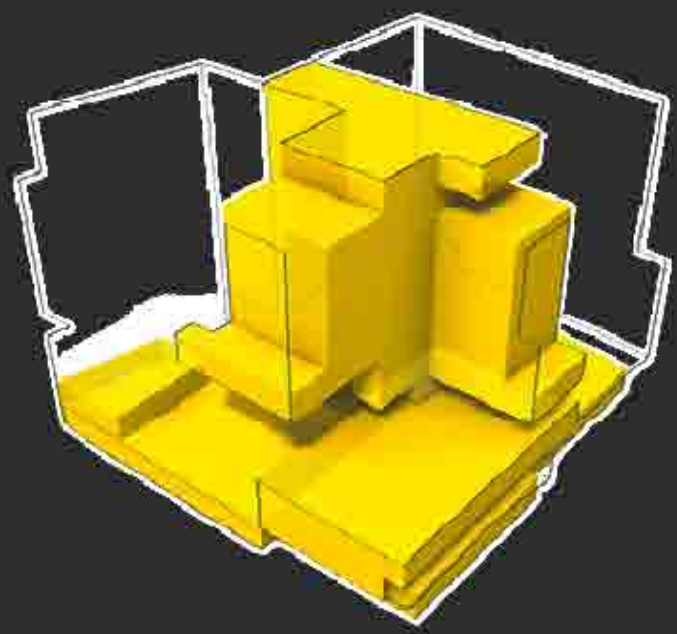

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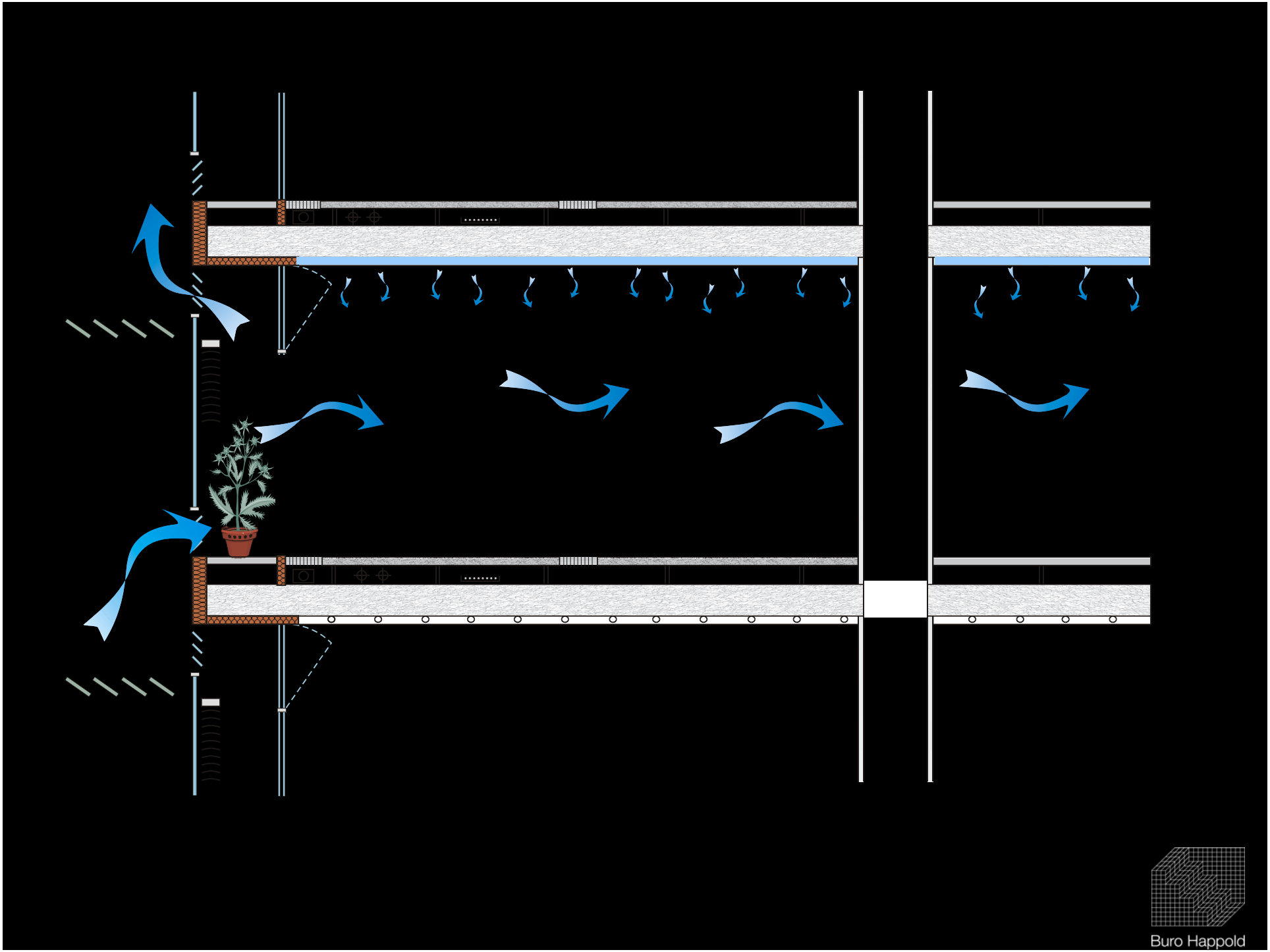
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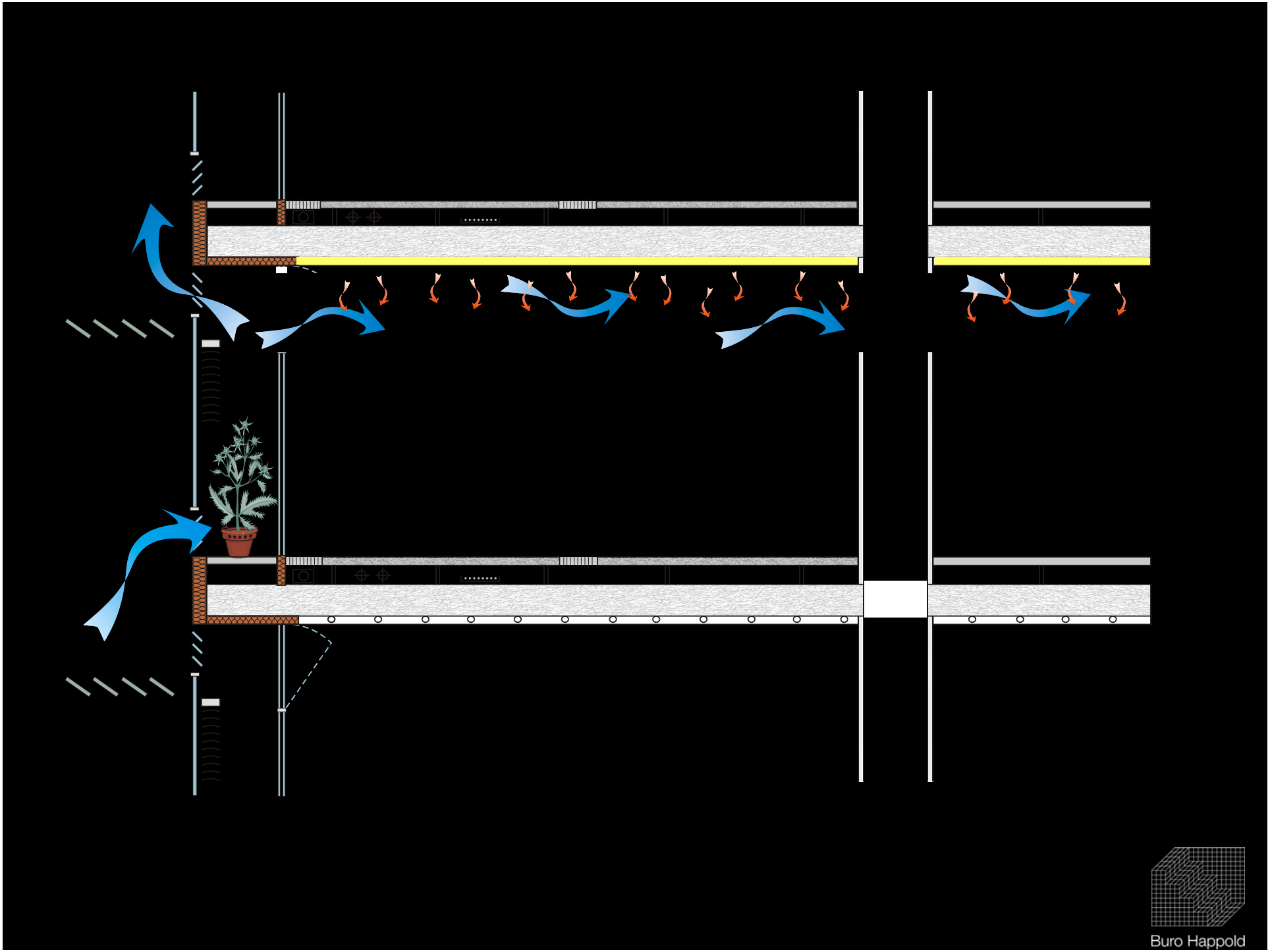
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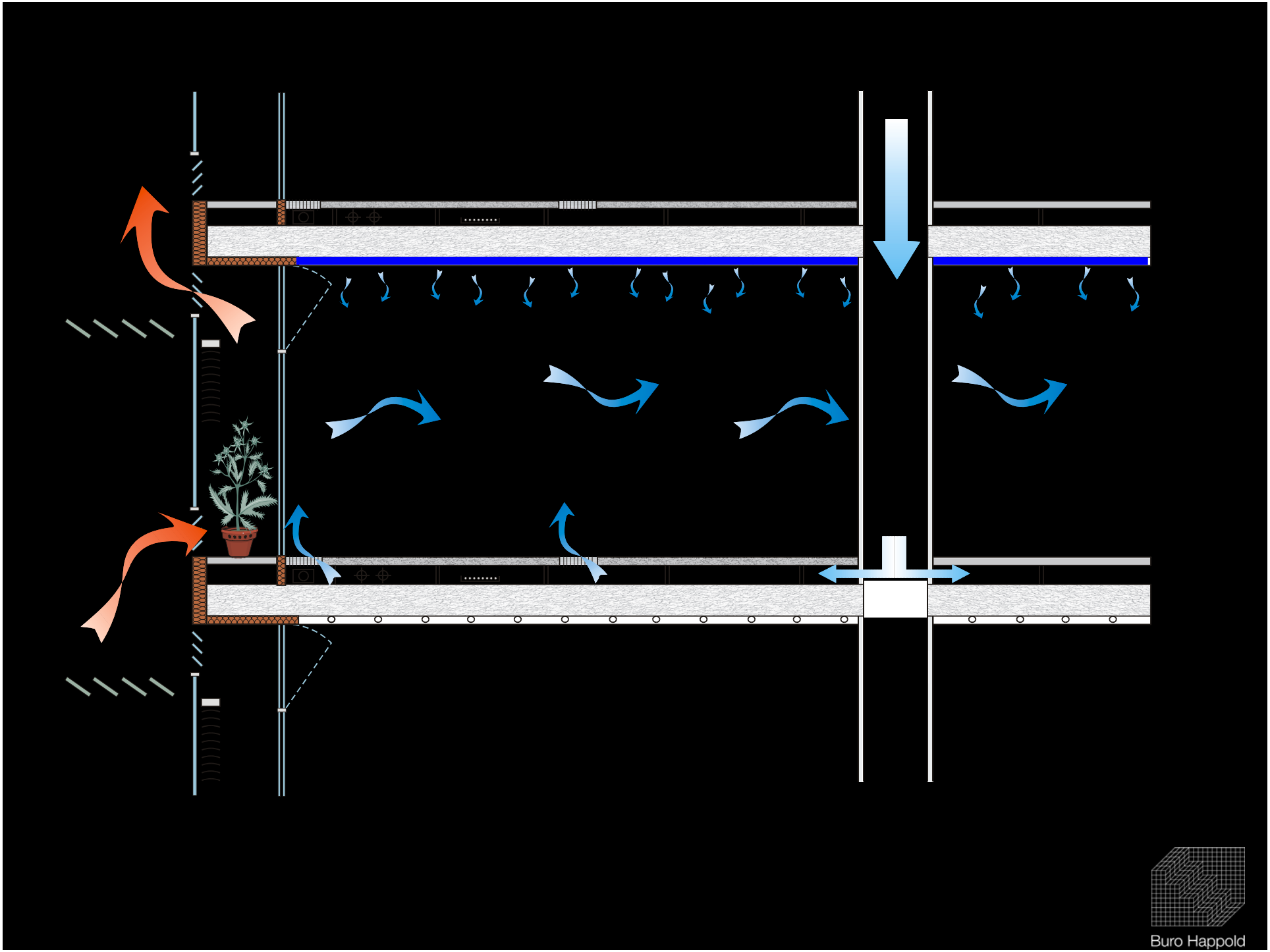
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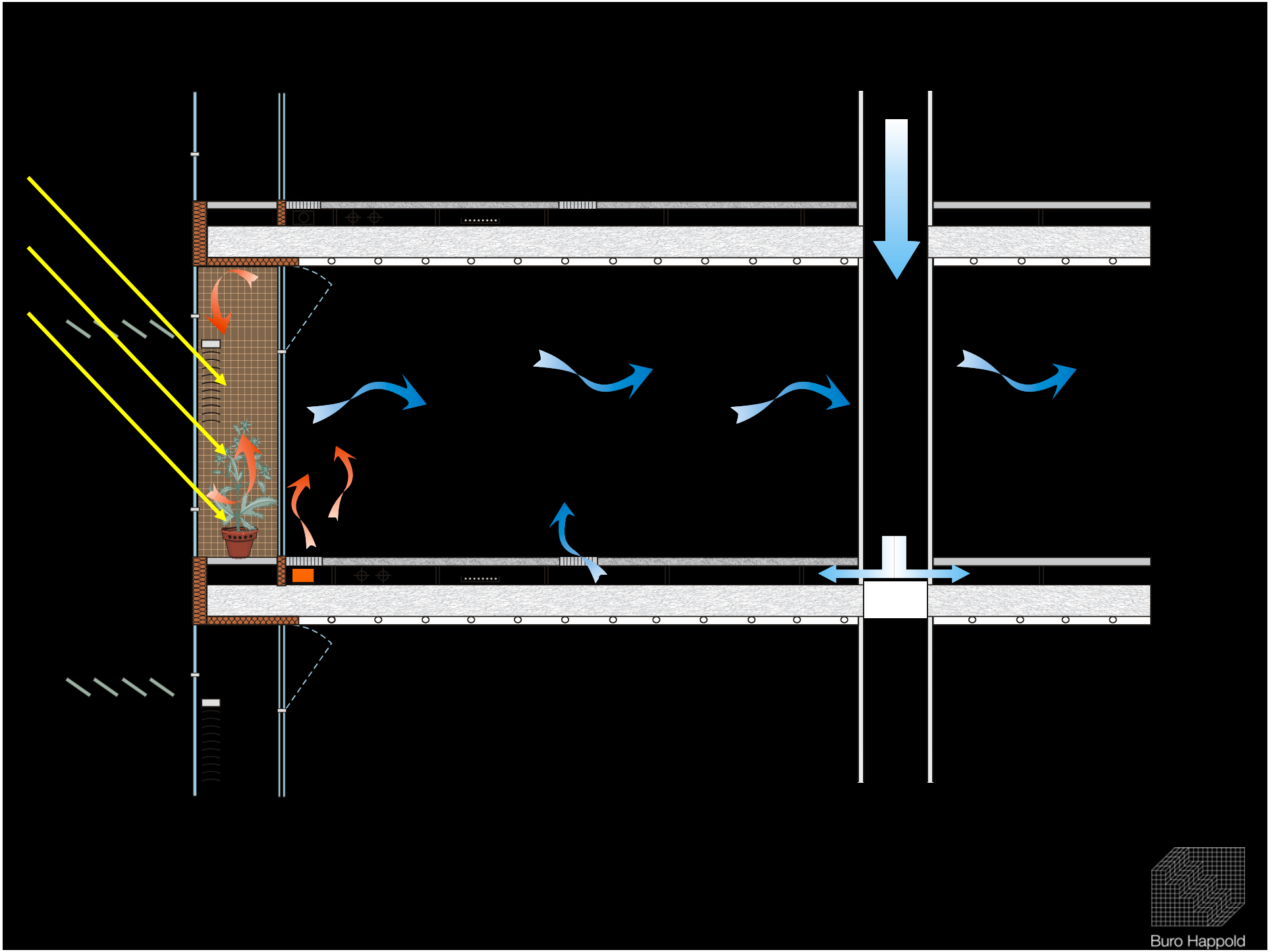
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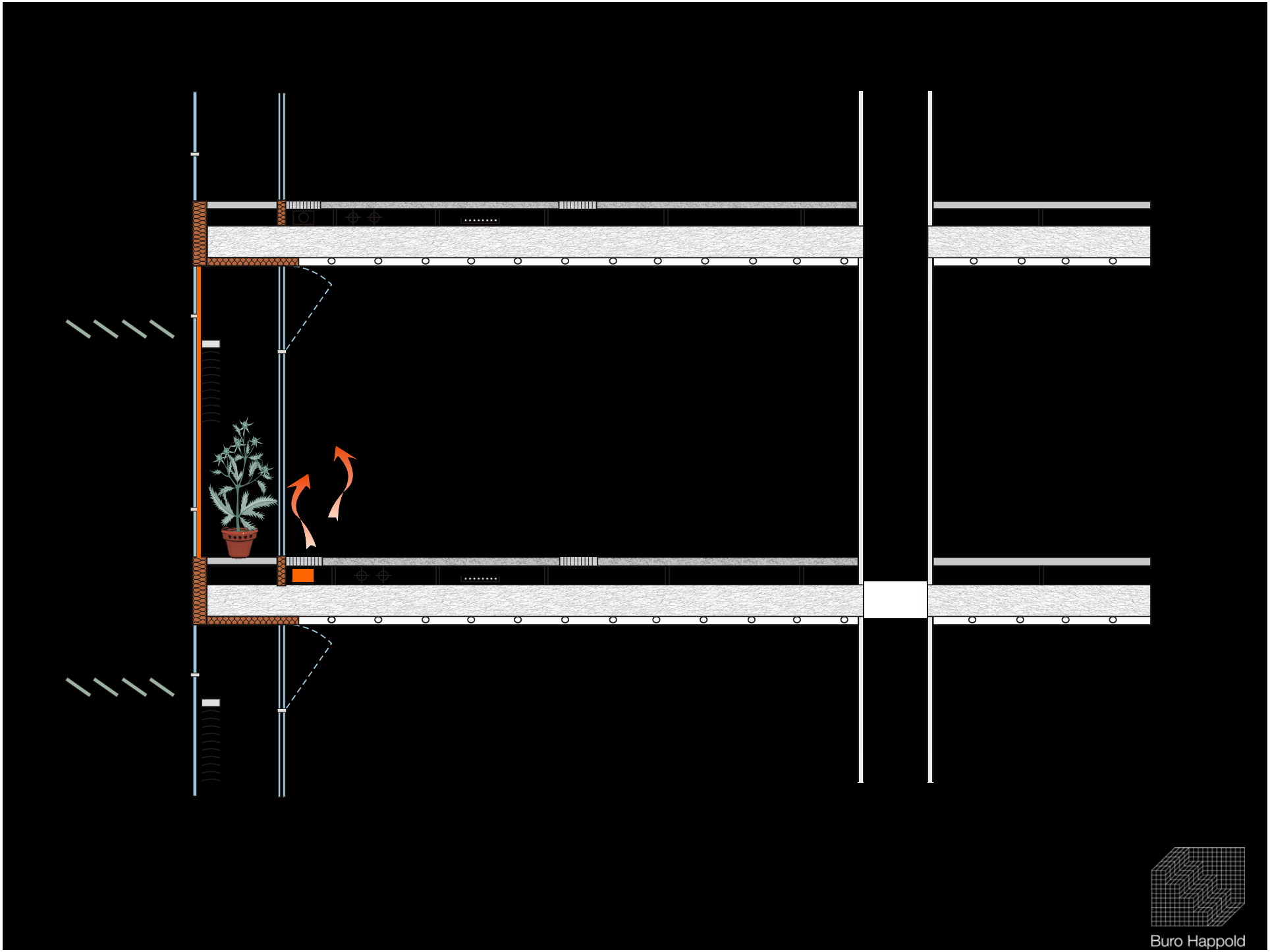
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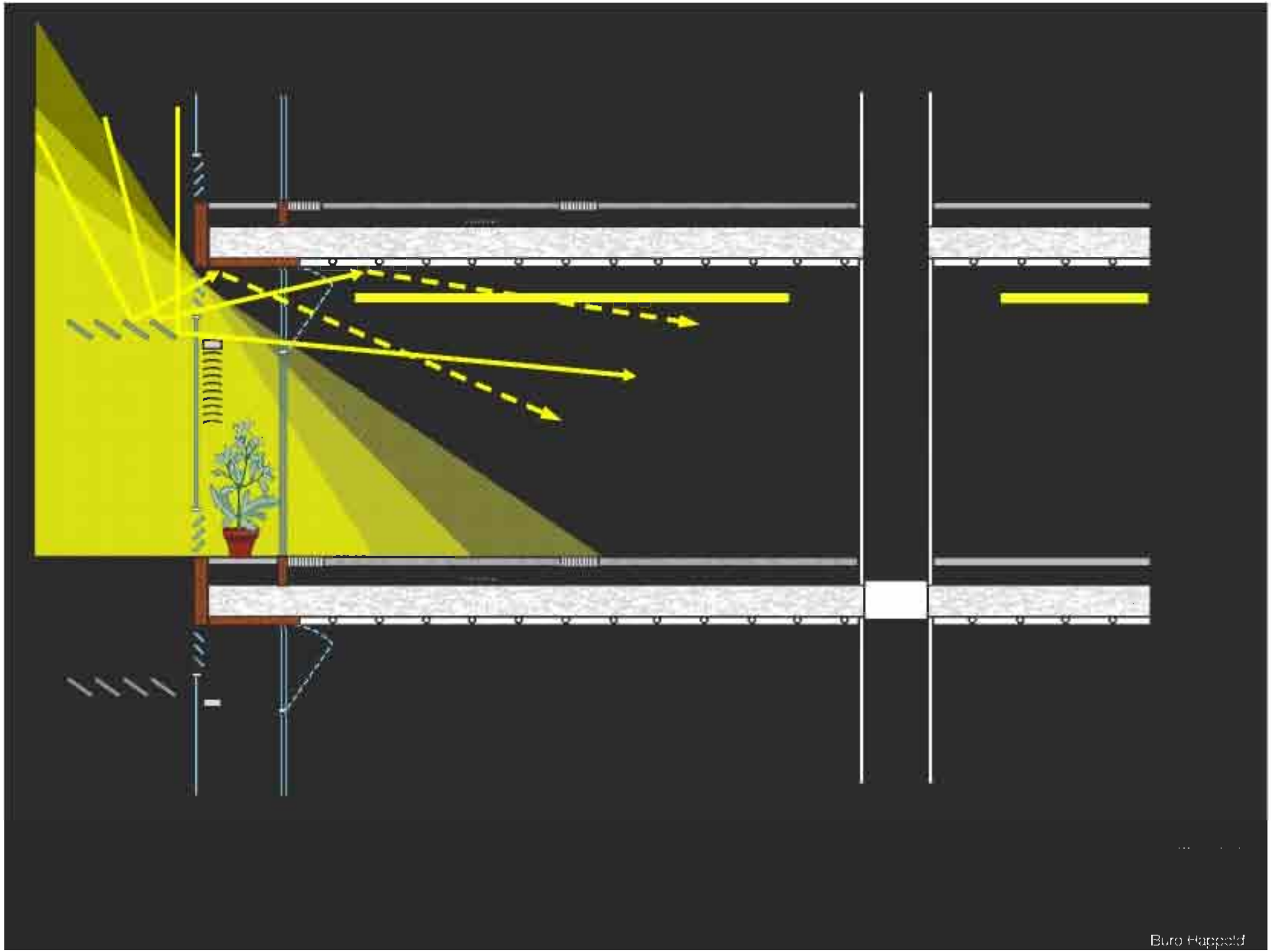
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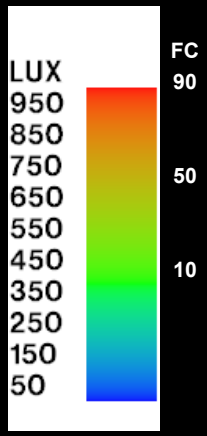
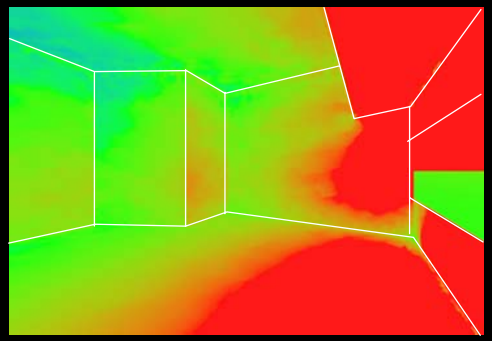
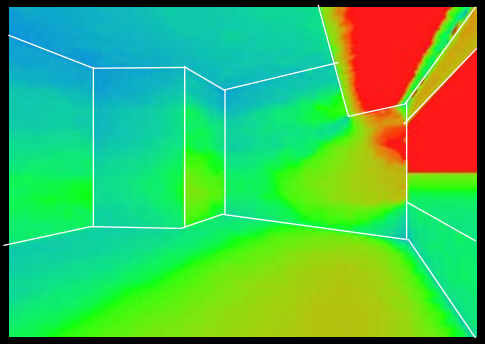


NW Room with light shelf

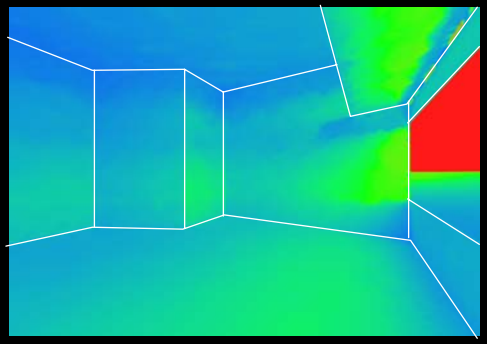
June 21 @ 14:00

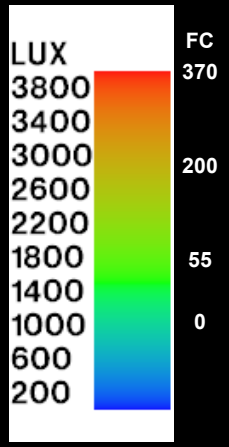


March 21 @ 14:00

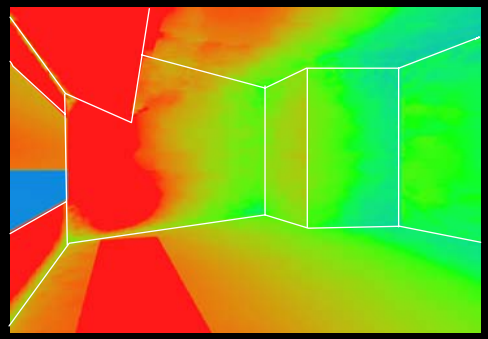


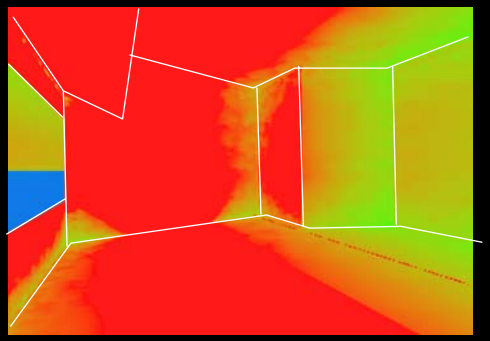
Dec 21 @ 14:00

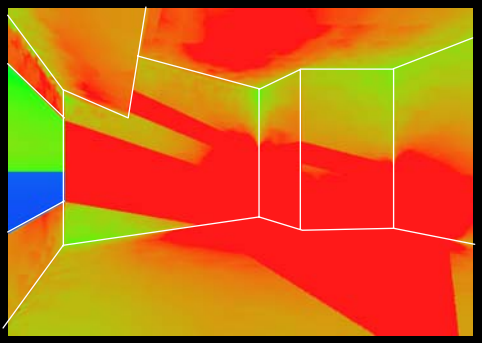




SW Room with light shelf







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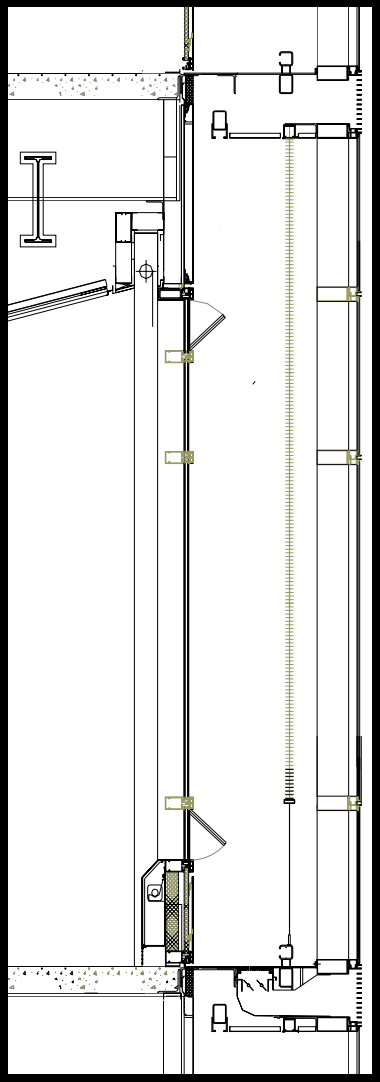

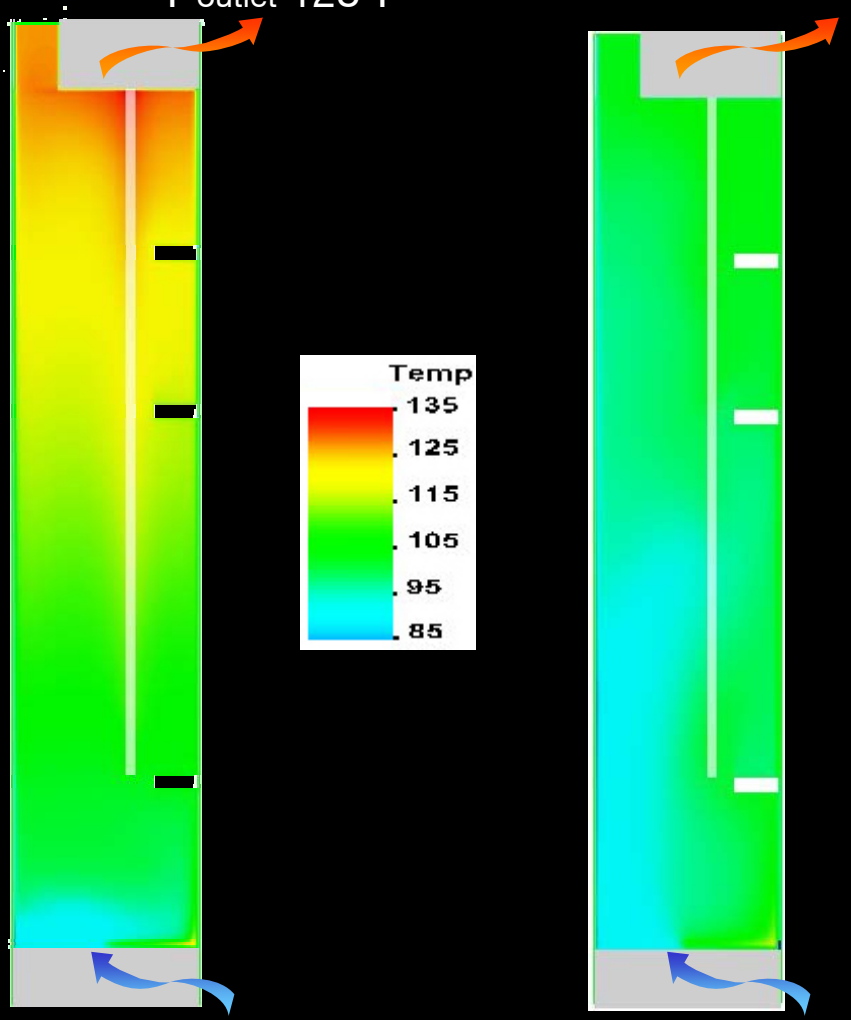

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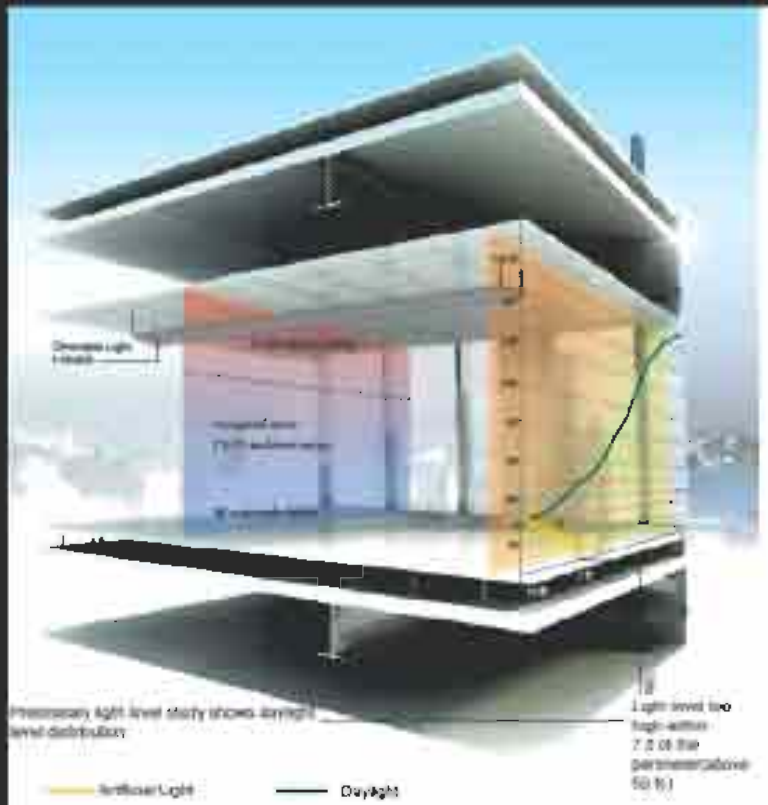


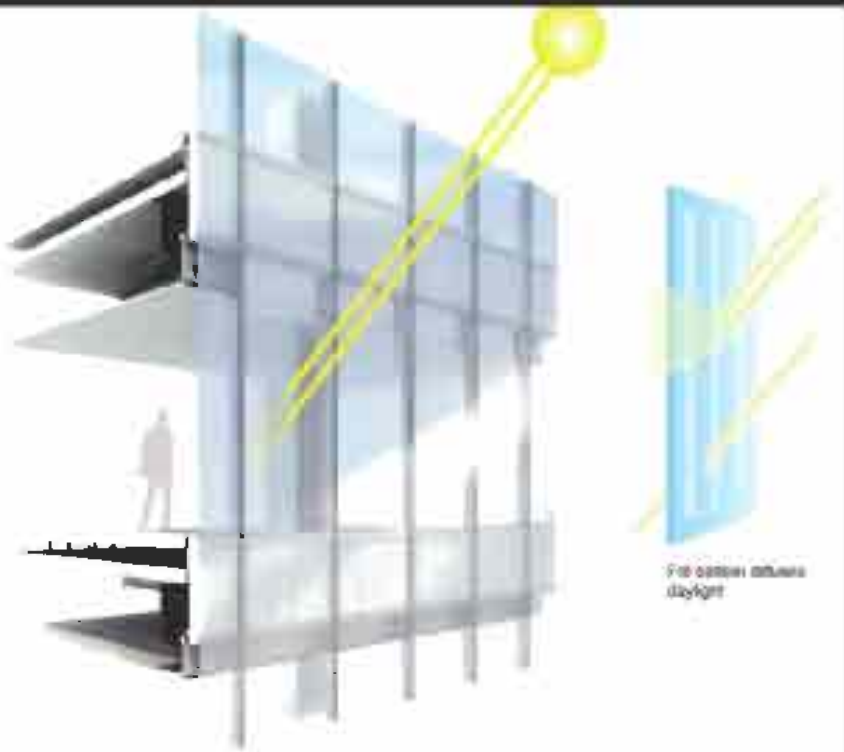
Photorealistic light level study shows daylight level distribution

Light level two foot within 7.5 of the perimeter(above 50 fc)

Artificial Light — Daylight

To maximize flexibility of floor layout a raised floor a plenum with and underfloor air distribution system. The height of each floor allows hvf air to rise above the occupied zone and assist in the distribution of daylight through the space

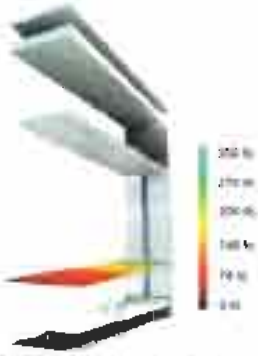
Raised floor system – Flexibility – Adaptability – Livability



Fritt pattern diffuses daylight

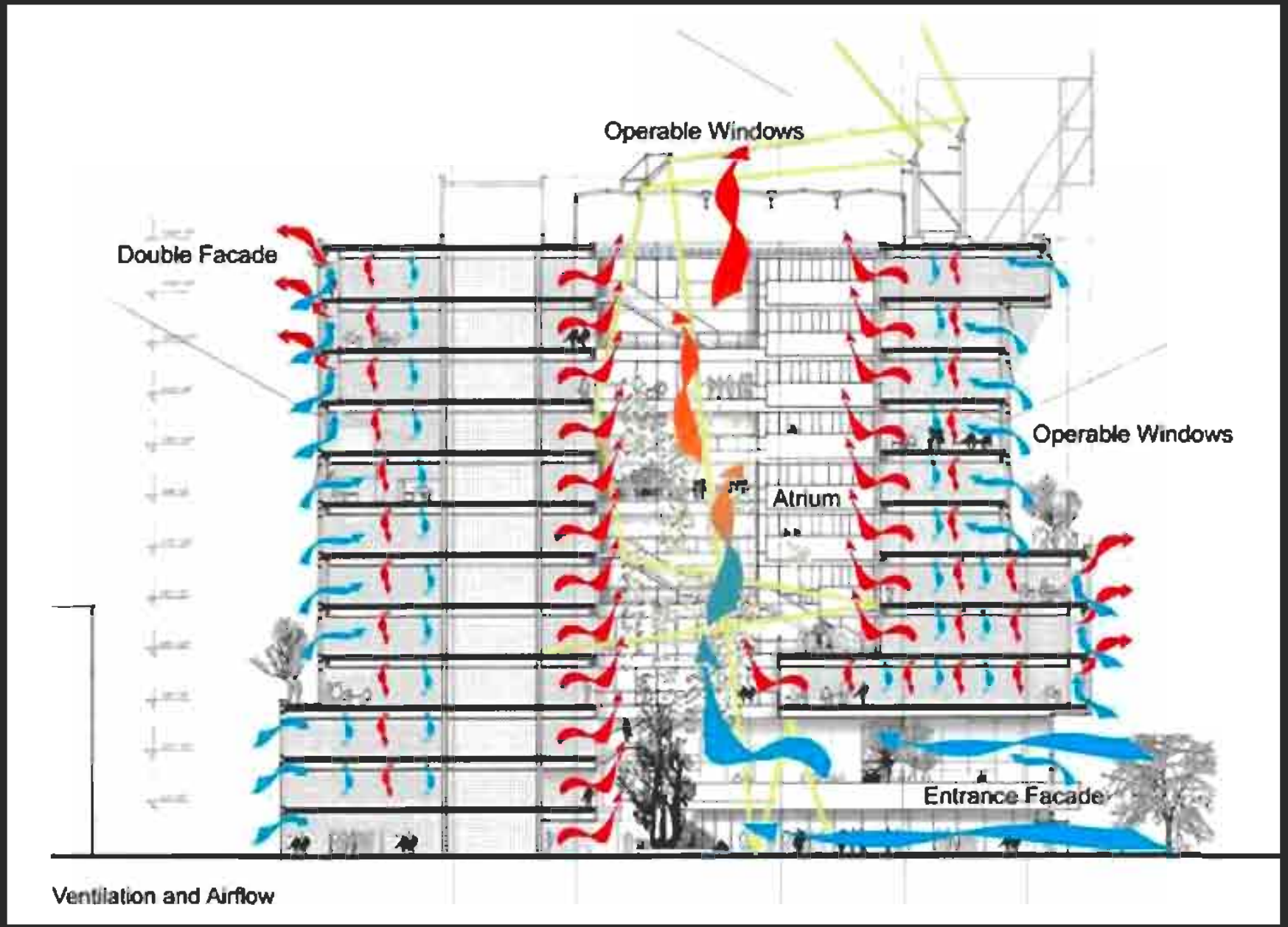
The glass selection for the façade has been balanced between daylight requirements, solar gain from the sun, and conductive loss through the glass unit. The resulting design employs a frit pattern to reduce glare, distribute daylight and moderate thermal loads

Under Floor air supply



Daylight Level at desk height

Reduced Solar Gain

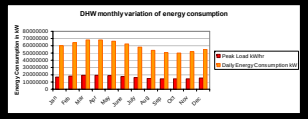


Ventilation and Airflow

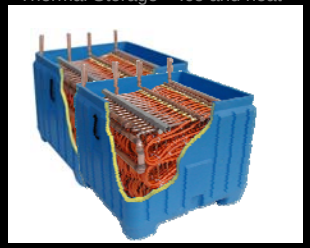
Solar collection

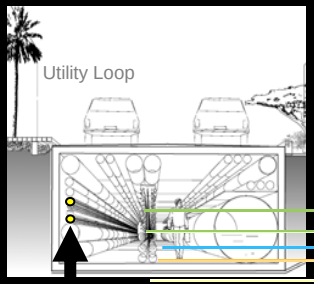
Absorption Chillers

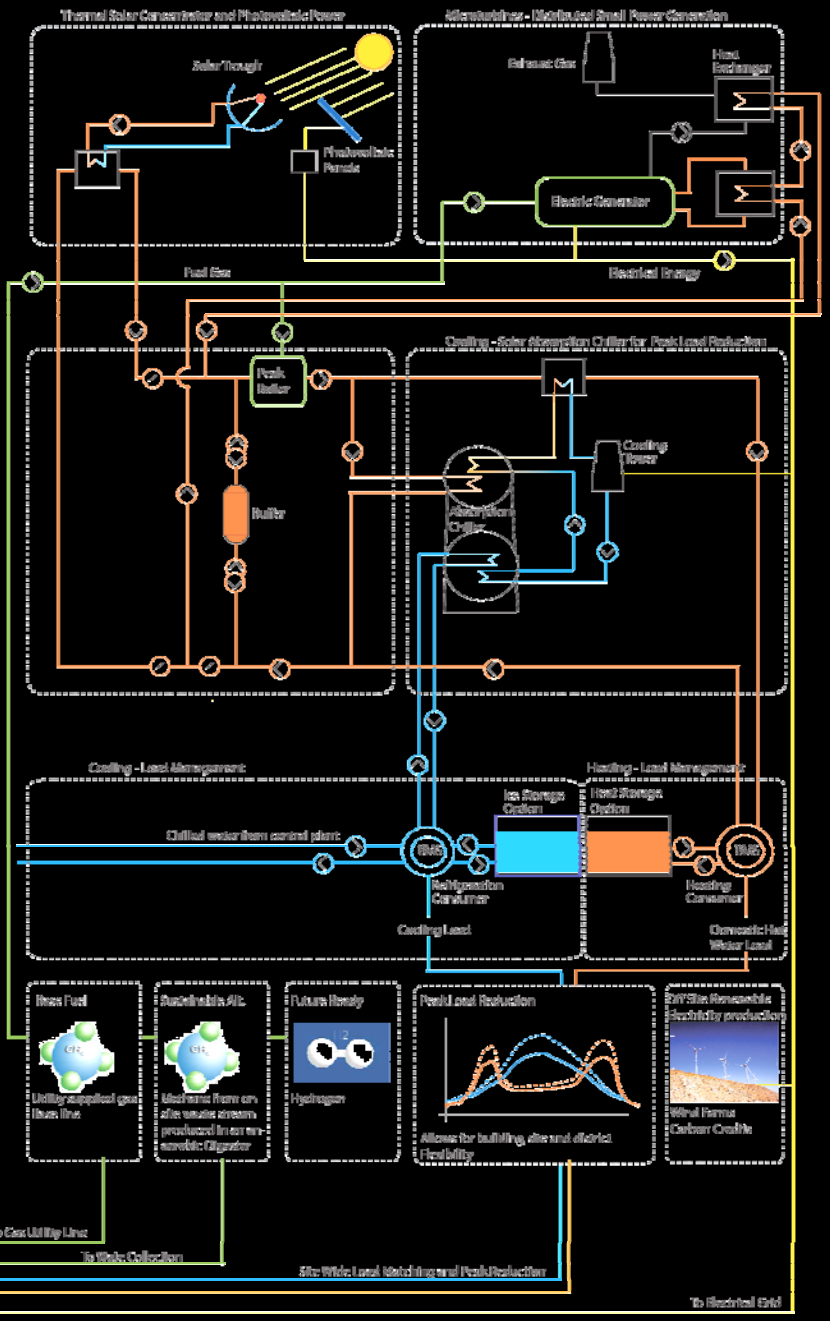
Hot Water Load



Thermal Storage – Ice and heat







The schematic design shown here illustrates the intent of the environmental hub. Any of a number of different types of systems can be added as a module to the environmental hub to maximize the efficiency of the system as whole. Smaller modules can be added to the central plant to reduce peak load or reclaim waste heat to be stored and used later in the day. Future technologies can be integrated into the system as they come on line.

power circuit

Utility Loop

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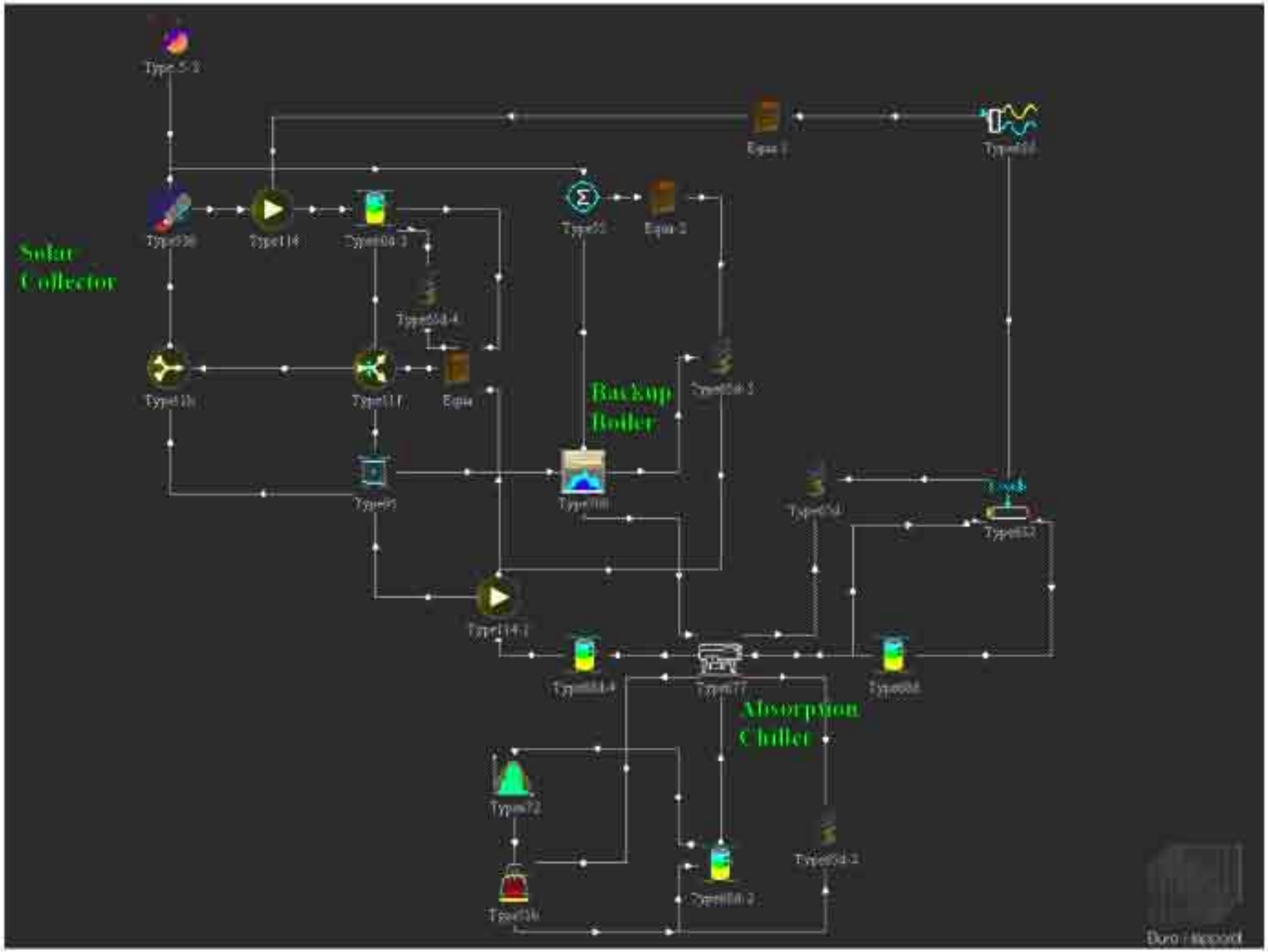
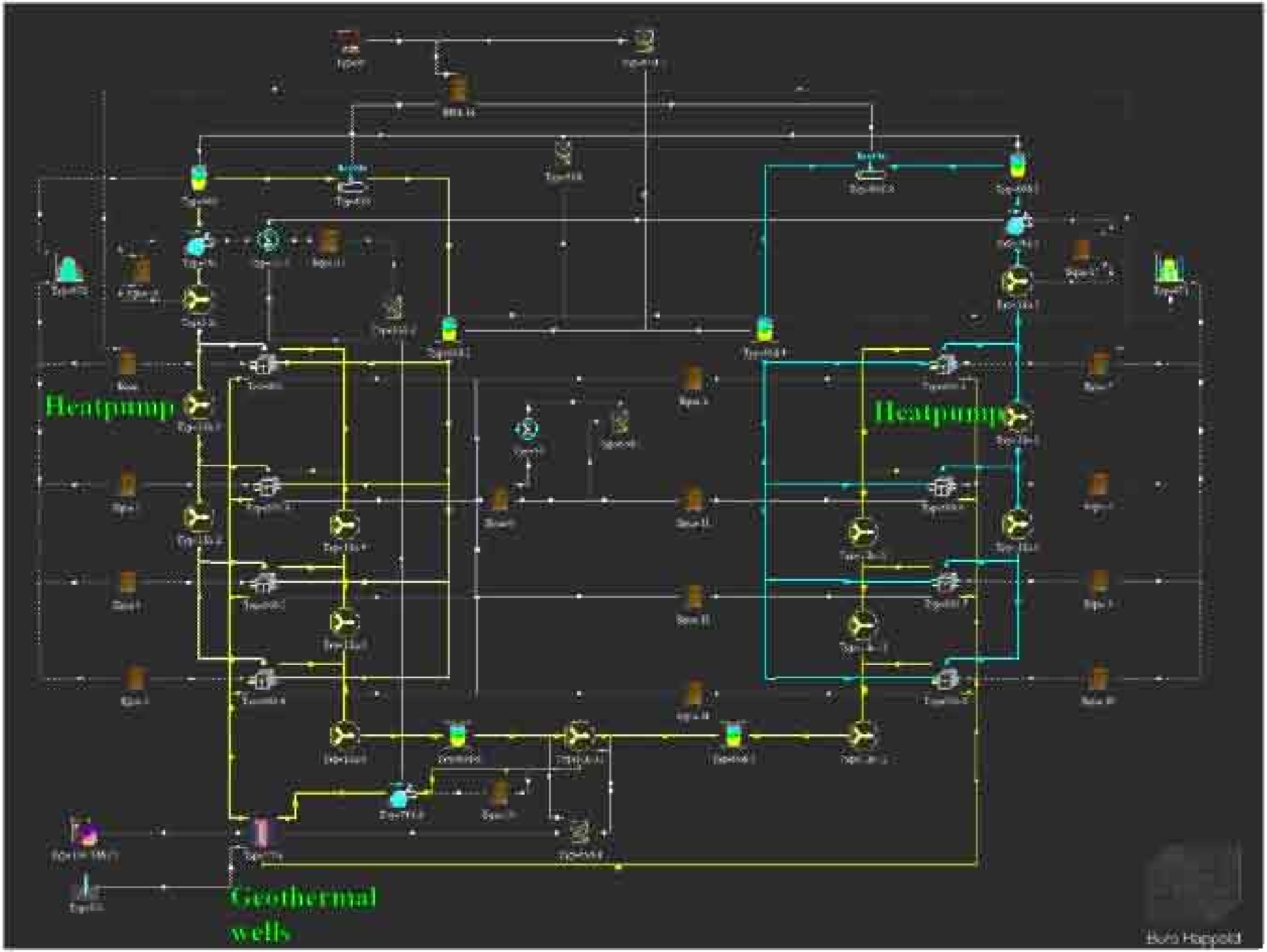
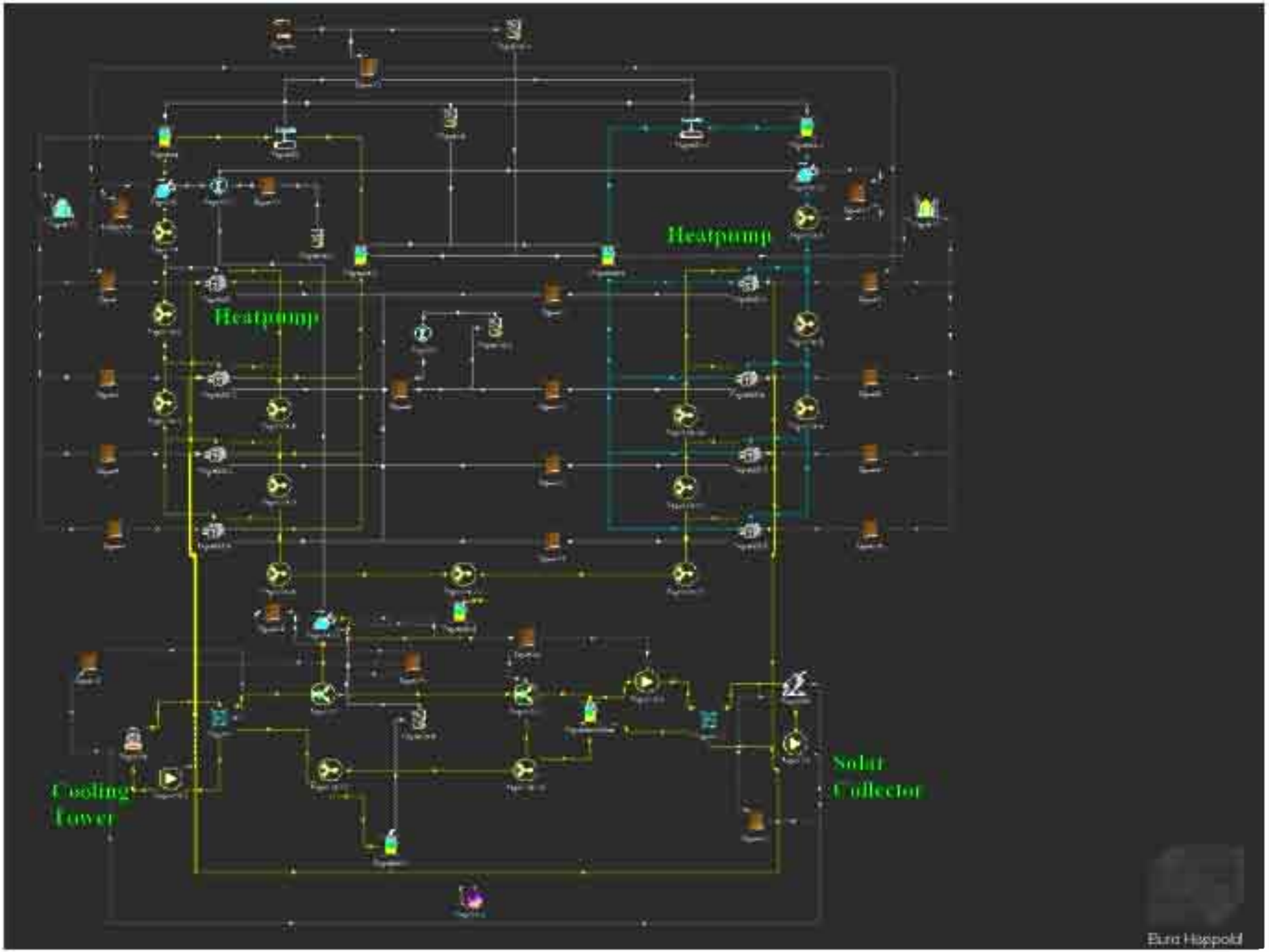
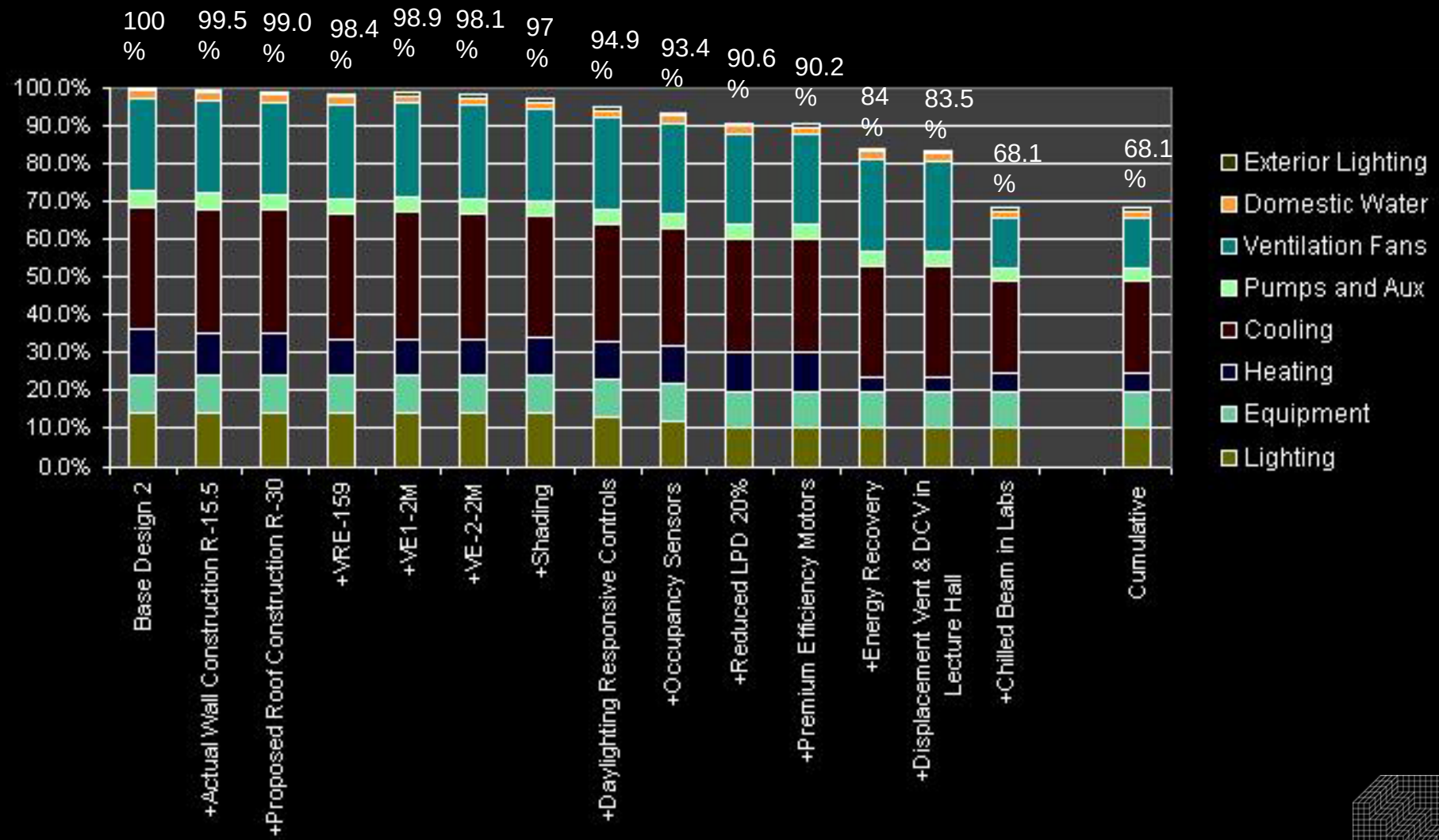

Solar
Collector
Backup
Boiler
Absorption
Chiller


Heatpump
Heatpump
Geothermal
wells


Heatpump
Heatpump
Cooling Tower
Solar Collector
Euro Hotpoint

LEED 2.2 Energy and Atmosphere Credit 1 and ASHRAE 90.1

EA Credit 1 – Optimize Energy Performance



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LEED 2.2 Energy and Atmosphere Credit 1 and ASHRAE 90.1

EA Credit 1 – Optimize Energy Performance

Performance Rating Method Compliance Report

Baseline Building Energy Summary by End Use

End Use	Process?	Energy Type	0° rotation		90° rotation		180° rotation		270° rotation		Average		
			Energy [10^6 Btu]	Peak [10^6 Btuh]	Energy [10^6 Btu]	Peak [10^6 Btuh]	Energy [10^6 Btu]	Peak [10^6 Btuh]	Energy [10^6 Btu]	Peak [10^6 Btuh]	Energy [10^6 Btu]	Peak [10^6 Btuh]	Cost [$/yr]
Interior Lighting		Electricity	1,137.2	418.7	1,137.2	418.7	1,137.2	418.7	1,137.2	418.7	1,137.2	418.7	$31,990
Interior Lighting (Process)	X	Electricity											$0
Exterior Lighting		Electricity	54.4	17.1	54.4	17.1	54.4	17.1	54.4	17.1	54.4	17.1	$1,531
Space Heating (fuel 1)		Natural Gas	515.8	2,300.0	525.6	2,300.0	486.7	2,300.0	494.3	2,300.0	505.6	2,300.0	$4,916
Space Heating (fuel 2)		Electricity											$0
Space Cooling		Electricity	1,299.4	836.8	1,308.9	843.8	1,298.1	815.7	1,310.3	812.3	1,304.2	827.1	$36,687
Pumps		Electricity	3.2	3.1	3.3	3.1	2.9	3.1	2.9	3.1	3.1	3.1	$86
Heat Rejection		Electricity											$0
Fans - Interior		Electricity	222.5	106.9	228.1	108.6	223.8	106.8	223.5	106.5	224.5	107.2	$6,315
Fans - Parking Garage		Electricity											$0
Service Water Heating (fuel 1)		Natural Gas	57.3	10.4	57.3	10.4	57.3	10.4	57.3	10.4	57.3	10.4	$557
Service Water Heating (fuel 2)		Electricity											$0
Receptacle Equipment	X	Electricity	1,040.7	273.0	1,040.7	273.0	1,040.7	273.0	1,040.7	273.0	1,040.7	273.0	$29,276
Refrigeration (food, etc.)	X	Electricity											$0
Cooking (commercial, fuel 1)	X	Electricity											$0
Cooking (commercial, fuel 2)	X	Electricity											$0
Elevators and Escalators	X	Electricity	16.7	17.1	16.7	17.1	16.7	17.1	16.7	17.1	16.7	17.1	$470
Other Process	X	Electricity	28.9	7.8	28.9	7.8	28.9	7.8	28.9	7.8	28.9	7.8	$813
Total Building Consumption/Demand			4,376.1	3,990.9	4,401.2	3,999.6	4,346.7	3,969.7	4,366.3	3,965.9	4,372.6	3,981.5	$112,641
Total Process Energy			1,086.3	297.9	1,086.3	297.9	1,086.3	297.9	1,086.3	297.9	1,086.3	297.9	$30,559

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LEED 2.2 Energy and Atmosphere Credit 1 and ASHRAE 90.1

EA Credit 1 – Optimize Energy Performance

Performance Rating Method Compliance Report

Baseline Building Energy Cost and Consumption by Fuel Type

Energy Type	0° rotation		90° rotation		180° rotation		270° rotation		Average	
	Energy Consumption [10^3 Btu]	Energy Cost [$/Yr]	Energy Consumption [10^3 Btu]	Energy Cost [$/Yr]	Energy Consumption [10^3 Btu]	Energy Cost [$/Yr]	Energy Consumption [10^3 Btu]	Energy Cost [$/Yr]	Energy Consumption [10^3 Btu]	Energy Cost [$/Yr]
Electricity	3,803.0	$107,174	3,818.3	$107.398	3,802.7	$107,021	3,814.7	$107,079	3,809.7	$107,168
Natural Gas	573.1	$5,563	582.9	$5,650	544.0	$5,305	551.6	$5,373	562.9	$5,473
Steam/Hot Water										
Other										
Total	4,376.1	$112,737	4,401.2	$113,048	4,346.7	$112,326	4,366.3	$112,452	4,372.6	$112,641

The process energy cost is 27% of the Baseline Building Performance. This meets the requirements of LEED EAc1.

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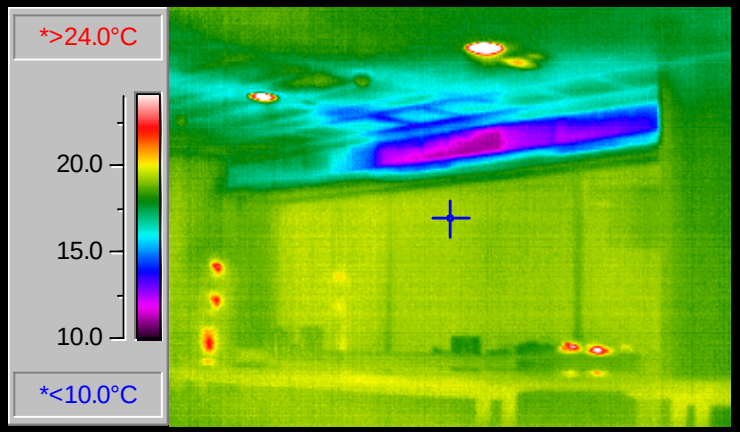
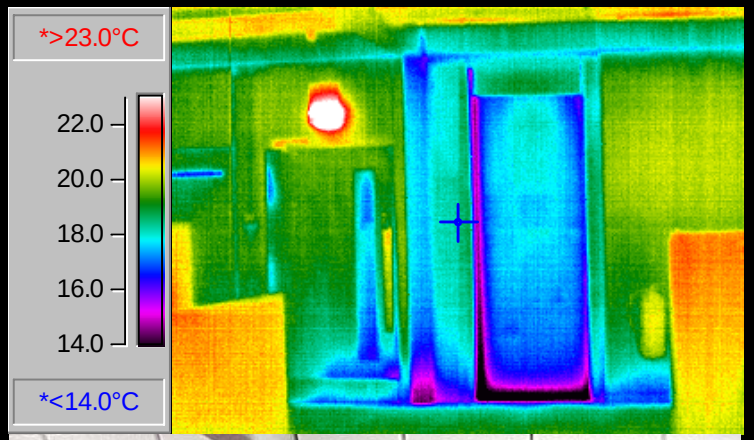
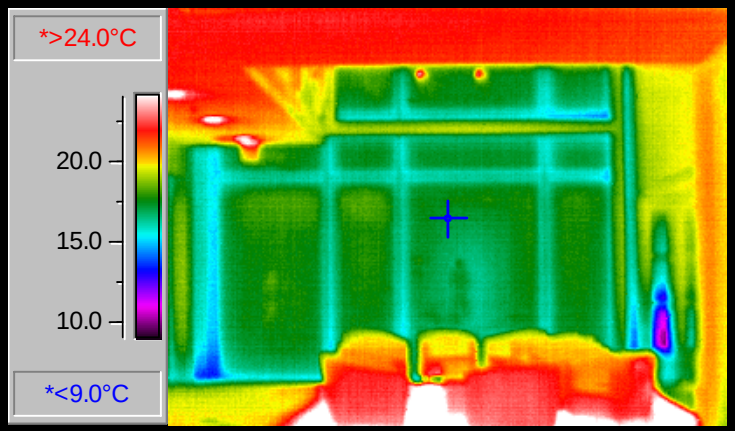
Post occupancy







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Post occupancy

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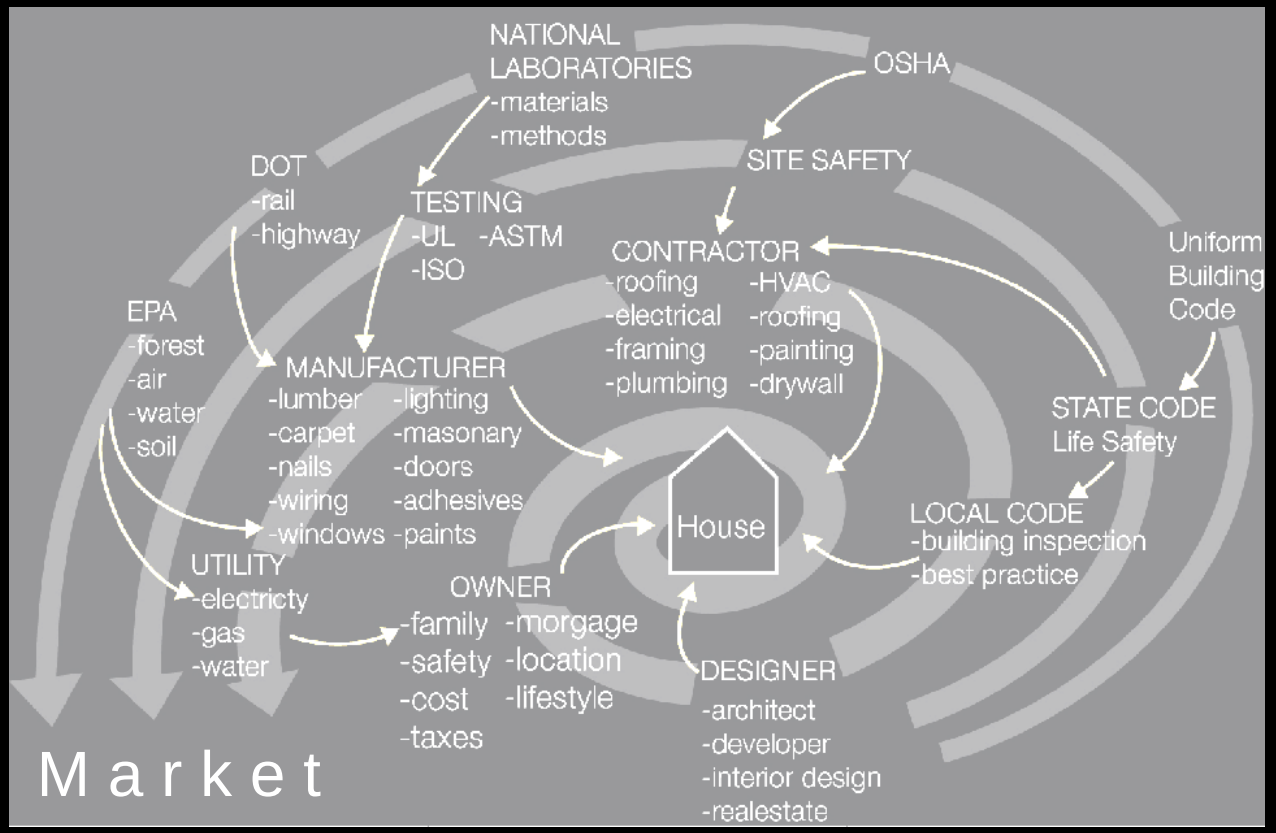
Market Process

Market Diagram

- Owner
- Designer
- Code
- Contractor
- Manufacturer
- Testing
- Research
- Safety



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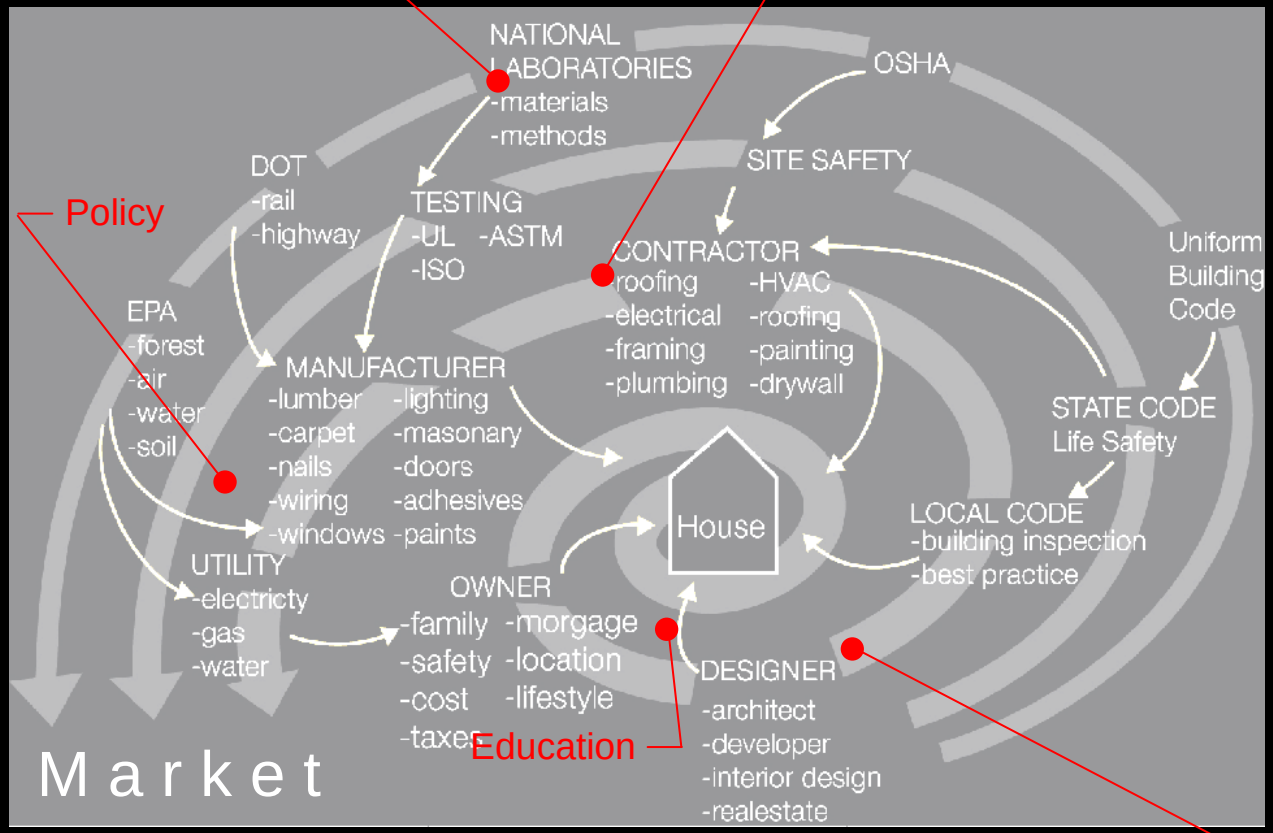
Market Process

- Insertion Points
  - Education
  - CAD/BIM Software
  - POM and Commissioning
  - Research
  - Policy



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Integrated Process

Goals

Owner

Value
Safety
Comfort

C2C goals - Demonstrate and educate ways to reduce environmental impact while maintaining value, safety, and comfort

Designer

Education
Information
Communication

C2C goals - Streamline data flows by integrating existing systems through common interfaces between building industry parties.

Fabricator

Quality Control
Material Tracking
Communication

C2C goals - Provide an example of a streamlined process that improves quality while reducing waste and environmental impact

Code

Protection
Enforcement
Accountability

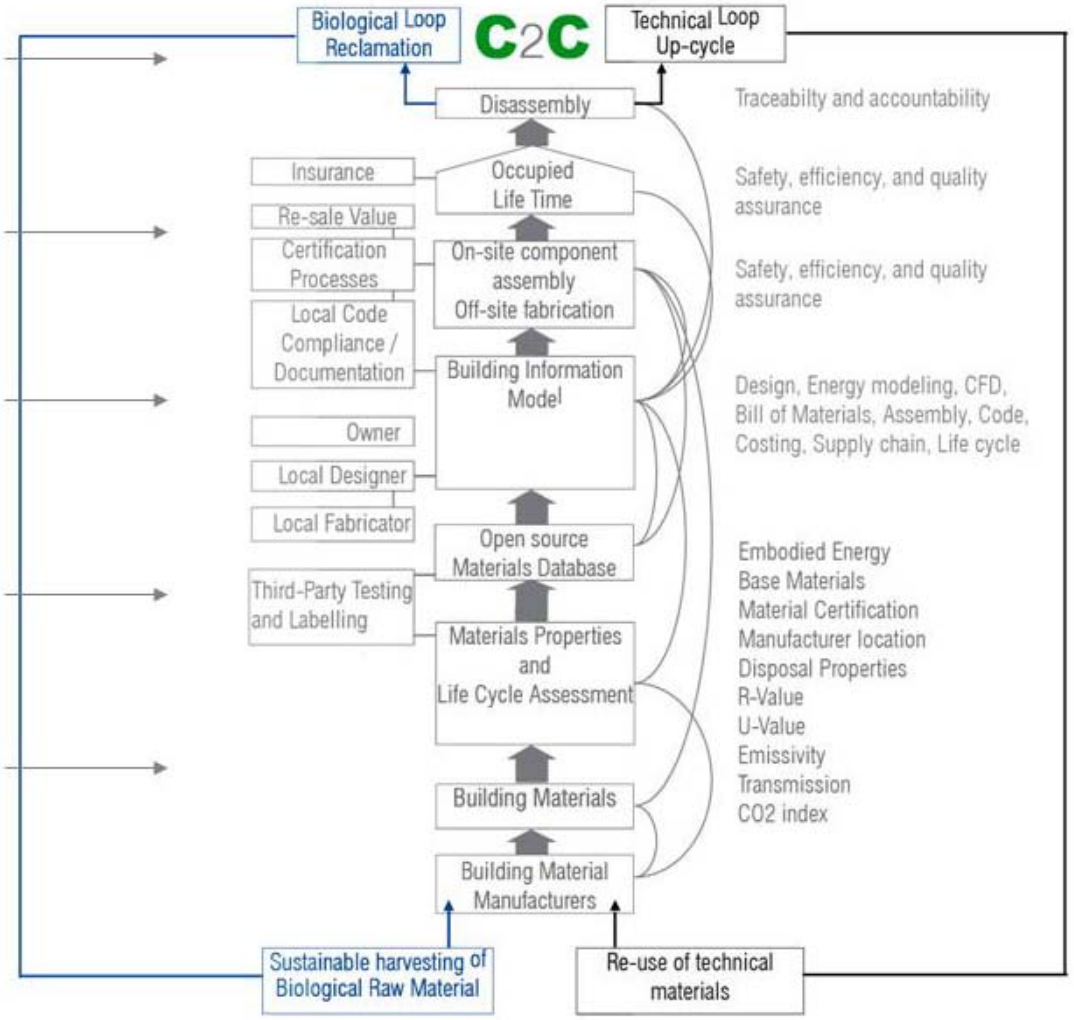
C2C goals - Demonstrate and educate areas where future building codes can be easily modified to raise industry sustainability and reduce environmental impact.

Manufacturer

Marketability
Liability
Supply Chain

C2C goals = Demonstrate standardized method for tracking and validating product performance during life cycle

Design Process



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