UNIVERSITÀ DEGLI STUDI FIRENZE
Scuola di Architettura

MULTIMEDIA | ARCHITECTURE | INTERACTION

MASS MODELING AND ENERGY SIMULATION FOR GREEN BUILDING USING REVIT

prof. arch. Giuseppe Ridolfi PhD

WHAT ARE:

- MASS MODELING
- ENERGY SIMULATION
- GREEN BUILDING
- REVIT

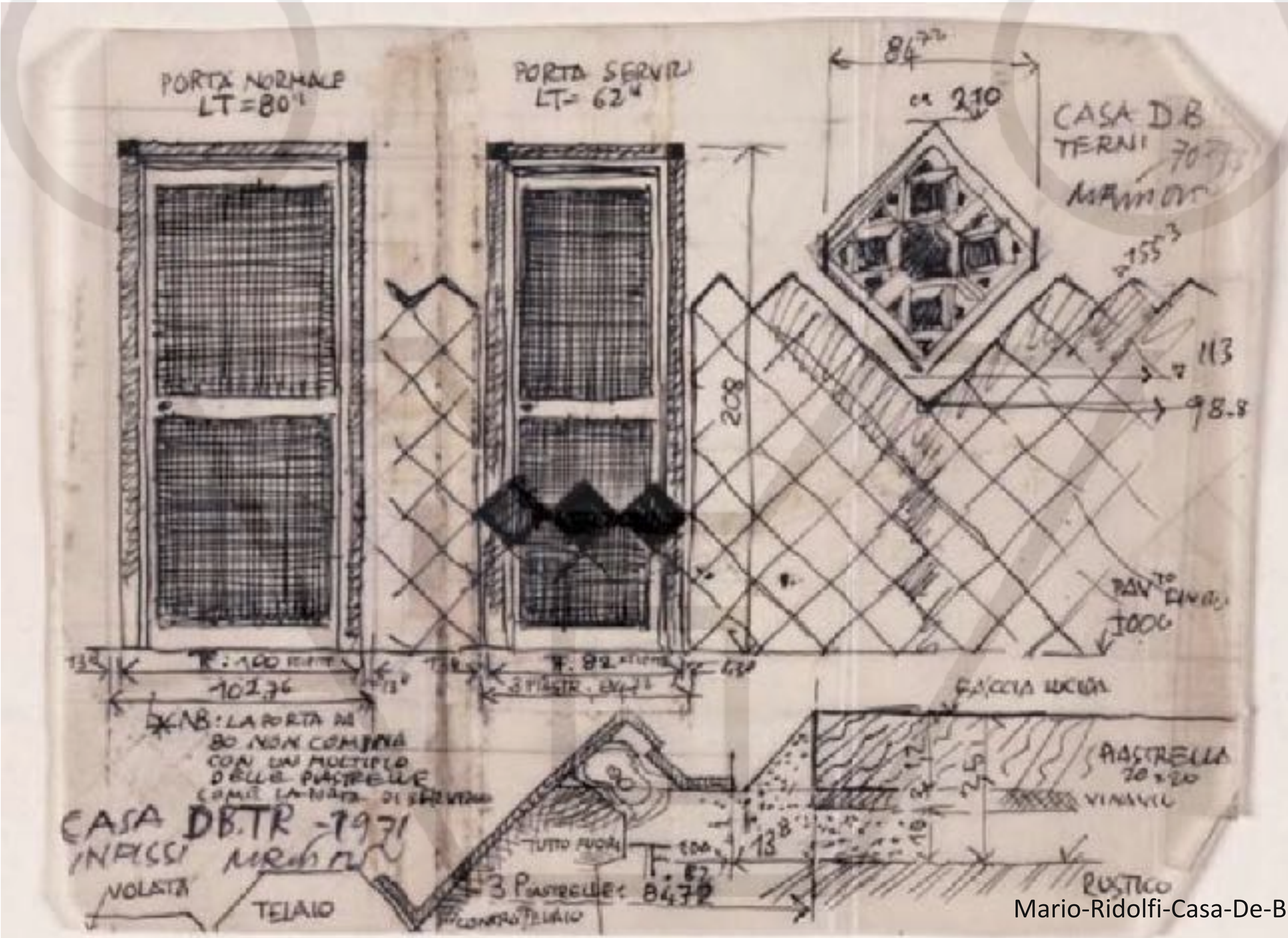
WHAT IS MODELING

SKETCHING • DRAWING • DRAFTING • MODELING

SKETCHING

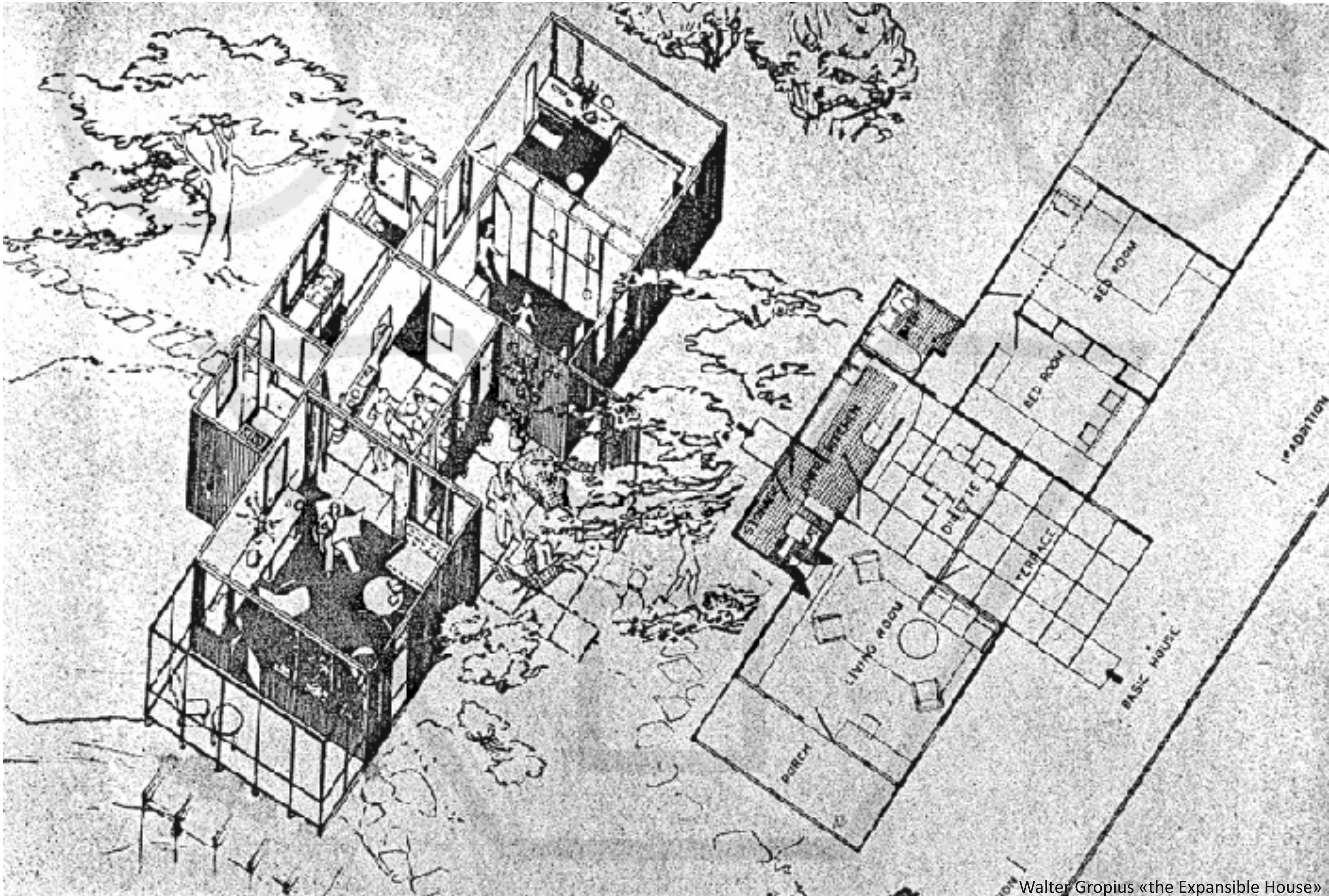
Van Gogh's Studies

DRAWING



Mario-Ridolfi-Casa-De-Bon

DRAFTING



Walter Gropius «the Expansible House»

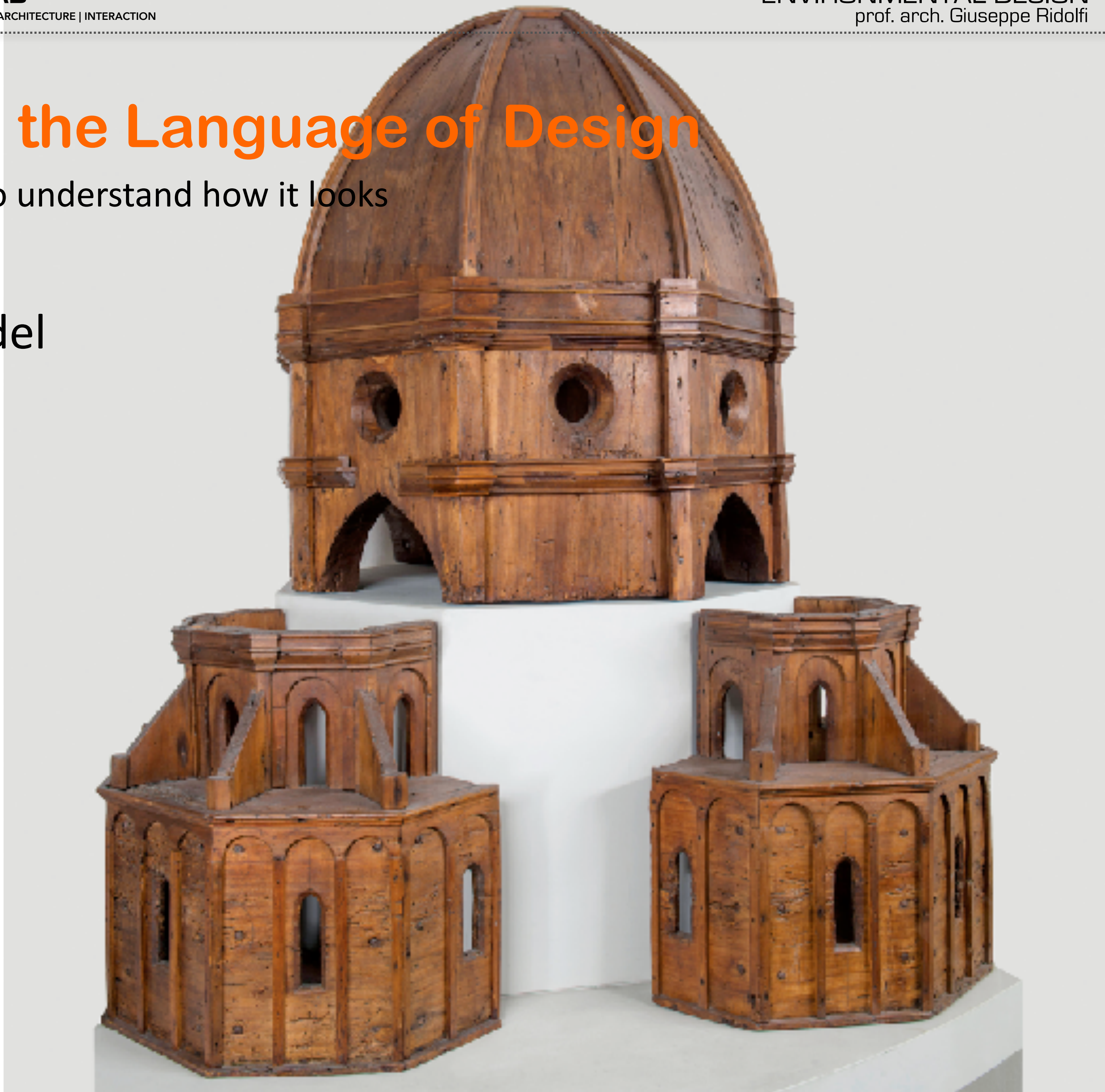
MODELING: the Language of Design

"Design is not just what it looks like and feels like. Design is how it works."

S. Jobs (1955-2011)

MODELING: the Language of Design

Simulation in order to understand how it looks



Morfological Model

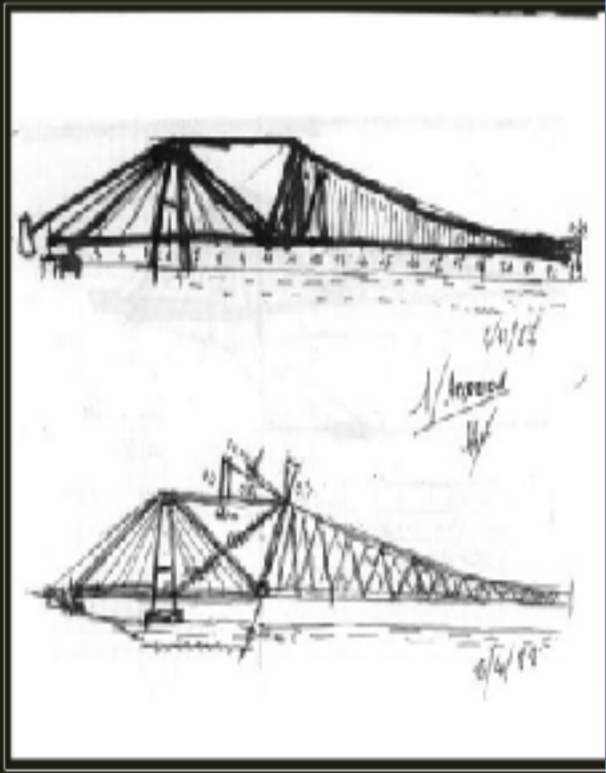
Filippo Brunelleschi, Modello ligneo Cupola del Duomo, 1420-1440 circa, Firenze, Museo dell'Opera di Santa Maria del Fiore – Firenze, Museo dell'Opera di Santa Maria del Fiore. Fotografia di Antonio Quattrone

MODELING: the Language of Design

Simulation in order to understand how it works

Leonardo da Vinci. Anatomical drawings (around 1510)

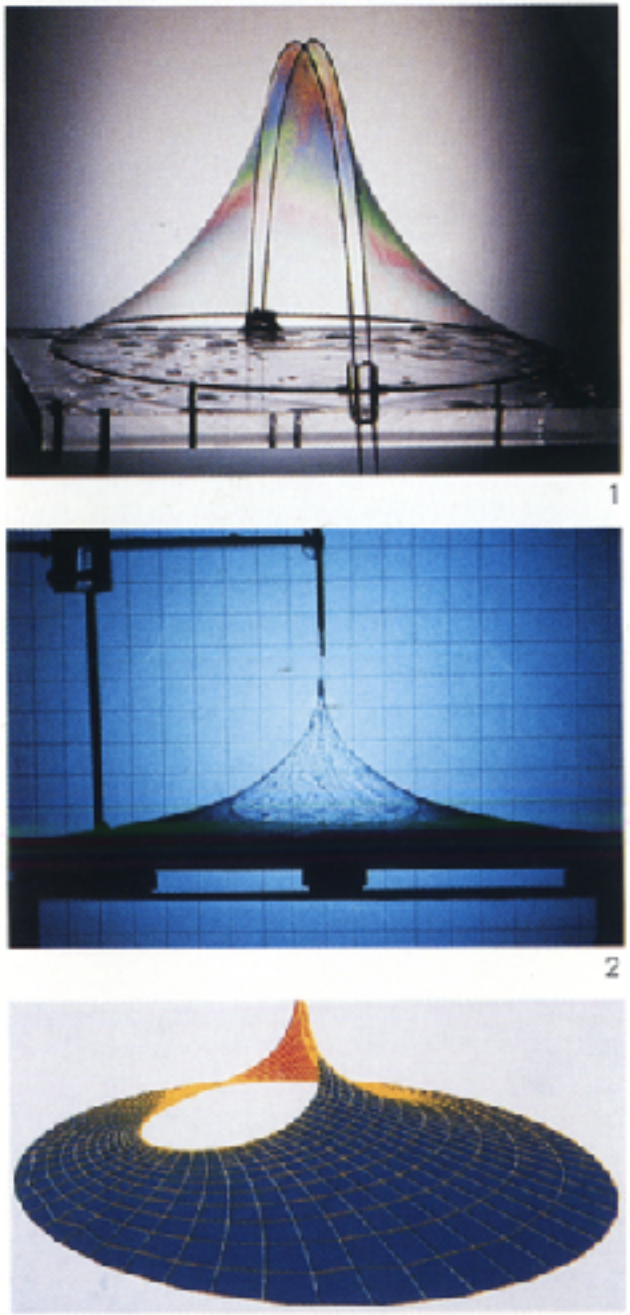
R. Mark. Force visualization on Gothic Cathedral usign polarized light and plexliglass ('70s)



Riccardo Morandi. Bridge studies (1987/89)

VISUALIZING MATTER

Functionality and Performance Design



Frey Otto's studies & researches

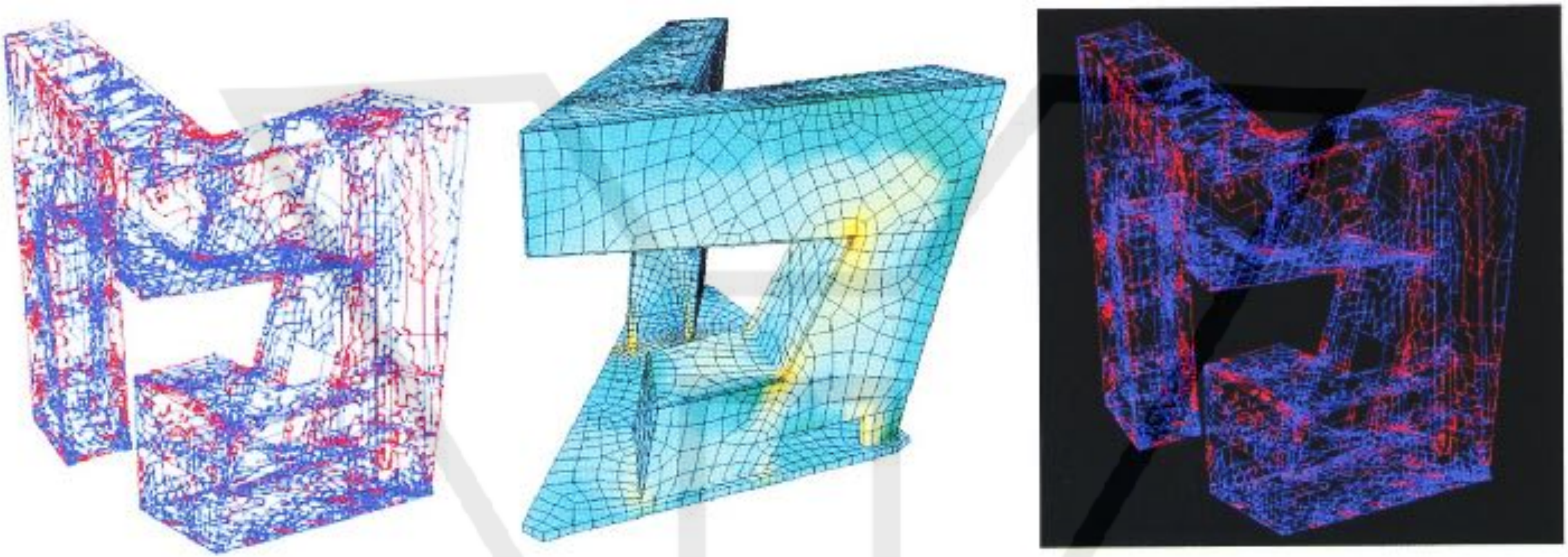
1 Soap film model of an arch-supported membrane.

2 Soap-film model of a membrane surface with rope loop as its high point.

3 Computer simulation of a minimal surface with rope loop.

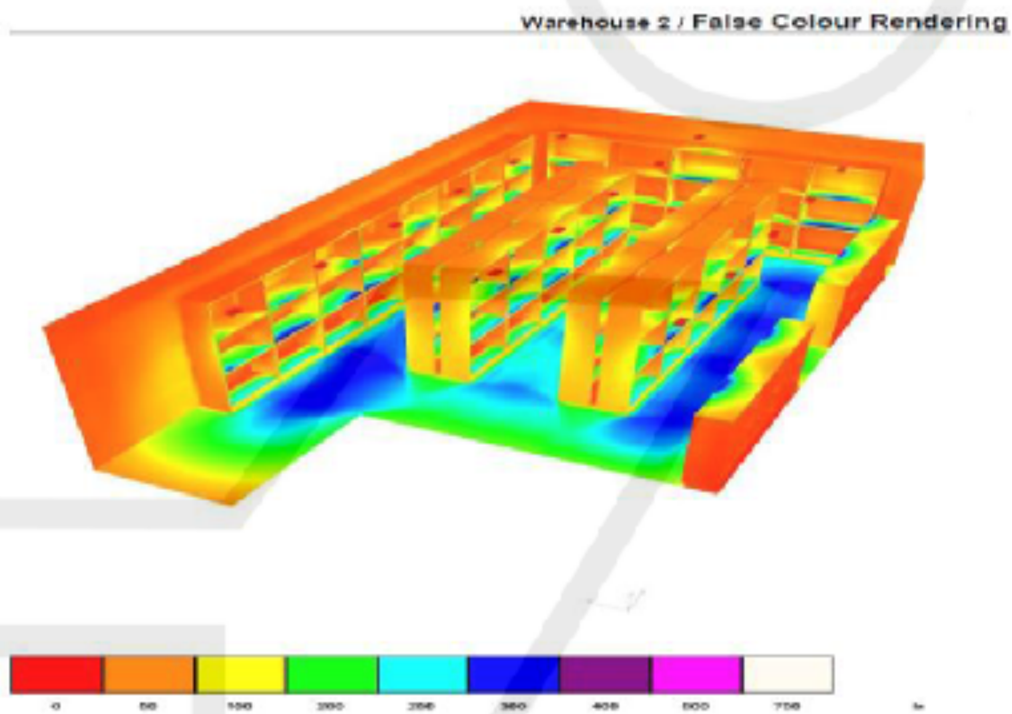
DIAGRAM:
THE ABSTRACT MACHINE

..a map of relations between forces”
Deleuze, A Thousand Plateaus (1988)



AKT, South Bank Pavilion (Zaha Hadid). Load paths. © Adams Kara Taylor (AKT).

"... digital tools give us an holistic and visual perception of fenomena in order to have a faster comprehension of a large quantity of aspects"
G.Ridolfi



What if ?

Designing as a scientific process

Reading Text: Learning Design Through Designerly Thinking. Holistic digital modeling in a graduate program in architecture.
https://www.mailab.biz/designerly/

defining the final solution through the evaluation of alternatives

OPTIONEERING

The race for the sky

Empire State Building

Designed by: Shreve, Lamb and Harmon

Facts:

102 storeys

381 m. tall

(443.2 m including the antenna)

20 months to open it

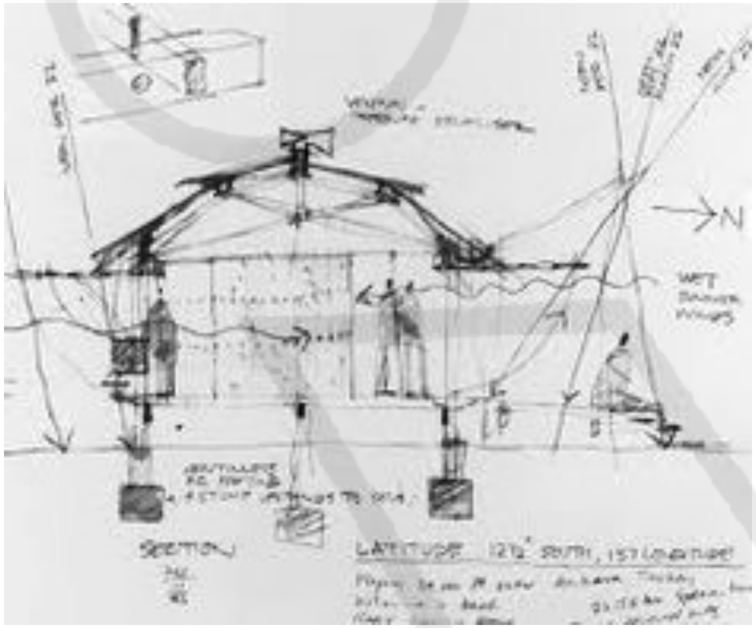
- Demolition of Waldorf Astoria Hotel
- Design
- Authorizations
- Financing
- Construction (1 year and 45 days)

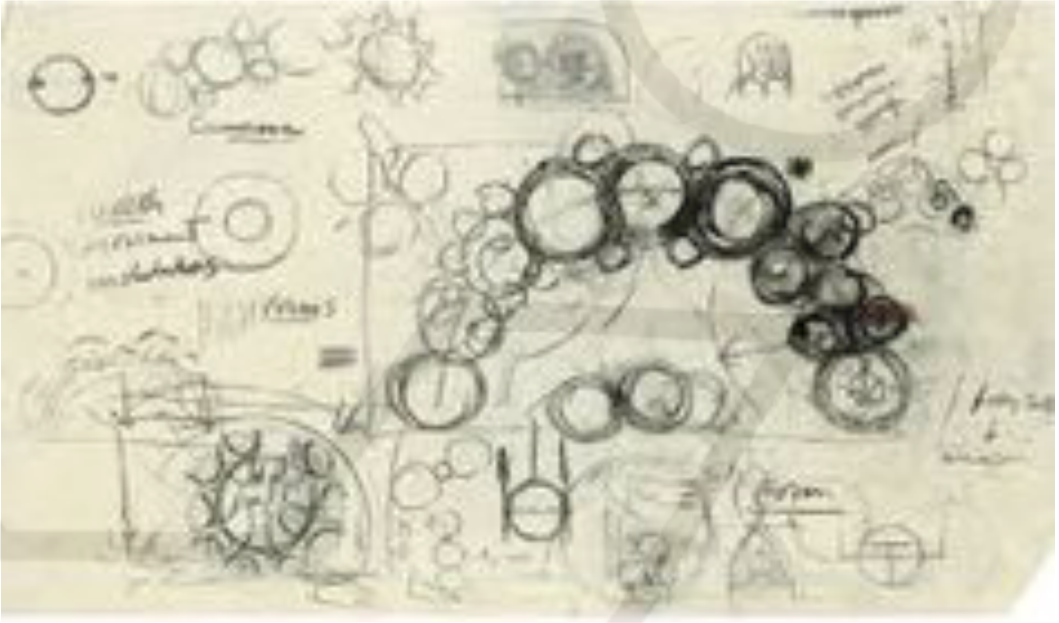
From Sep. the 16th to October the 3d, 1929
16 alternatives (2 by day) were delivered and compared.

The night of the last day the 17th solution (the Solution K) was approved

Modeling using Computational Design

TRADITIONAL APPROACH





louis kahn sketches

Decision-Making through:

-rules of thumb

-individual intuition

-experience & tacit knowledge

COMPUTATIONAL MODELING FOR SIMULATION

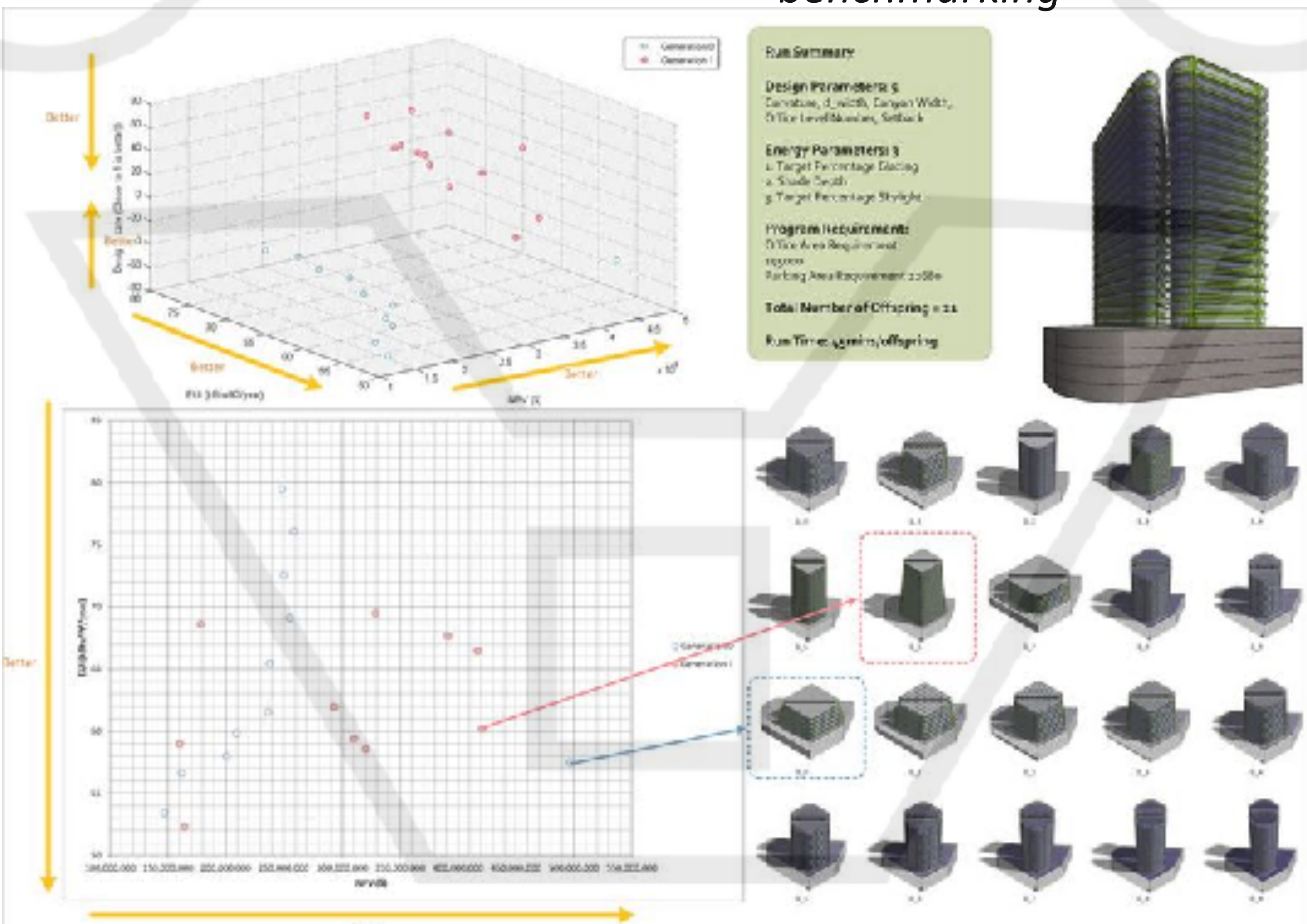
“ This process is similar to the scientific process, which involves asking questions, framing a solvable experiment to answer the question, testing, and intepreting the results” K. Andersonn

DIGITAL APPROACH

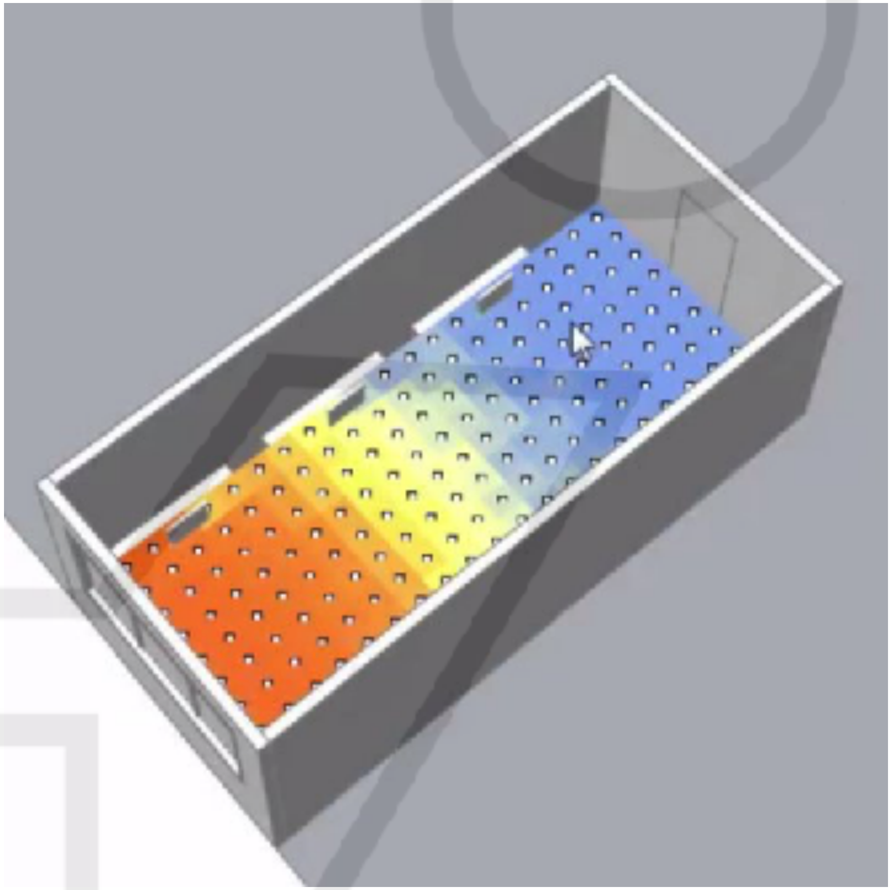
Computational Design as a scientific research

Decision-Making through:

- *formal procedures*
- *evidence-based observation*
- *benchmarking*

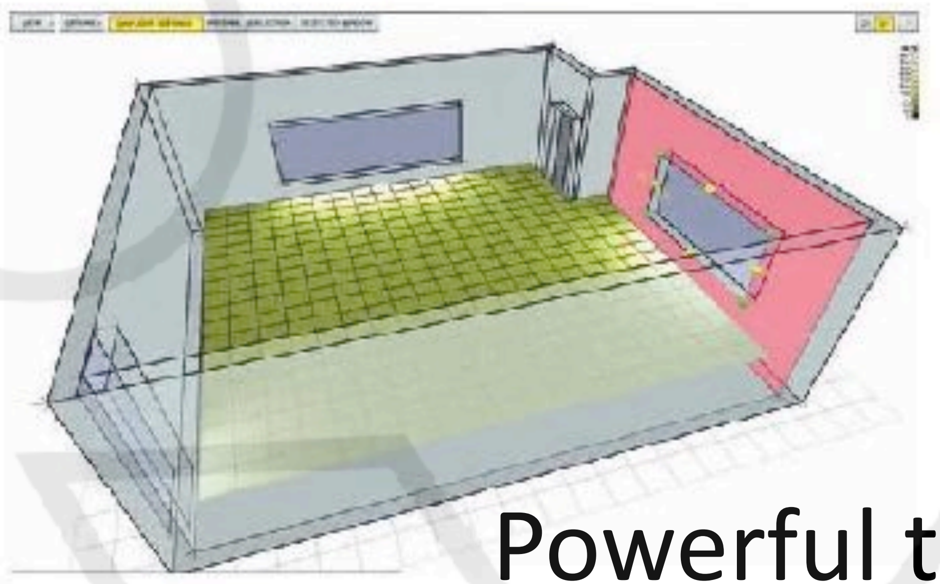


MODELING FOR SIMULATION NUMERICALLY PERFORMANCE BASED



features:

- precision
- objectivity
- replicability
- communicability

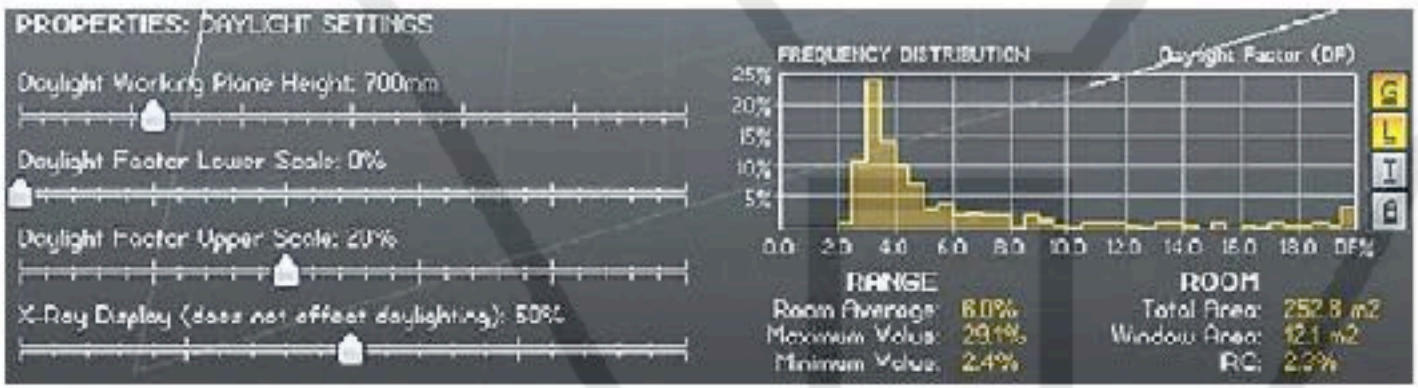


2.3 and 2.4

Andrew Marsh, creator of Ecotect, has been experimenting with real-time, on-line daylighting simulation. The room and windows can be adjusted to see real-time daylight factor results.

Source: Courtesy of Andrew Marsh. http://andrewmarsh.com/blog/2010/04/11/real-time-dynamic-daylighting.

Powerful tools for gamers



PLAYING OPTIONS AND UNDERSTANDING CAUSALITY

http://andrewmarsh.com

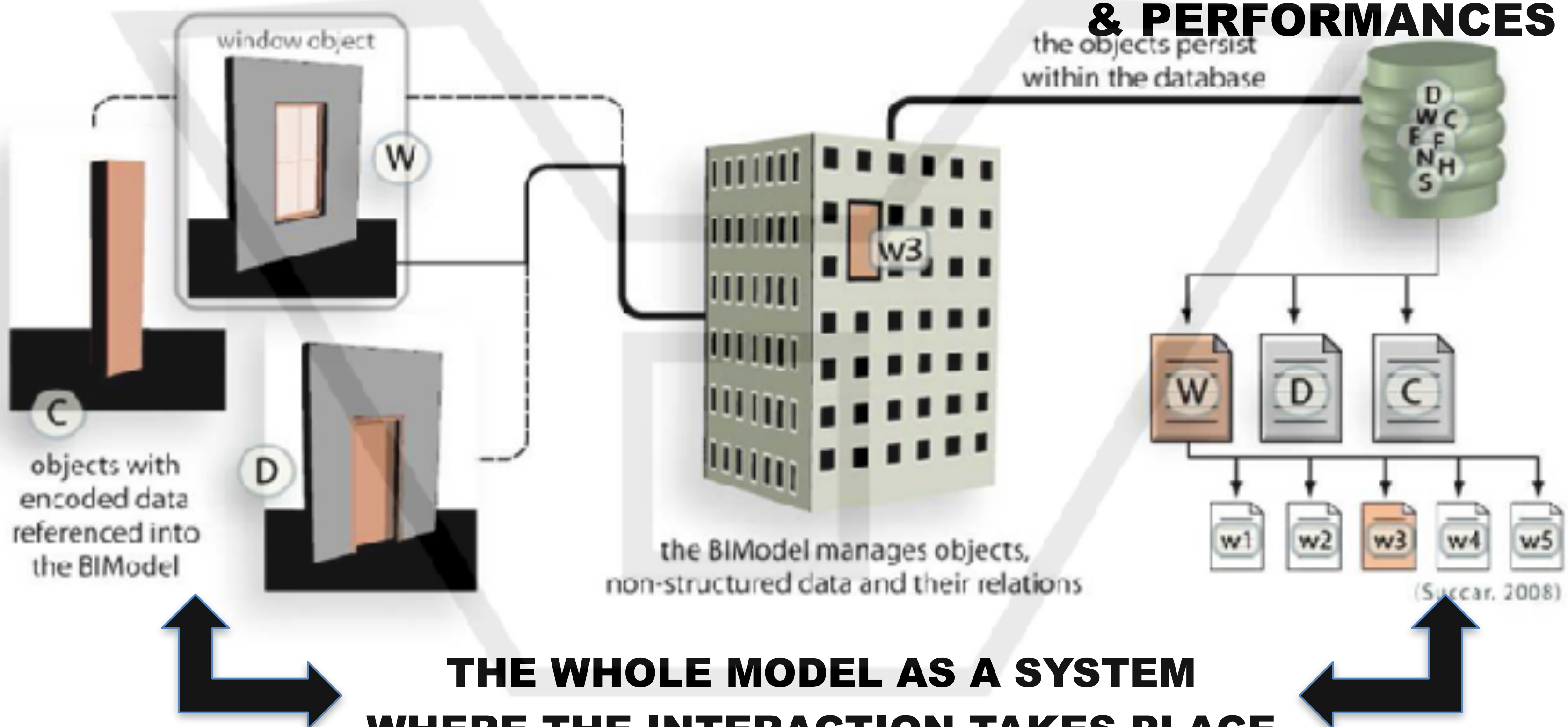
Parametric computation A procedure where the model is structured through constraints, parameters, instances and variables representing and affecting phenomenological attributes such as geometry, physical property, users behaviours,...

All these aspects can be modified dinamically and in an interrelated manner

BIM FOR INTEGRATED DELIVERY PROJECT

ELEMENTS / LIBRARIES

DATASET OF FACTS & PERFORMANCES



THE WHOLE MODEL AS A SYSTEM WHERE THE INTERACTION TAKES PLACE

Testing the trade-off in order to be aware of how configurations and elements can affect behaviours and produce differente results

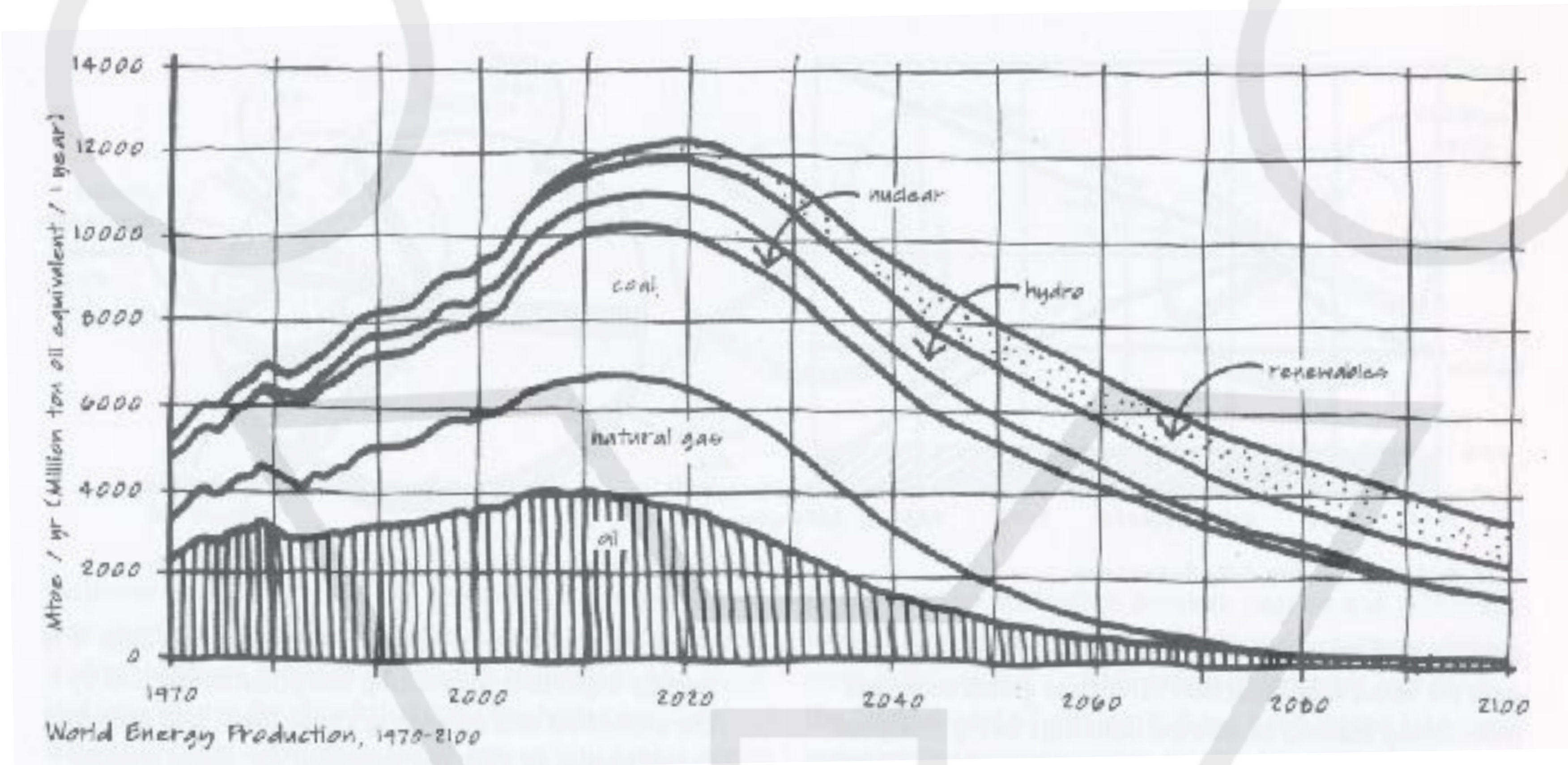
Testing the trade-off in order to be aware of how configurations and elements can affect behaviours and produce differente results

Digital Modeling give us ethical responsabilities of our choices based on evidence of proof

Ethical responsibility about us and the environment we live

Because the built environment and constructions are one of the largest factor that affect our living

Inside the US Construction, Buildings sector represents:
49% Energy consumption
77% Electricity consumption
47% Carbon Dioxide emission



For architects reducing impacts is a big ethical responsability

According *Architecture 2030 Program* in 2035
75% of building will be renovated or rebuilt

GREEN BUILDINGS

GREEN BUILDINGS

Building with nearly zero emission and consumption

HOW TO EVALUATE ENERGY PERFORMANCE

GREEN METRICS & CERTIFICATIONS

ZEPHIR

PASSIVHAUS ITALIA

Affiliato iPHA

iPHA Affiliate

is a voluntary standard based on EUI

HOW TO EVALUATE ENERGY PERFORMANCE

GREEN METRICS & CERTIFICATION

Baseline solution or standardized metrics

Voluntary certifications

international sustainable building certification program

USA

- **LEED** - Leadership in Energy and Environmental Design (very expensive)- U.S. Green Building Council (USGBC)
- **ENERGY STAR,** U.S. Environmental Protection Agency in conjunction with the U.S. Department of Energy
- **NATIONAL GREEN BUILDING STANDARD,** National Association of Home Builders (NAHB)
- **GREEN GLOBES** operates in the US by the Green Building Initiative
- **GREENGUARD,** Greenguard Environmental Institute, (focused on quality of indoor air)

US-CANADA

- LBC - Living Building Challenge, 2006, International Living Future Institute.

EU

- NZE - Nearly Zero Energy > Net Zero Energy (considering energy produced)
- PASSIVEHAUS, 1988 Adamson Lund University (Sweden) + Wolfgang Feist dell'Institut für Umwelt und Wohnen (D)
- BREEAM (Building Research Establishment Environmental Assessment Method), BRE

2030 Framework for climate and energy

https://www.biggerpockets.com/renewsblog/2011/03/11/green-building-certification/

HOW THESE CONSUMPTION ARE MEASURED?

EUI ANNUAL ENERGY USE INTENSITY = EDI - EPI

Energy Demand Intensity (EDI)
Energy Production Intensity (EPI)

EUI ANNUAL ENERGY USE INTENSITY = EDI - EPI

EUI (Energy Use Intensity)

Definition: Energy Use Intensity is a building's annual energy use per unit area. It is typically measured in thousands of BTU per square foot per year **(kBTU/ft2/yr)** or **kWh/m2/yr**. EUI **can measure "site" energy use** (what the building consumes) or "source" energy use (the amount of fuel the power plant burns to produce that much energy). Unless otherwise specified, **EUI typically refers to "site" energy use**.

Energy Demand Intensity (EDI)
Energy Production Intensity (EPI)

https://sefaira.com/resources/six-metrics-every-architect-should-know-and-how-to-use-them/

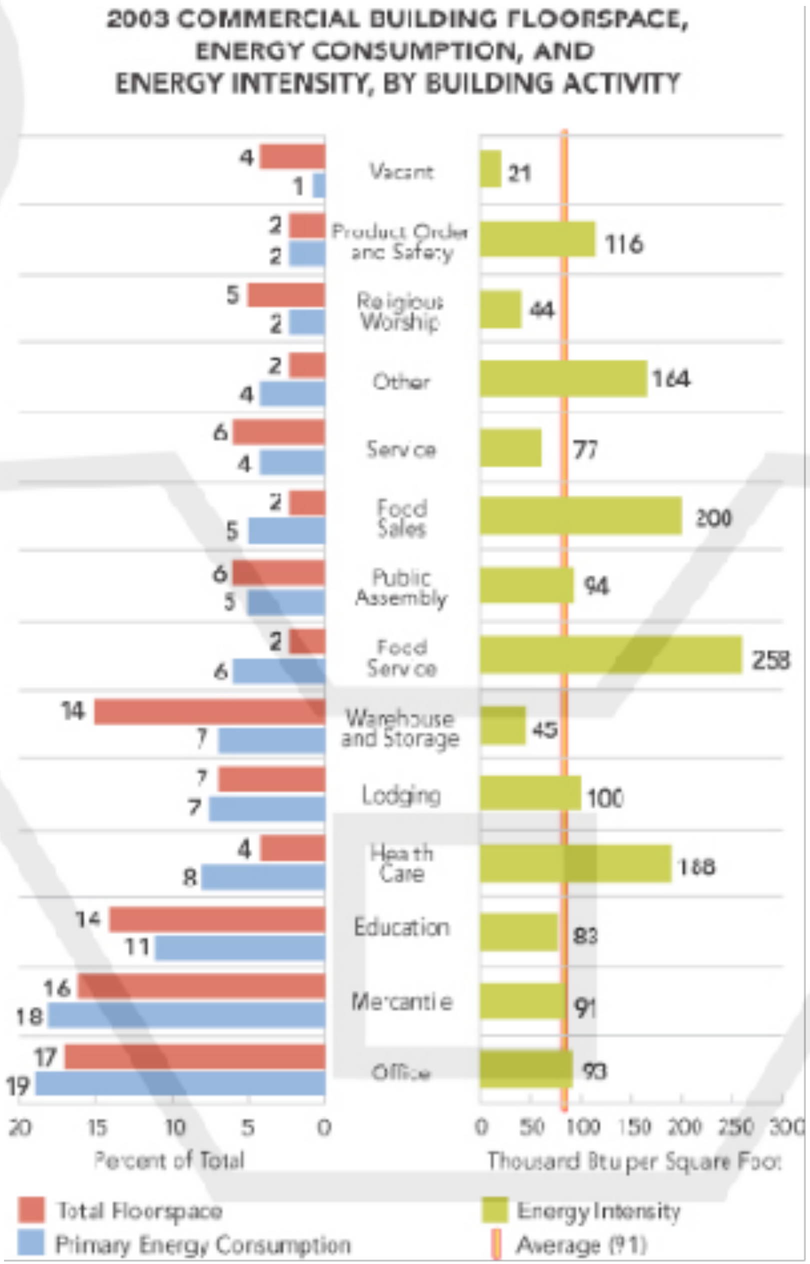
EUI - ANNUAL ENERGY USE INTENSITY kBtu/sf/year kW/m2/year

allows us to run energy comparison between different buildings on a per unit area basis

Evaluation also considers in which way energy is produced inside the whole production and distribution process including looses.
For example for coal is considered a reduction of 50%

But he evaluation of CO_2 emissions is more meaningful

EVALUATION IN RELATIONSHIP WITH BASELINE SOLUTION based on current average benchmark



Conversions of Common Energy Modeling Units

From Inch-Pound (IP) to the International System (SI)

1 footcandle	=	10.76 Lux (illuminance: most practitioners assume 1 footcandle = 10 Lux)
1 Btu/h/ft²	=	3.16 Watts/m² (instantaneous power incident on a surface)
1 Btu/ft²	=	3.16 Watts * hours/m² (units of energy on a surface over time)
1 Btu	=	.293 Wh (unit of energy)
kBtu/ft²/year	=	11.352 MegaJoules/m²/year (Energy Use Intensity, annual measure of energy use per unit area)
1 W/ft²	=	.093 W/m² (Plug Load or Lighting Power Density, usually per room area)
U value (Btu/ft²/h/°F)	=	5.678 U value (W/m²/°C) (conductivity of a material or assembly, where U = 1/R)
1 ft³/minute	=	.000472 m³/second (air change rate due to infiltration or fresh air supply)
1 Foot/second	=	.681 miles/hour = .3048 m/second = 1.097 km/hour (speed, often in relation to airspeed)
°F	=	(5/9)°C + 32 (Temperature)

Check this website for converter: http://www.endmemo.com/sconvert/w_m2btu_sft2.php

USING MICROSOFT EXCEL TO CONVERTE EVERYTHING.

Syntax in English version

=CONVERT (B6, "BTU”,"Wh")/CONVERT(CONVERT(1,"ft”,"m"),"ft”,"m")

Syntax in Italian version

=CONVERTI(B6;"BTU";"Wh")/CONVERTI(CONVERTI(1;"ft";"m");"ft";"m")

Energy	Unit
Joule	"J"
Erg	"e"
Thermodynamic calorie	"c"
IT calorie	"cal"
Electron volt	"eV" (or "ev")
Horsepower-hour	"HPh" (or "hh")
Watt-hour	"Wh" (or "wh")
Foot-pound	"flb"
BTU	"BTU" (or "btu")

Power	Unit
Horsepower	"HP" (or "h")
Watt	"W" (or "w")

https://sefaira.com/resources/six-metrics-every-architect-should-know-and-how-to-use-them/

sefaira

Search...

LOGIN

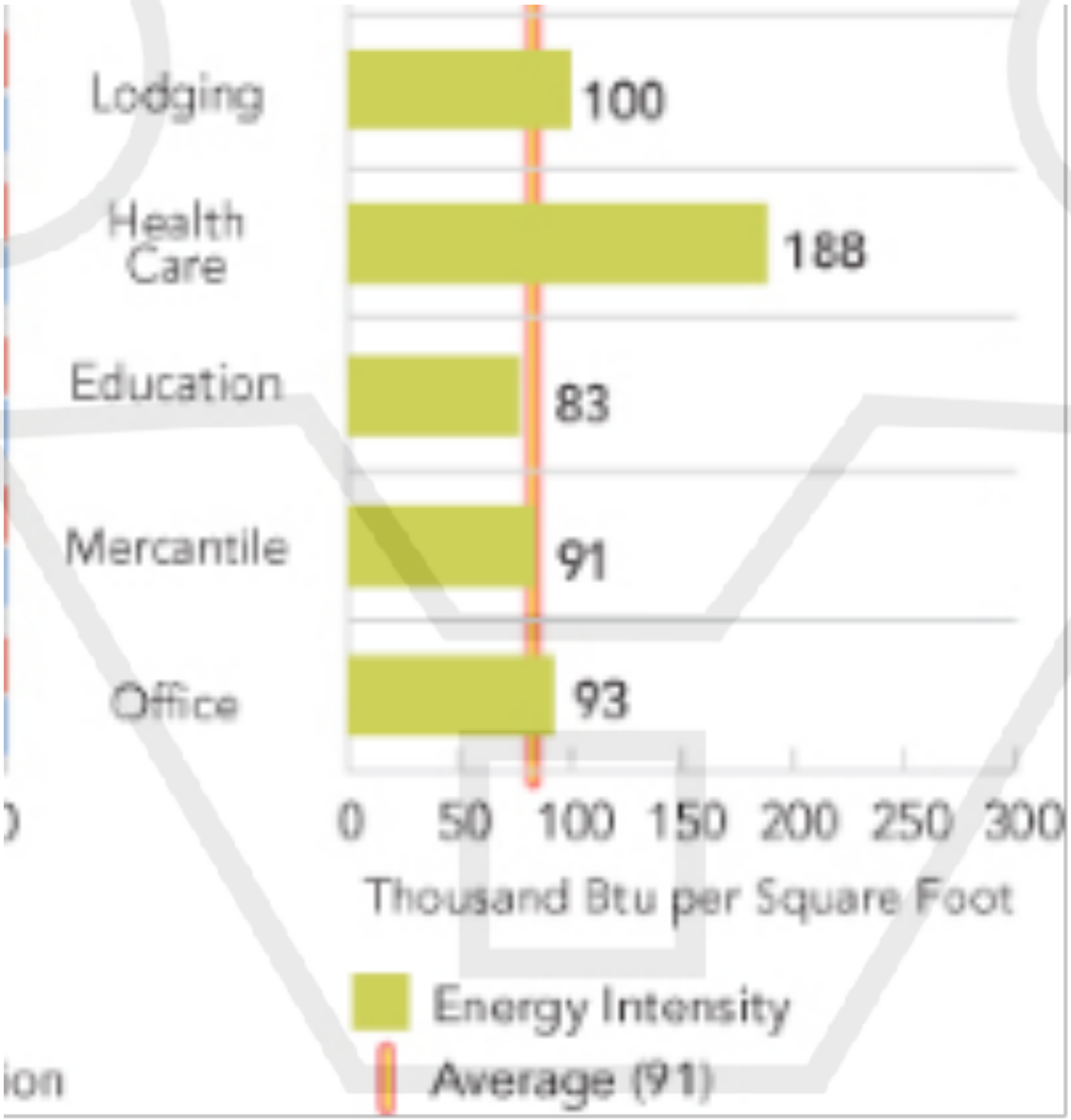
Definition: Energy Use Intensity is a building's annual energy use per unit area. It is typically measured in thousands of BTU per square foot per year (kBTU/ft2/yr) or kWh/m2/yr. EUI can measure "site" energy use (what the building consumes) or "source" energy use (the amount of fuel the power plant burns to produce that much energy). Unless otherwise specified, EUI typically refers to "site" energy use.

Why it's important: EUI is useful for comparing performance of buildings across sizes, types, and locations. It can help you design buildings with low energy use, and, as a likely result, lower operating costs. It is used by programs like ENERGY STAR and the 2030 Challenge, which have specific EUI goals for different building types. It is also being used to benchmark buildings for public reporting in many cities.

Typical values: Below are some average EUIs for three building types in the US. (These are meant to give a rough idea of EUI ranges; actual values can vary widely based upon location & specific space uses.)

	Source EUI (power plant's energy consumption)	**Site EUI** (building energy consumption)	**2030 Challenge target** (60% reduction, site EUI)
Office	**148** kBTU/ft2/yr 467 kWh/m2/yr	**67** kBTU/ft2/yr 211 kWh/m2/yr	**27** kBTU/ft2/yr 85 kWh/m2/yr
K-12 Education	**141** kBTU/ft2/yr 445 kWh/m2/yr	**58** kBTU/ft2/yr 183 kWh/m2/yr	**23** kBTU/ft2/yr 73 kWh/m2/yr
Single-family residence	**68** kBTU/ft2/yr 215 kWh/m2/yr	**46** kBTU/ft2/yr 145 kWh/m2/yr	**18** kBTU/ft2/yr 57 kWh/m2/yr

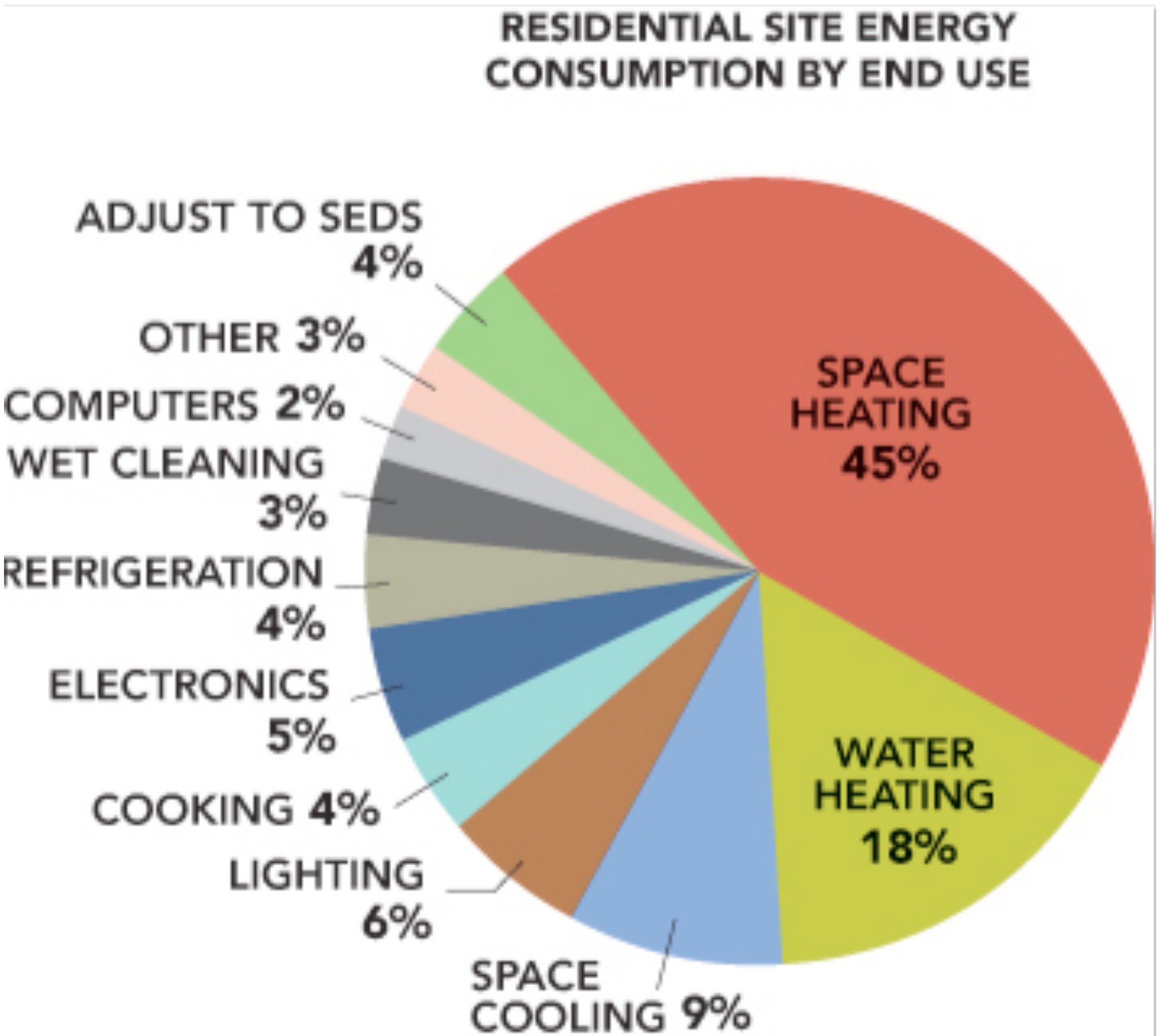
EVALUATION IN RELATIONSHIP WITH BASELINE SOLUTION based on current average benchmark



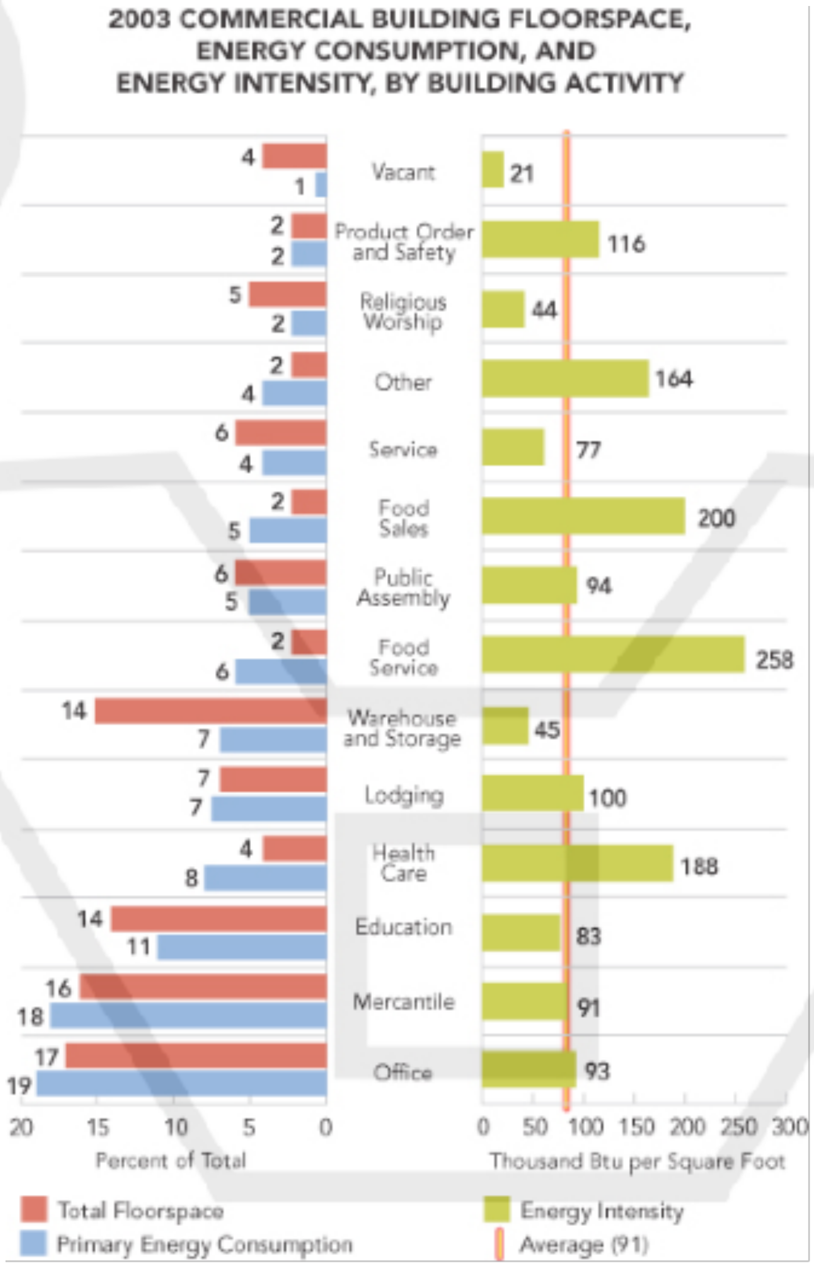
ELEMENTS THAT AFFECT ENERGY CONSUMPTION

- HEATING
- COOLING
- APPLIANCES
- HOT WATER
- LIGHTING

EVALUATION IN RELATIONSHIP WITH BASELINE SOLUTION
based on current average benchmark



EVALUATION IN RELATIONSHIP WITH BASELINE SOLUTION based on current average benchmark



Targets based on U.S. Commercial Building National Average

Primary Space / Building Type	Ave. % Electric	Site EUI med	Site EUI 70%	Site EUI 90%
Education	63	58	17.4	5.8
College/University (campus-level)	63	104	31.2	10.4
Food Sales	86	193	57.9	19.3
Convenience Store (w/ or w/o gas)	90	228	68.4	22.8
Food Service	59	267	80.1	26.7
Fast Food	64	418	125.4	41.8
Restaurant/Food Market	53	207	62.1	20.7
Health Care and Outpatient	72	62	18.6	6.2
Clinic/ Other Outpatient Health	76	67	20.1	6.7
Lodging	61	72	21.6	7.2
Mall (strip mall and enclosed)	71	94	28.2	9.4
Public Assembly	57	42	12.6	4.2
Entertainment/Culture	63	46	13.8	4.6
Library	59	92	27.6	9.2
Recreation	55	39	11.7	3.9
Social/Meeting	57	43	12.9	4.3
Public Order & Safety	57	82	24.6	8.2
Fire Station/Police Station	56	82	24.6	8.2
Service (vehicle repair/postal service)	63	45	13.5	4.5
Storage/Shipping/ Non-refrigerated warehouse	56	10	3.0	1.0
Retail Store (non-mall stores, vehicle dealerships)	67	53	15.9	5.3
Other (varies greatly)	56	70	21.0	7.0

Energy Use Intensity (EUI) Targets, U.S. Commercial Buildings, National Averages, kBtu/ft^2-yr

Use for occupancy types not in "EPA Target Finder" or in "Energy Use Intensity (EUI) Targets by Building Type and Climate Zone."

Derived from Architecture 2030 (2012), based on EPA (2011) and Energy Information Administration's Commercial Building Energy Use Survey (CBECS), 2003; using the EPA's Table 1: 2003 CBECS National Average Source Energy Use and Performance Comparisons by Building Type.

ASHRAE Climate Zones	City	Small Office 5,500 sf / 1 story			Medium Office 53,628 sf / 3 story			Large Office 498,588 sf / 12 story			Medical Office 40,946 sf / 3 story			Primary School 73,960 sf / 1 story			Secondary School 210,887 sf / 2 story			Hospital (general medical & surgical) 241,351 sf / 5 st			Senior Care Facility 70,025 sf / 1 story			Hotel (small) 43,200 sf / 4 story		
		med	70%	90%	med	70%	90%	med	70%	90%	med	70%	90%	med	70%	90%	med	70%	90%	med	70%	90%	med	70%	90%	med	70%	90%
1A	Honolulu, HI	64	19	6	91	27	9	107	32	11	155	47	15	42	13	4	74	22	7	302	91	30	157	47	16	82	25	8
1A	San Juan, PR	53	16	5	75	23	8	88	26	9	185	56	18	27	8	3	51	15	5	172	52	17	105	32	11	58	17	6
1A	Miami, FL	63	19	6	88	27	9	105	32	11	140	42	14	49	15	5	76	23	8	266	80	27	140	42	14	73	22	7
2A	Houston, TX	61	18	6	88	26	9	103	31	10	122	37	12	58	18	6	76	23	8	256	77	26	135	41	14	72	22	7
2B	Phoenix, AZ	68	20	7	96	29	10	112	34	11	173	52	17	72	22	7	107	32	11	306	92	31	163	49	16	89	27	8
3A	Atlanta, GA	57	17	6	84	25	8	99	30	10	96	29	10	59	18	6	62	19	6	239	72	24	125	38	13	67	20	7
3B-CA	Los Angeles, CA	47	14	5	74	22	7	90	27	9	69	21	7	65	20	7	55	17	6	249	75	25	120	36	12	57	17	6
3B-other	Las Vegas, NV	66	20	7	84	25	8	106	32	11	140	42	14	74	22	7	93	28	9	289	87	29	153	46	15	84	25	8
3C	San Francisco	51	15	5	78	23	8	94	28	9	73	22	7	62	19	6	59	18	6	247	74	25	123	37	12	64	19	6
4A	Baltimore, MD	59	18	6	86	26	9	101	30	10	91	27	9	60	18	6	56	17	6	233	70	23	123	37	12	70	21	7
4B	Albuquerque, NM	61	18	6	88	26	9	104	31	10	106	32	11	74	22	7	73	22	7	266	80	27	140	42	14	79	24	8
4C	Seattle, WA	57	17	6	84	25	8	100	30	10	82	25	8	67	20	7	60	18	6	247	74	25	129	39	13	74	22	7
5A	Chicago, IL	73	22	7	104	31	10	122	37	12	113	34	11	88	26	9	79	24	8	263	79	26	152	46	15	92	28	9
5B	Boulder, CO	63	19	6	90	27	9	106	32	11	101	30	10	74	22	7	66	20	7	257	77	26	139	42	14	83	25	8
5C	Ketchikan, AK	66	20	7	93	28	9	109	33	11	97	29	10	55	17	6	72	22	7	245	74	25	138	41	14	89	27	9
6A	Minneapolis, MN	77	23	8	108	32	11	126	38	13	121	35	12	89	27	9	80	24	8	263	79	26	156	47	16	97	29	10
6B	Helena, MT	65	20	7	92	28	9	108	32	11	96	29	10	72	22	7	62	19	6	250	75	25	138	41	14	86	26	9
7	Duluth, MN	78	23	8	110	33	11	109	32	11	114	34	11	65	26	9	73	22	7	254	76	25	153	46	15	101	30	10
7.5	Kenai, AK	70	21	7	97	29	10	113	34	11	105	32	11	56	17	6	73	22	7	246	74	25	141	42	14	96	29	10
8	Fairbanks, AK	76	23	8	104	31	10	120	36	12	119	36	12	69	21	7	64	19	6	247	74	25	146	44	15	107	32	11

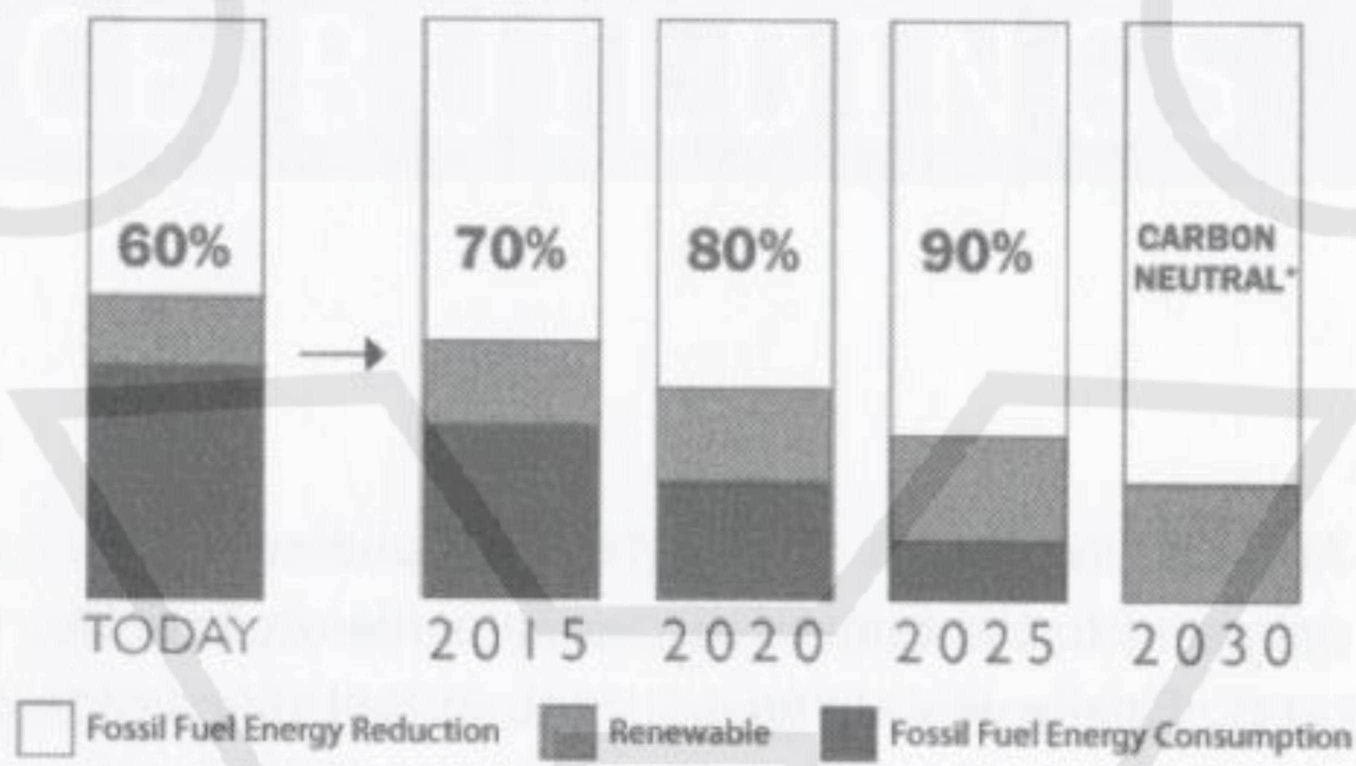
Energy Use Intensity (EUI) Targets, by Building Type and Climate Zone, kBtu/ft^2-yr
na = not available in EPA "Target Finder"

EVALUATION IN RELATIONSHIP WITH
BASELINE SOLUTION based on Code* compliant element as a basic benchmark

*) *for example: LEED certification uses ASHRAE 90.1*

City	Miami	Houston	Phoenix	Atlanta	Los Angeles	Las Vegas	San Francisco	Baltimore
Medium Office	39	42	40	41	33	37	30	45
Stand alone Retail	62	62	60	61	44	56	50	72
Quick Service Restaurant	535	549	550	561	496	541	594	609
Large Hotel	99	100	100	110	105	105	110	127
Mid Rise Apartment	38	38	36	36	31	36	33	42

City	Albuquerque	Seattle	Chicago	Denver	Minneapolis	Helena	Duluth	Fairbanks
Medium Office	38	42	48	47	54	48	57	77
Stand alone Retail	67	58	81	69	93	83	104	146
Quick Service Restaurant	567	575	657	604	711	663	765	945
Large Hotel	119	124	130	101	152	144	163	190
Mid Rise Apartment	37	38	47	41	51	48	58	76

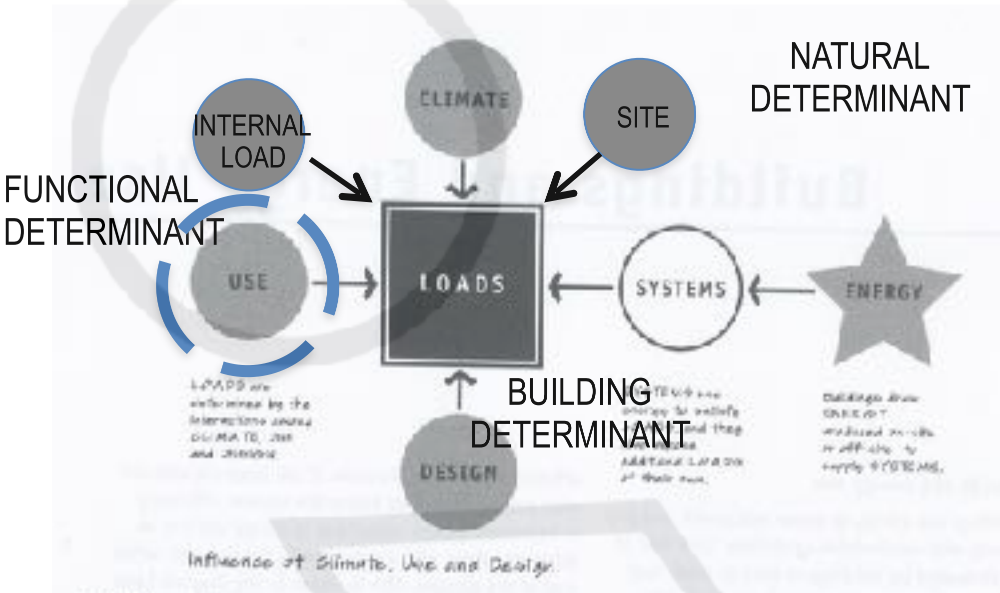


The 2030 Challenge Targets

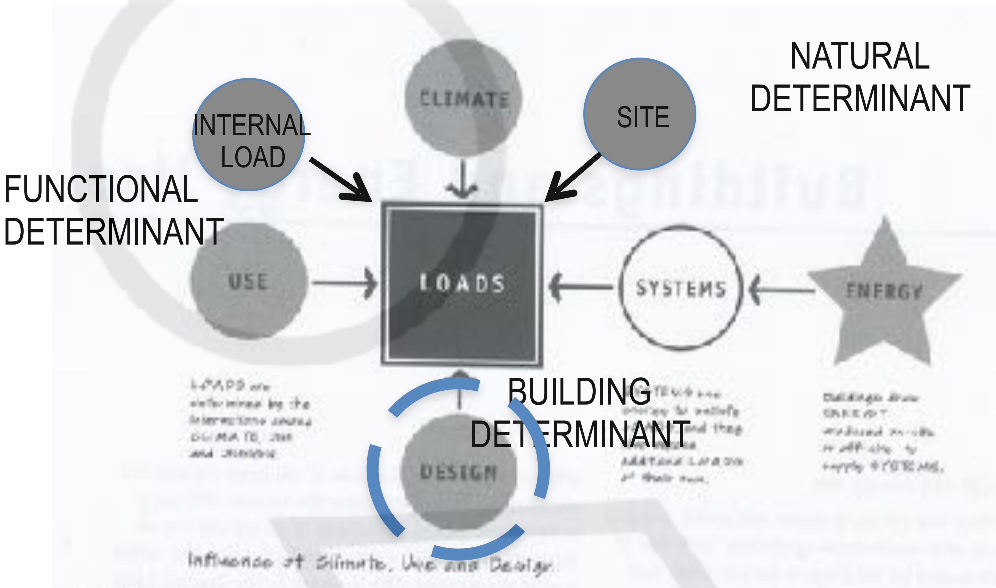
The Architecture 2030 Challenge allows up to 20% of the overall energy reduction to come from off-site renewable energy. The carbon-neutral target uses no fossil fuel/GHG-emitting energy to operate.

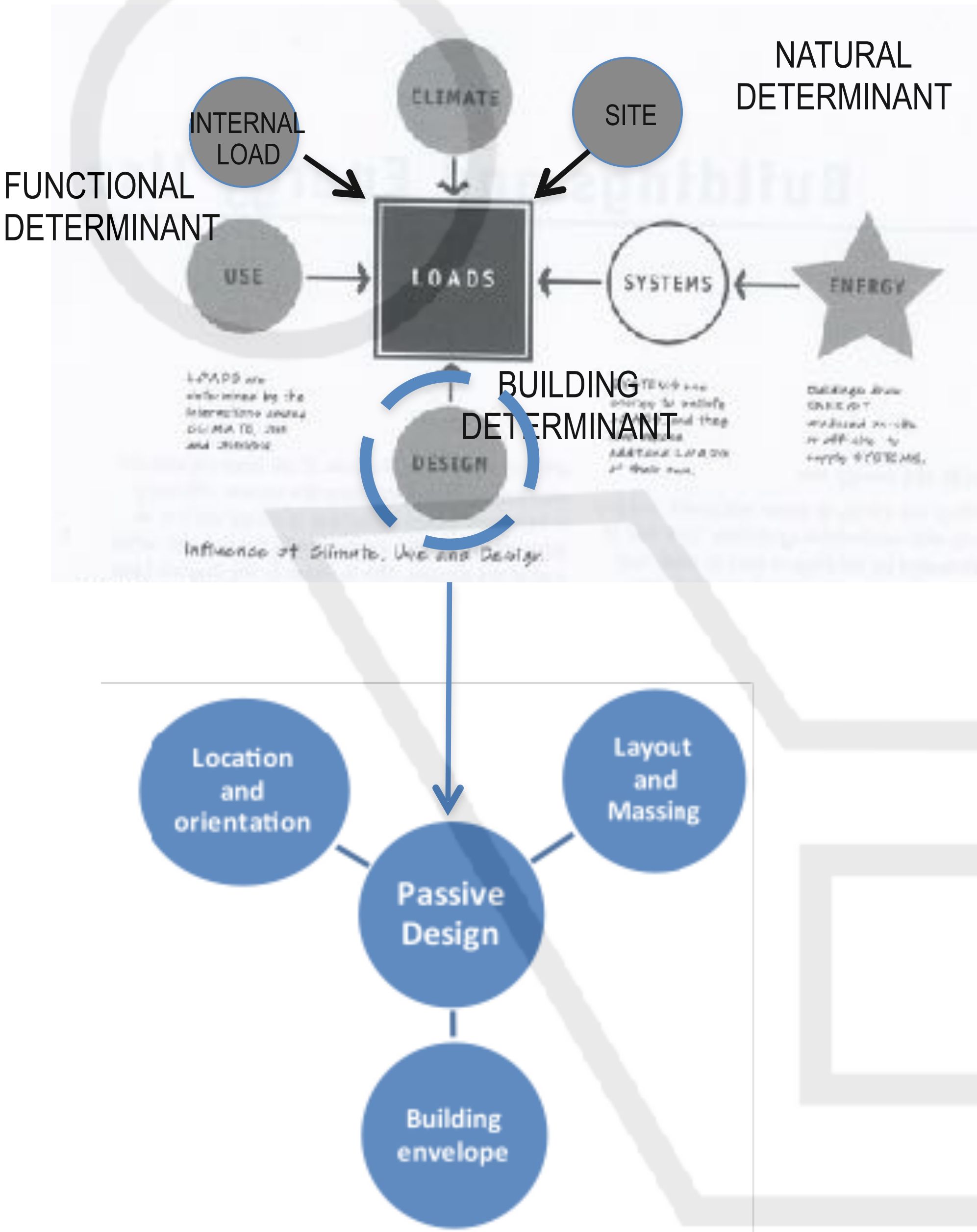
WHY, AS ARCHITECTS, WE NEED TO DEAL WITH ENERGY SIMULATION?

ENVIRONMENTAL SYSTEM DETERMINANTS



ENVIRONMENTAL SYSTEM DETERMINANTS



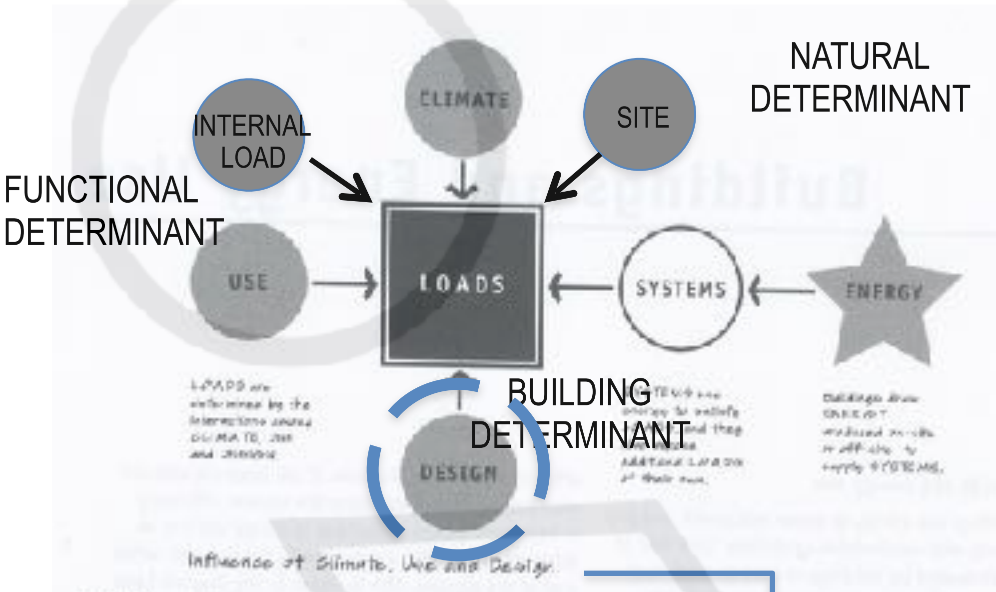


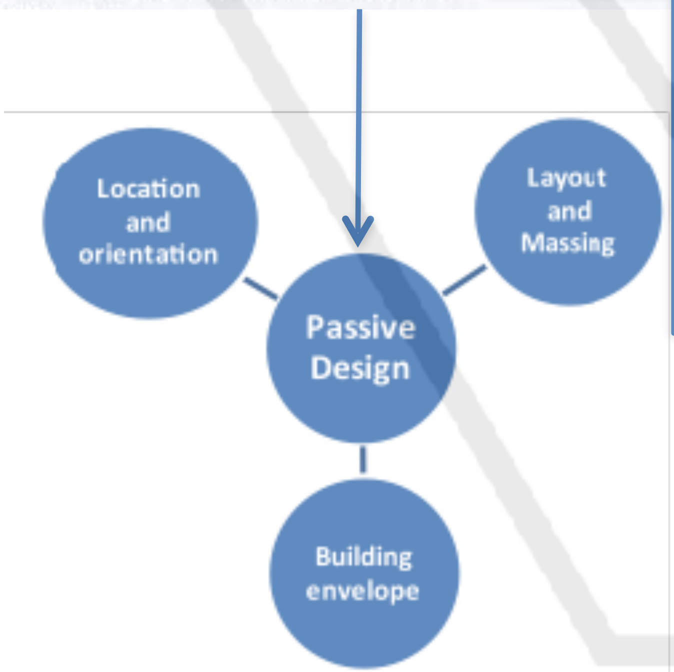
MODELING FOR PASSIVE DESIGN

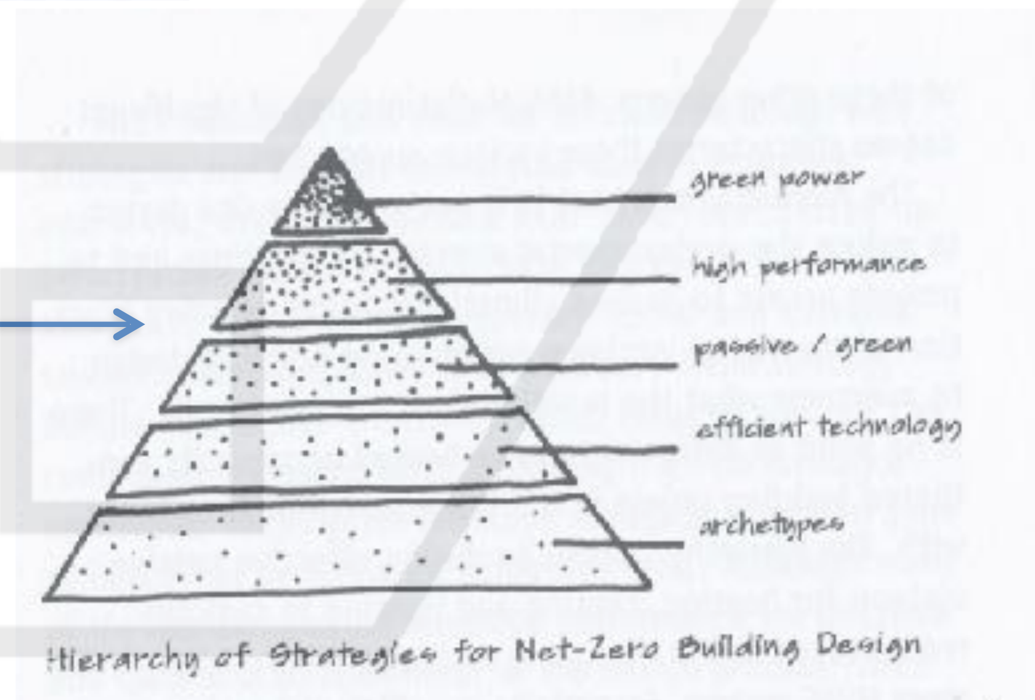
The term 'Passive Design' here refers to design strategies, technologies and solutions that effectively take advantage of the environmental conditions outside the building to maximise the energy and cost savings while ensuring the core building facilities and provisions (such as indoor comfort, safety, health, etc.) are not compromised. The environmental conditions can provide several advantages or disadvantages to the building such as the following:

- Day lighting: can reduce the energy used for artificial lighting but excessive and improper exposure may result in glare and other forms of visual discomfort
- Natural ventilation: can reduce mechanical ventilation energy to move air around but can result in hygiene issues and over-cooling in cold climates
- Natural cooling: to reduce the need for excessive air-conditioning or mechanical cooling in hot climates
- Natural heating: to use the energy from the sun to provide heat indoors in cold climates instead of providing excessive artificial heating. But this needs to be managed in hot climates to reduce air-conditioning energy use
- Shading: (from trees or neighbouring buildings) can reduce heat from direct sun exposure in hot climates but can obstruct views and natural light and heat in cold climates.

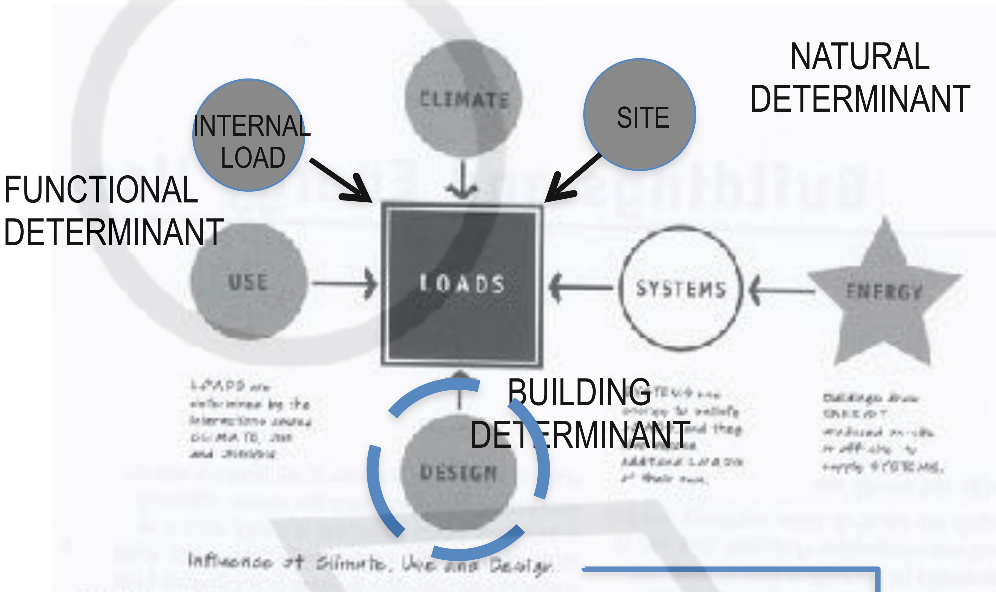
MODELING FOR PASSIVE DESIGN

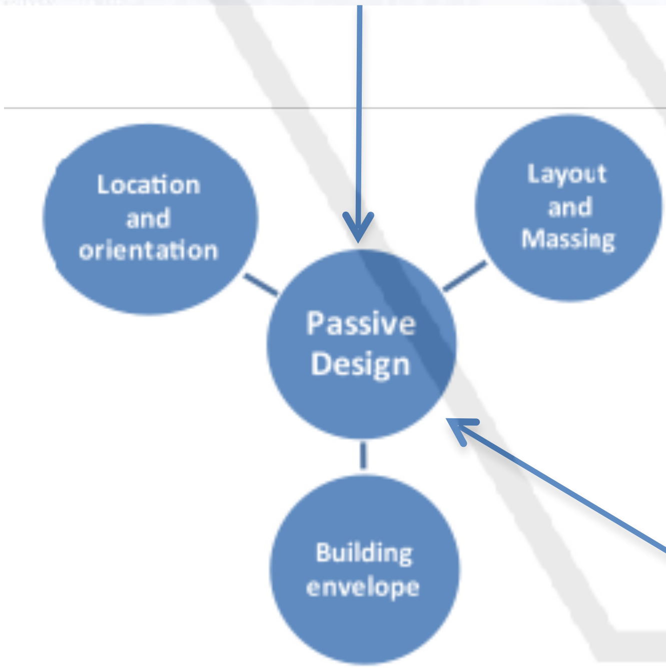


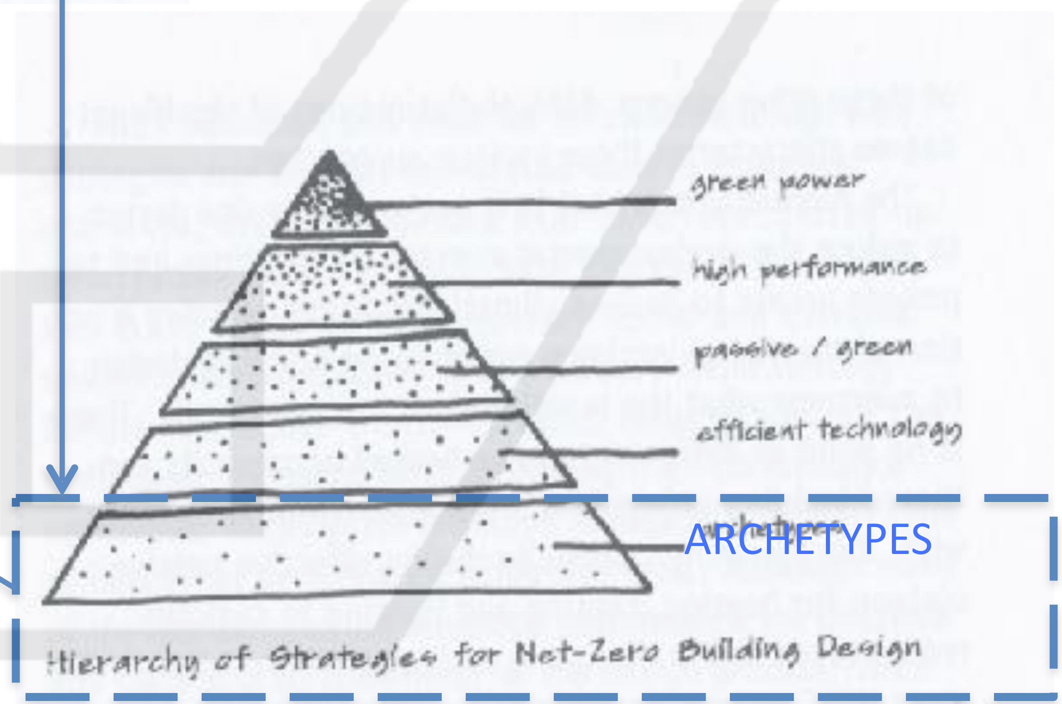




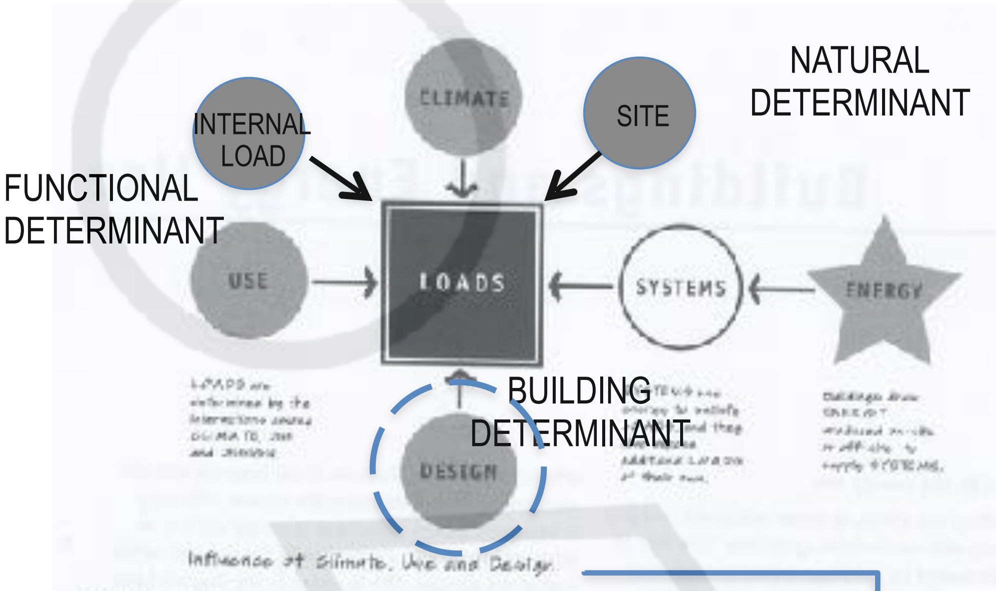
MODELING FOR PASSIVE DESIGN



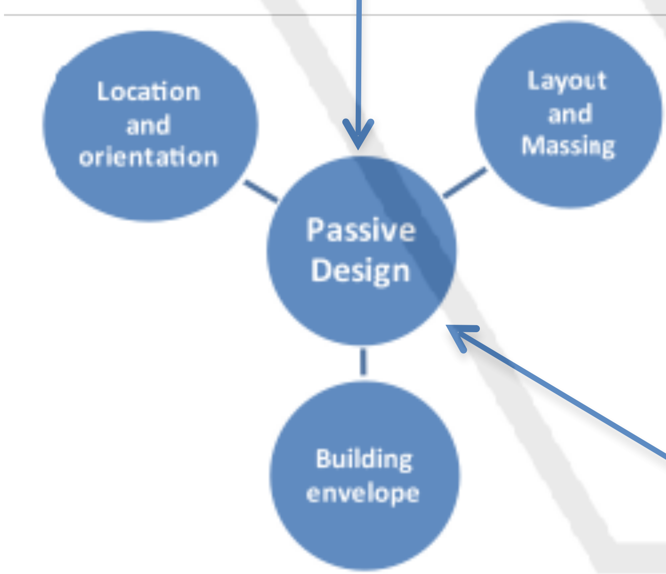


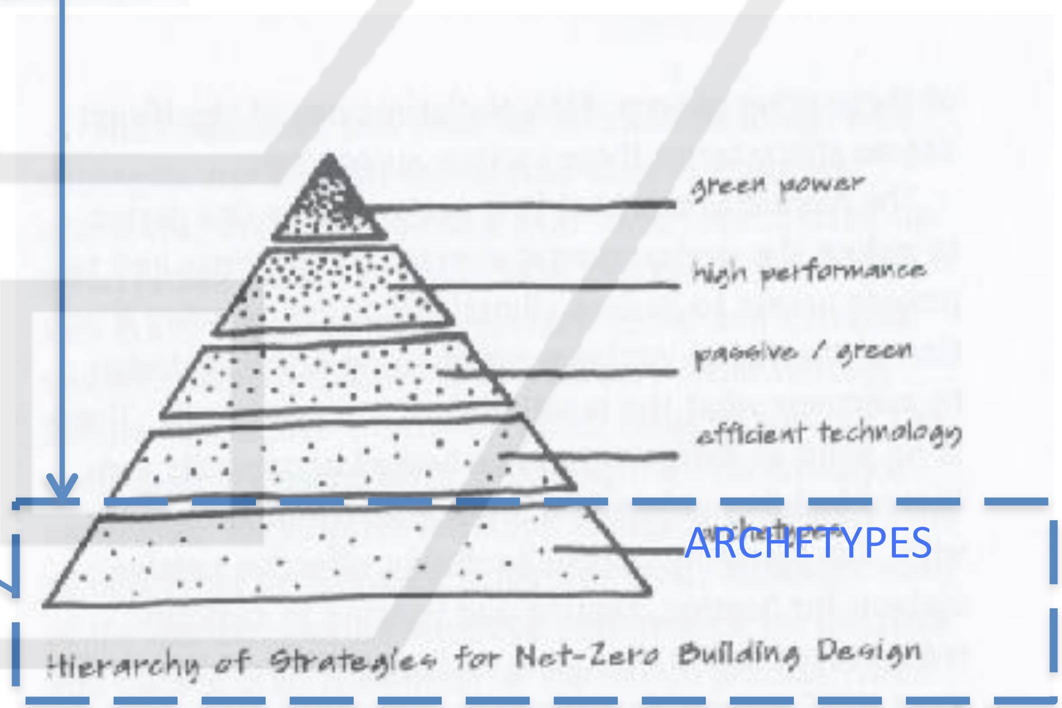


MODELING FOR PASSIVE DESIGN

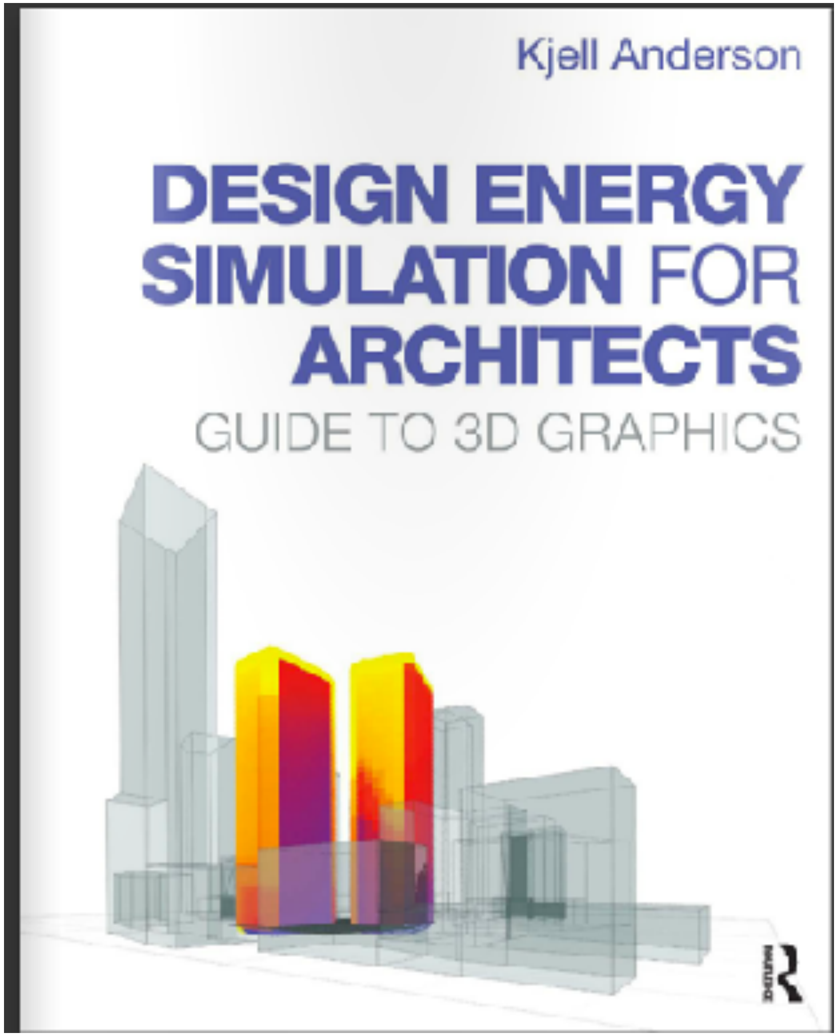


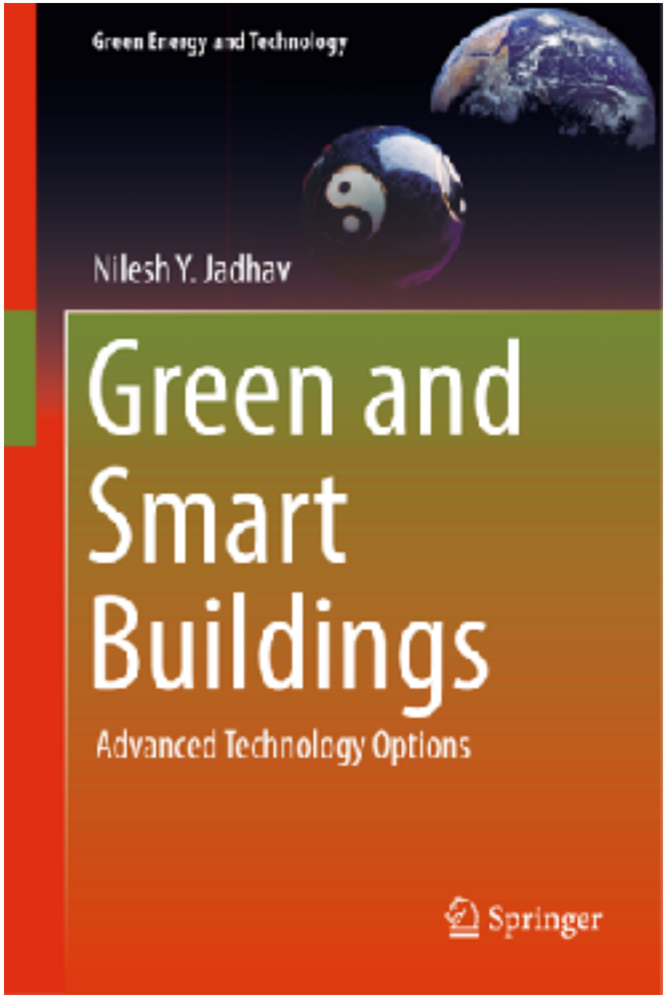
”**archetypes** is the level of basic architectural design where issues of siting, orientation, location, shape, proportions and surface to volume ratio are considered, along with neighborhood or urban fabric context of building groups that set the pattern for access to sun, wind and lights”-SW&L pg.6





ENVIRONMENTAL DESIGN USING MASS COMPUTATIONAL MODELING





Class Text-books

For other resources check Mailab class portal out

USING MASS COMPUTATIONAL MODELING FOR PRELIMINARY ENERGY ASSESSMENT

WHY? :

Initial mass modeling address fundamental design parameters, including the building envelope, orientation and form, typically without including mechanical or electrical systems in a manner it can speed up analysis and allow the evaluation of many different alternatives.

It provides crucial design guidance and useful feedback to the design team on how the form, orientation, programmatic strategies, and other variables will likely affect the project's performance in terms of energy, daylighting, comfort, and other design characteristics.

BIM FOR INTEGRATED DELIVERY PROJECT (IPD)

1. We need to go with an engineering-integrated process since the early stage
2. Bim is not a new and more efficient way of production. BIM is a chance.
3. It is a way to integrated specialisms, to have a comprehensive view of the whole building and more than that a view to anticipate the construction and all the problems and conflicts that can arise on the site.
4. It is a way to visualize materiality and for that reason to have an understanding on how the building works.
5. BIM and object oriented computing in general are providing us a way to get an holistic approach to design

BIM allows us to integrate time, costs, manufacturing, facility management and maintanance information; to check conflicts.
More than that BIM let us to anticipate decisions, evaluate alternatives and their effects, to extend and speed up optioneering

It's a way to be aware about our decisions

AVAILABLE COMPUTATIONAL TOOLS FOR ENERGY MODELING

ENERGY ANALYSIS SOFTWARE

1. EnergyPlus by the U.S. Department of energy (free tool), available at: https:// energyplus.net/.
2. IES Virtual Environment (VE): http://www.iesve.com/.
3. eQUEST, quick energy simulation tool: http://www.doe2.com/equest/.
   AutodeskGreenBuildingStudio:https://gbs.autodesk.com/GBS/(cloudbased).

ENERGY MODELING AND SIMULATION SOFTWARE

1. 23 TRNSYS: http://www.trnsys.com/.
2. DesignBuilder: http://www.designbuilder.co.uk/.
3. Radiance: Lighting simulation tool: http://www.radiance-online.org/.
4. OpenStudio by NREL: https://www.openstudio.net/ (open source, free interface

TOOLS USING ENERGY PLUS AND RADIANCE

1. Dymola: http://www.3ds.com/products-services/catia/products/dymola.
2. Autodesk Revit Energy plug in (previously known as Ecotect).

Tools that Support gbXML

- CAD/BIM
  - Autodesk
    - AutoCAD Architecture & MEP
    - Revit Architecture & MEP
    - Green Building Studio (GBS)
    - Ecotect
    - Vasari
  - Bentley
    - Architecture
    - Building Mechanical Systems
  - Trimble
    - SketchUp
  - Graphisoft
    - ArchiCAD
    - Mac and Windows
  - BIMStorm
  - Rhino/Grasshopper

- HVAC/Energy/Lighting
  - Bentley Hevacomp
  - blueCAPE CFD
  - Cadsoft Envisioneer
  - Carrier
    - Hourly Analysis Program (HAP)
  - DesignBuilder
  - DIALux
  - DOE-2.2 & eQuest (via GBS)
  - Elite Software
  - EnergySoft
  - Environmental Design Solutions Ltd.
    - Tas
  - GreenSpace Live (gModeller)
  - IES, Ltd.
    - IES <Virtual Environment>
  - Trane
    - TRACE 700

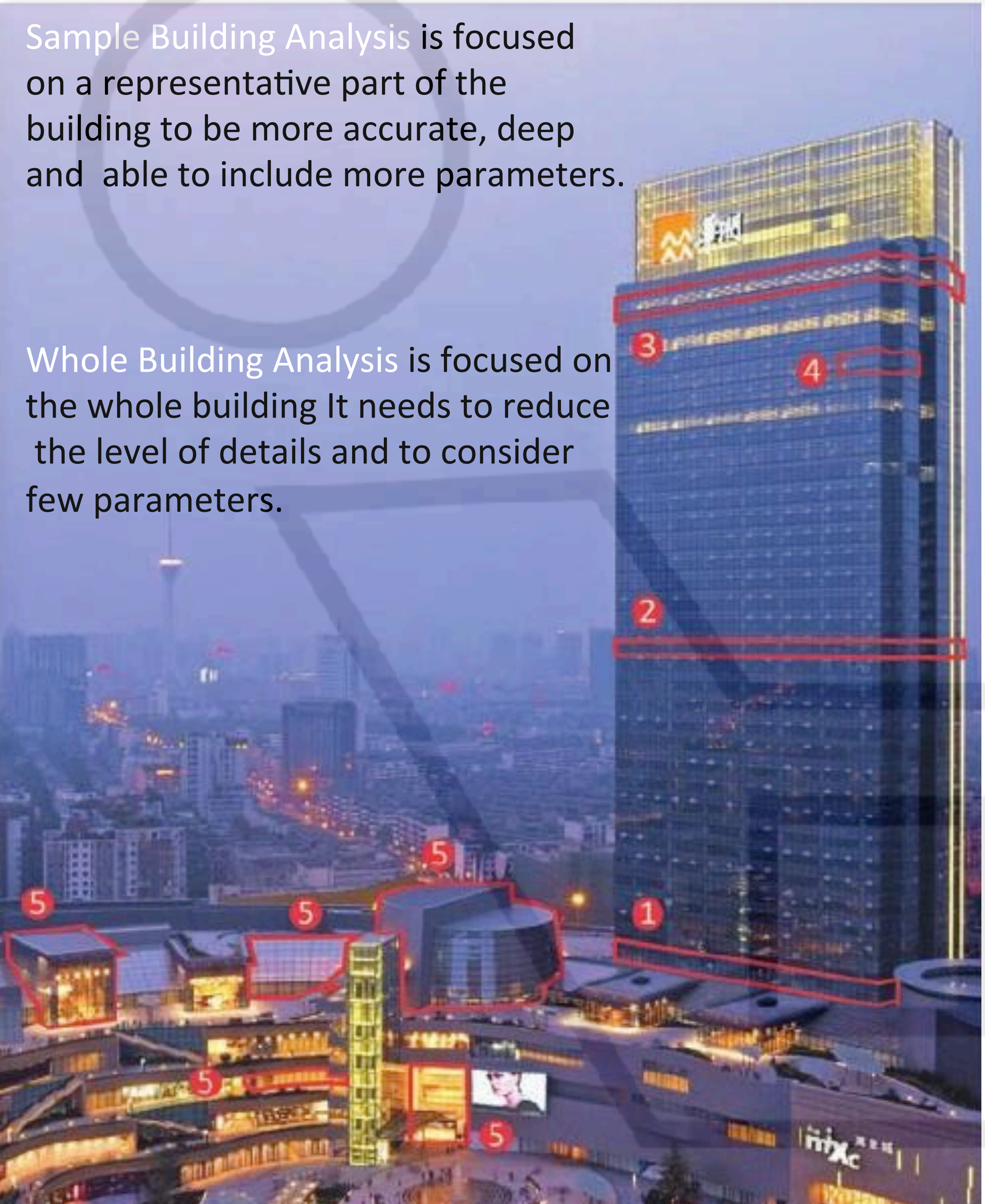
Massing contribution to a passive design

1. Building location and orientation on the site
2. Building layout and form
3. Building envelope characteristics (windows, walls, roof, insulation and shading).

It is important to note that Building Energy Modeling is a computer program and the accuracy of results would largely depend on the inputs provided to the model. In this context, one should be mindful of the expression ‘garbage-in-garbage-out’.

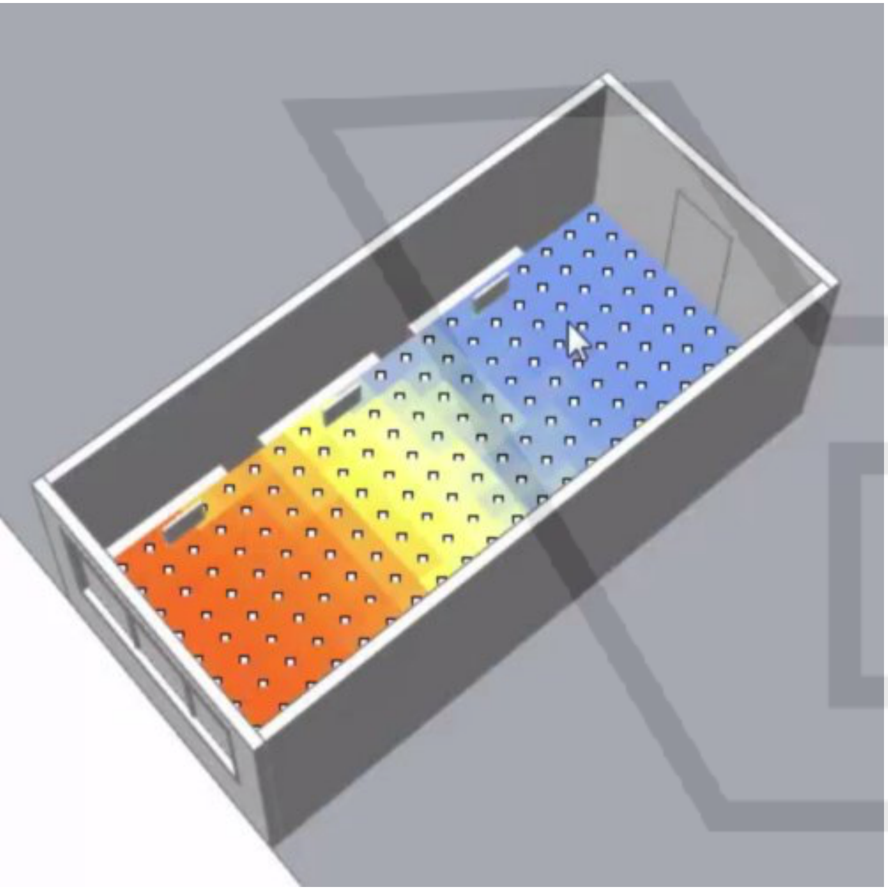
Sample Building Analysis is focused on a representative part of the building to be more accurate, deep and able to include more parameters.

Whole Building Analysis is focused on the whole building It needs to reduce the level of details and to consider few parameters.



While a whole building energy simulation estimates the performance for an entire building, representative floors are typically modeled, including the lowest (1), middle (2), and top floors (3) of a high-rise, with multipliers being used to account for the other floors. Each atypical floor is modeled separately. Shoebox modeling analyzes a single floor or space within a floor for energy performance. For instance, a corner of a building (4) that may be exposed to solar energy from multiple directions can be tested for comfort and energy performance. A shoebox model can also be used to estimate and improve the energy use of smaller or unique spaces (5). Any scale can be studied more quickly with a single-aspect analysis, including an entire building, a single floor, or unique condition.

Source: Photo of LEED Gold certified MixC Chengdu © 2012 Callison LLC.



SHOEBOX ANALYSIS

1-Set boundary conditions able to represent meaningful or critical parts, systems, aspects of the building

2-Set adiabatic perimeters

3-Iterative input of different conditions in order to test different behaviours

4. Run analysis

5. Analize and evaluate

OTHER TYPES OF MODELING FOR SIMULATION

STATIC

DINAMIC

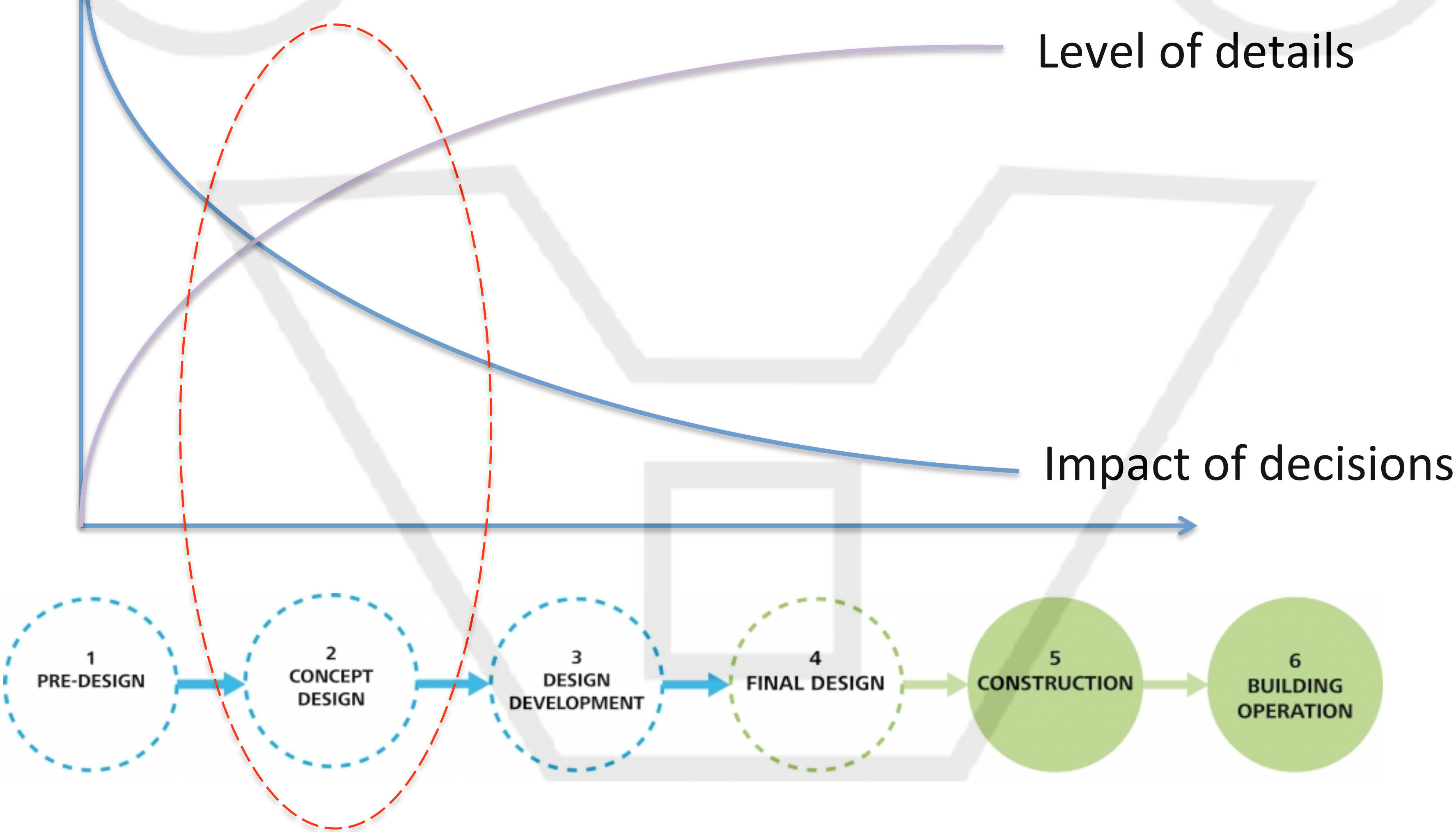
TIME-STEP analysis = over a period of time hour season, year

POINT-IN-TIME (PIT) analysis= in a precise single moment segment like hottest hours

MODELING & SIMULATION IN THE EARLY STAGE

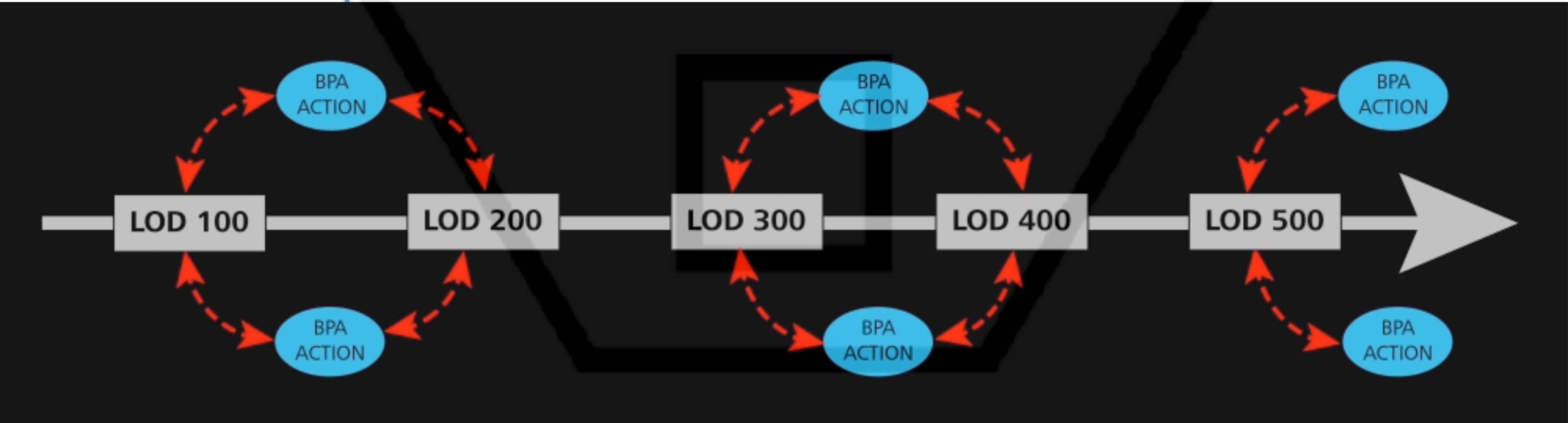
Conceptual & Schematic Design

involves the evaluation of different ideas.
It is not an analytical activity but more conceptual, not detailed

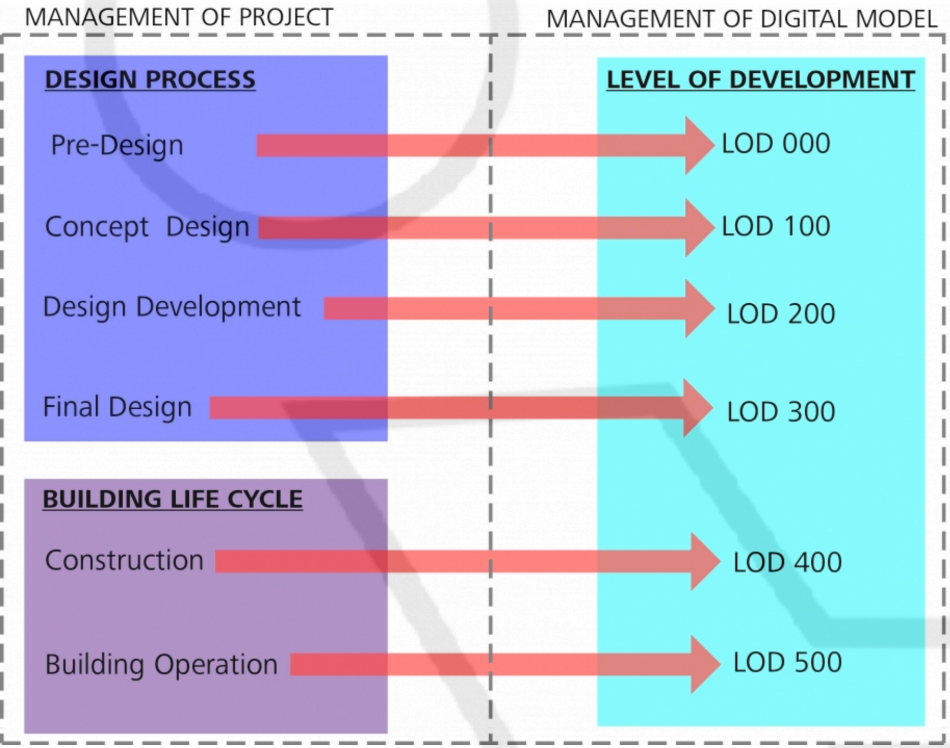


WHICH LEVEL OF DETAIL IS REQUIRED IN THE EARLY STAGE THE BIM PROCESS

Early Stage Design



WHICH LEVEL OF DETAIL IS REQUIRED IN THE EARLY STAGE THE BIM PROCESS



https://sustainabilityworkshop.autodesk.com/buildings/project-phases-level-development

LOD phases can be summarized as follows.

LOD 100: Modeled elements are at a conceptual point of development. Information can be conveyed with massing forms, written narratives, and 2D symbols.

LOD 200: Modeled elements have approximate relationships to quantities, size, location, and orientation. Some information may still be conveyed with written narratives.

LOD 300: Modeled elements are explained in terms of specific systems, quantities, size, shape, location, and orientation.

LOD 400: Continuation of LOD 300 with enough information added to facilitate fabrication, assembly, and installation.

LOD 500: Modeled elements are representative of as installed conditions and can be utilized for ongoing facilities management.


4.43 | 0.27
1.52
USD / ft² / yr
Denver Office Option 2
4.41 | 0.35
1.46
USD / ft² / yr
Denver Office
7.56 | -0.1
1.89
USD / ft² / yr
Office Building
USD / ft² / yr
Denver Office Option 2
Denver Office
Office Building
4.43
0.27
4.41
0.35
7.56
-0.1
Lighting Efficiency

In any case the optimized solution is a compromise between different aspects

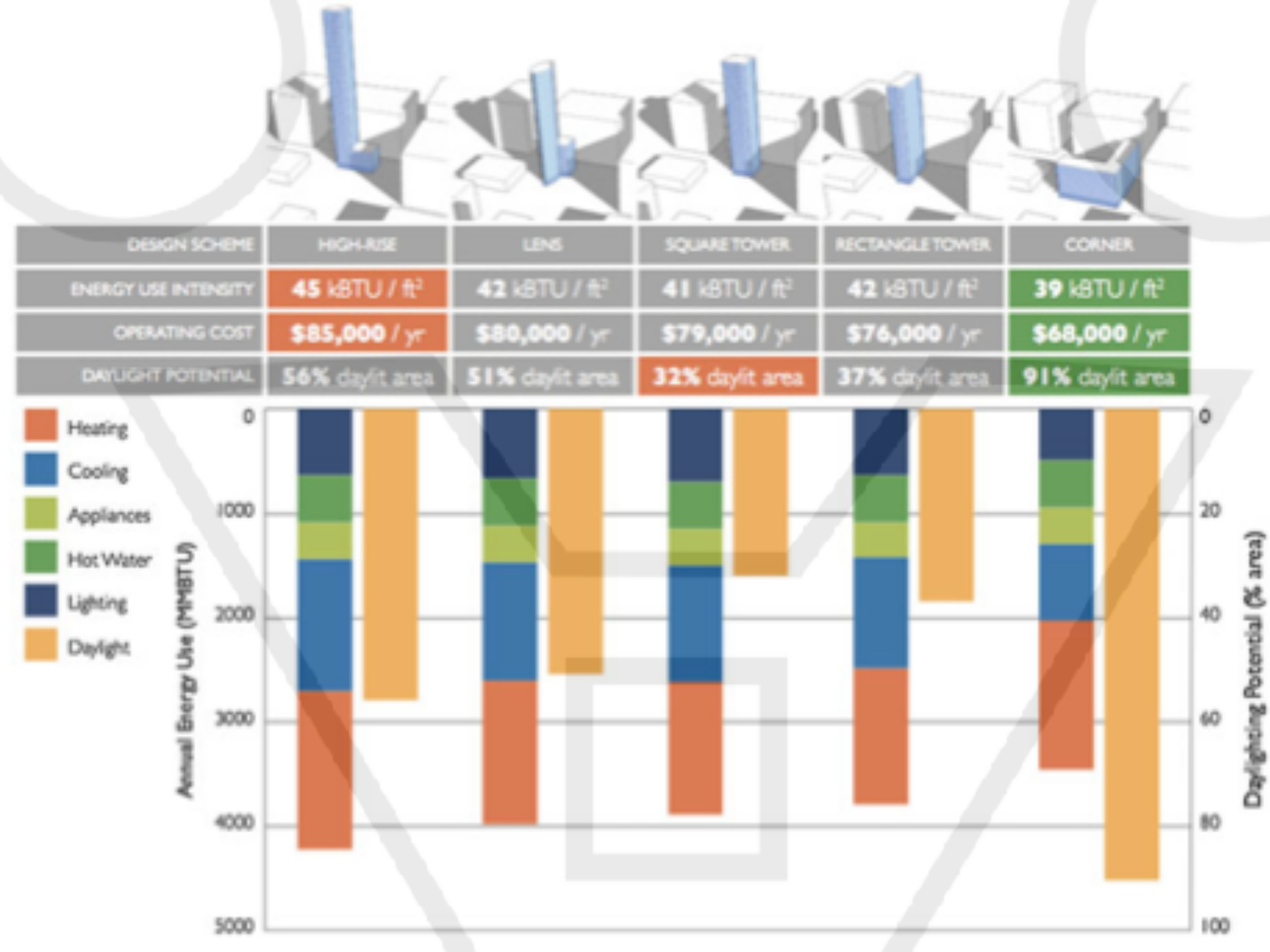
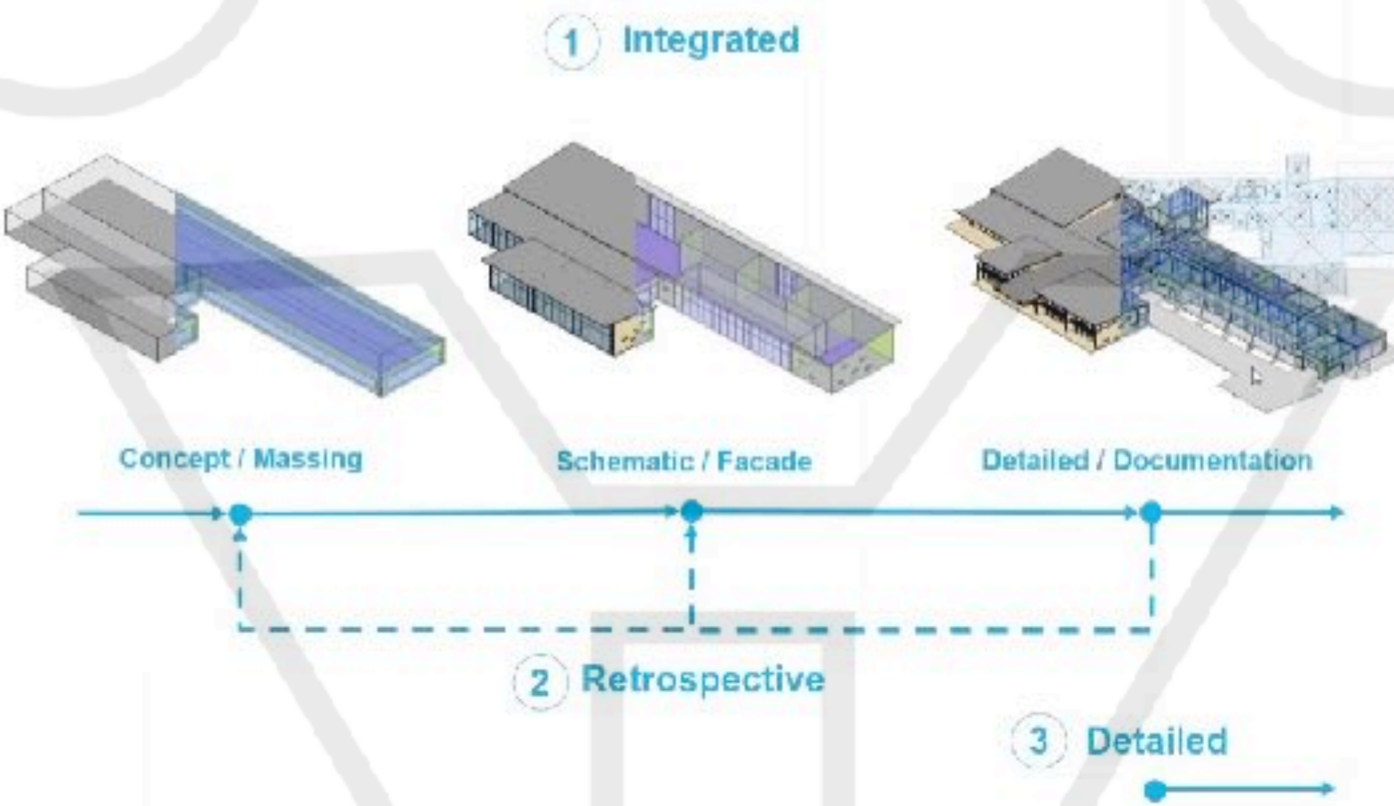
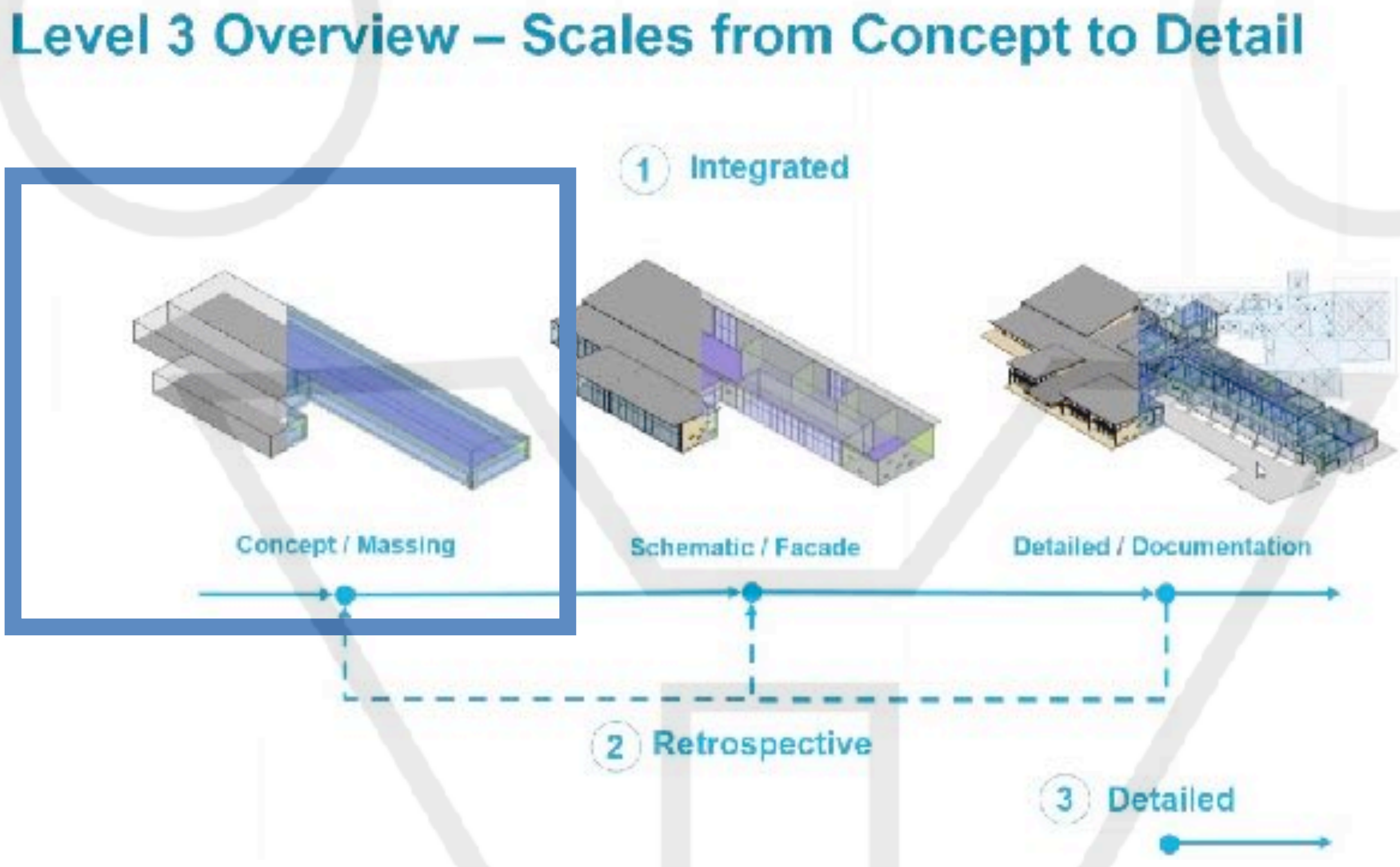


Fig. 4.4 Massing options and implication on building performance (Sefaira 2013)

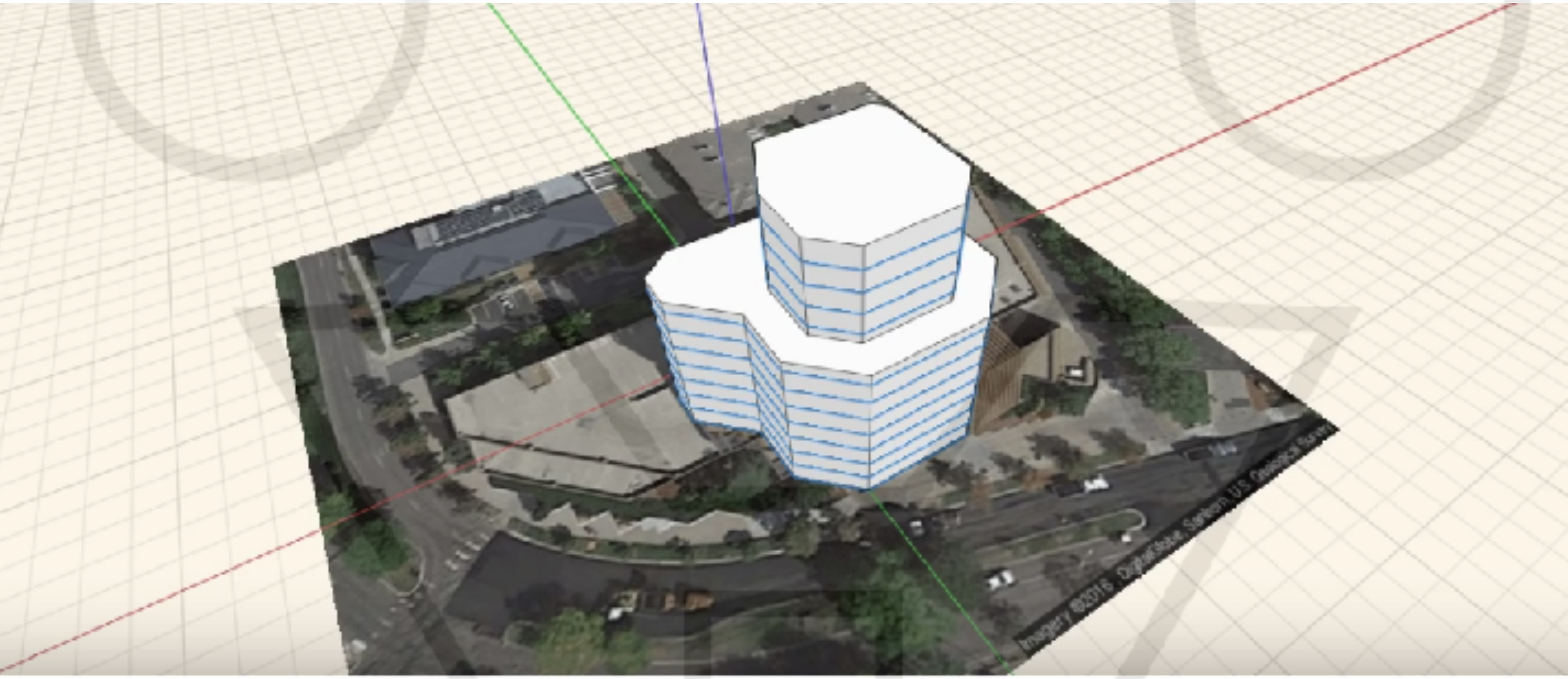
Level 3 Overview – Scales from Concept to Detail



DO THE RIGHT CHOICE FROM THE BEGINNING



CONCEPTUAL MASS MODELING IN THE EARLY STAGE DESIGN



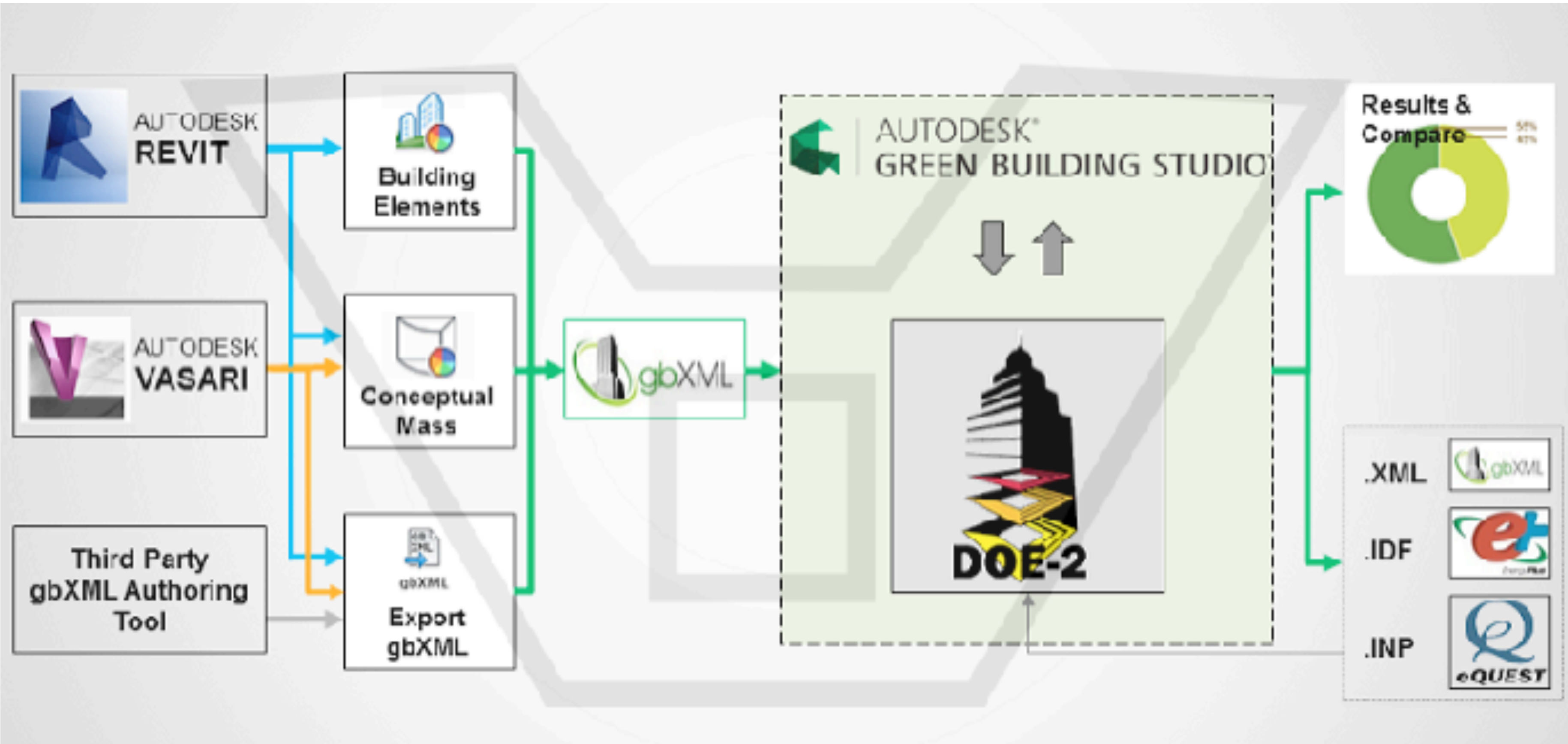
CONCEPTUAL MASS MODELING IN THE EARLY STAGE DESIGN

CONCEPTUAL MASS MODELING IN THE EARLY STAGE DESIGN

MASS MODELING FOR ENERGY EVALUATION

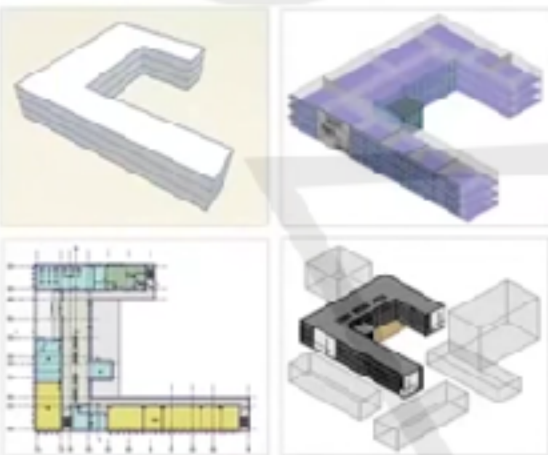
USING REVIT + INSIGHT

WHAT IS REVIT?



MASS ENERGY EVALUATION WORKFLOW IN AUTODESK

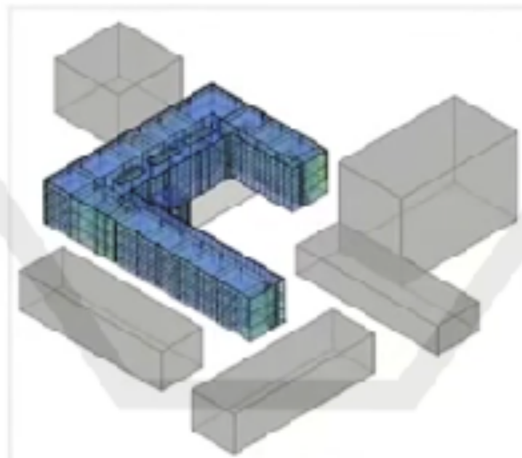
Architectural Modeling



Develops from Concept to Detail with a variety of modeling practices.

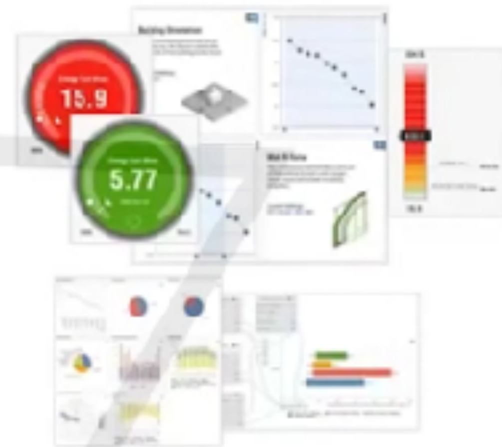
Typically includes many small modeling inaccuracies & omissions.

Energy Analytical Model Creation



Fully automated using Architectural Model elements with little to no 'cleaning or special modifications'.

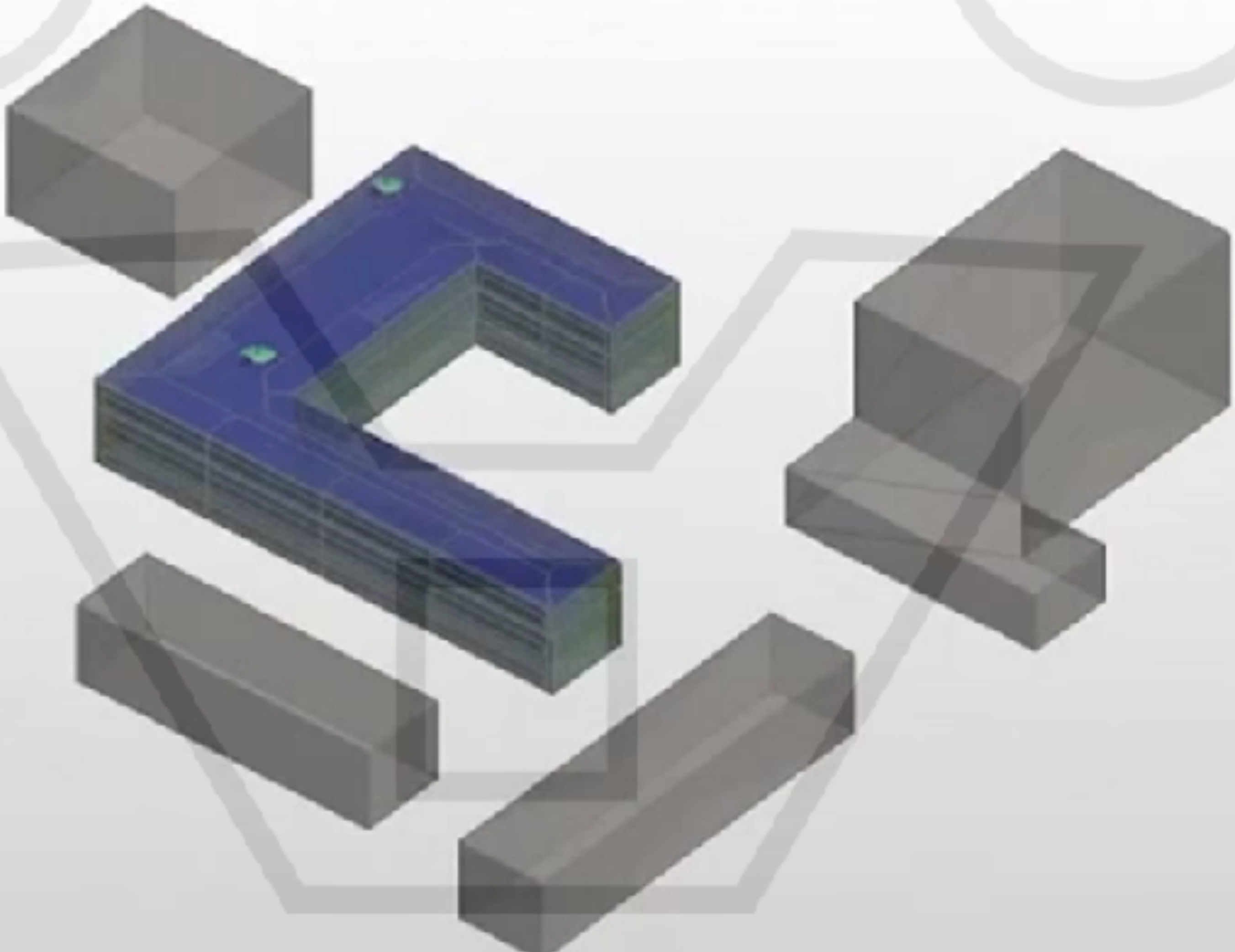
Whole Building Energy Simulation



Clear indicators of performance range with real time cause and effect feedback.

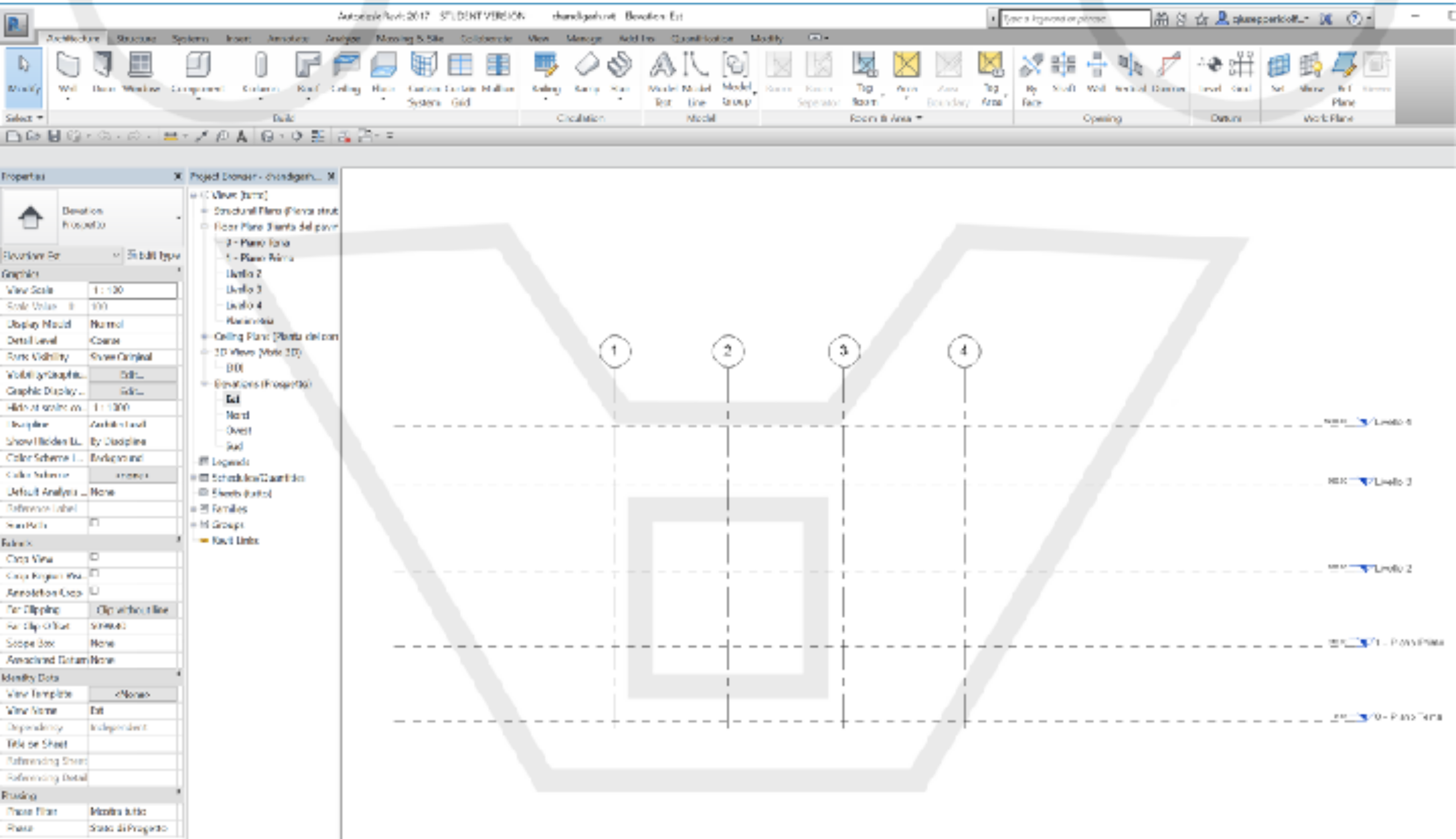
Custom detailed dashboards and parametric run configuration.

1st STEP: MODEL ARCHITECTURAL MASSES



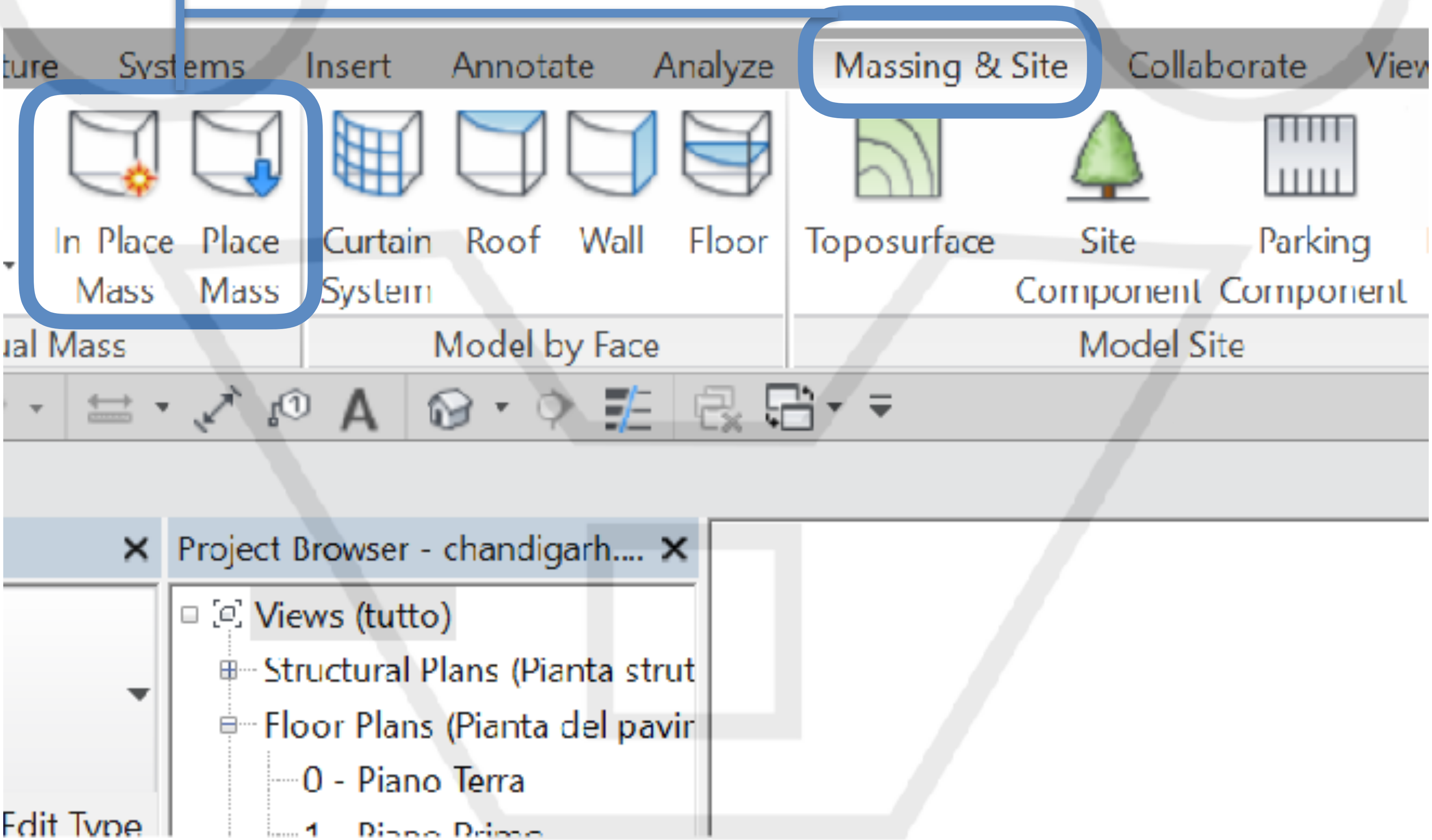
1st STEP: MODEL ARCHITECTURAL MASSES

- create grid levels



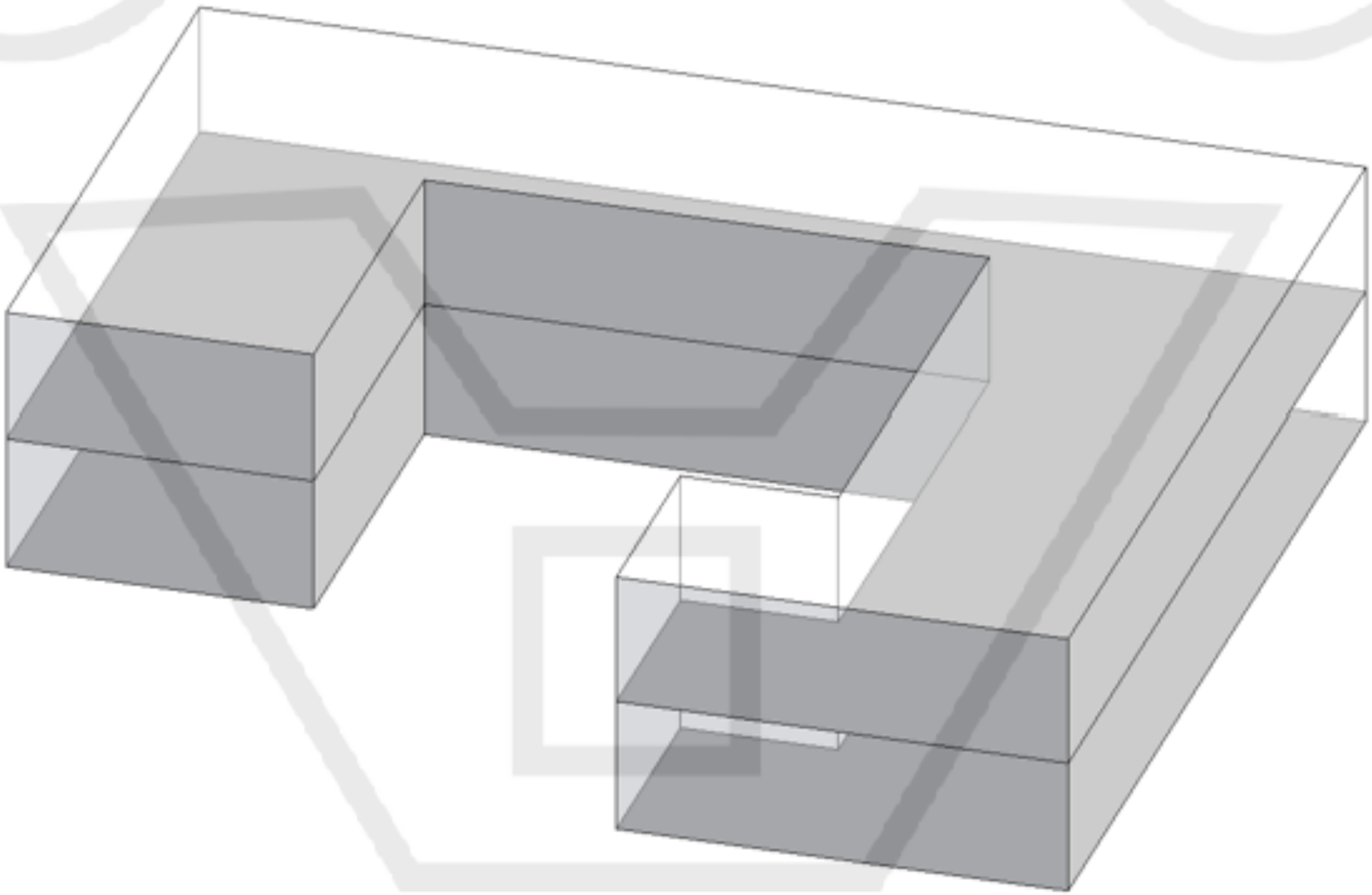
1st STEP: MODEL ARCHITECTURAL MASSES

- start mass modeling



1st STEP: MODEL ARCHITECTURAL MASSES

- create floors from the generic mass using grid level



2st STEP: SET FUNCTIONAL DESTINATION

Advanced Energy Settings

Parameter	Value
Detailed Model	
Target Percentage Glazing	40%
Target Sill Height	75.00
Glazing is Shaded	☐
Shade Depth	60.00
Target Percentage Skylights	0%
Skylight Width & Depth	91.44
Building Data	
Building Type	Office
Building Operating Schedule	12/5 Facility

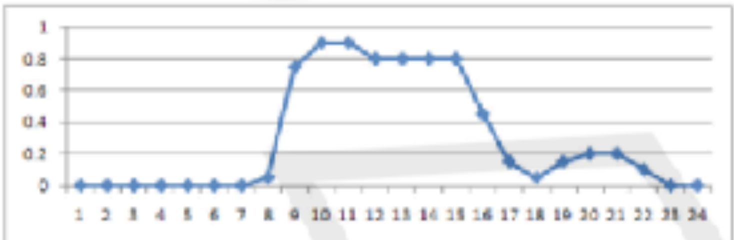
TYPICAL INPUT PARAMETERS FOR BUILDING ENERGY MODELING

Model input set	Input parameters
Location specific	• Local climate data (typically imported via a weather file in the software) • Interior conditions and set points
Architectural massing and form	(Typically imported through 3D geometrical modeling tools such as Google Sketchup) • Building shape and orientation • Total floor area • Number of floors and thermal zoning • Floor-to-ceiling height
Building envelope	• Window-to-wall ratio • Area, orientation, solar absorptance, and thermal transmittance of all opaque building surface • Area, orientation, solar heat gain coefficient, visible light and thermal transmittance, and shading of all glazing components • Mass of building components • Infiltration rates
Thermal and electric loads	• Lighting intensity • Plug loads intensity • Sensible and latent (moisture) loads from people and other equipment • Pumps, motors, fans, elevators
Schedule of operations	• Lighting schedules • Plug-load schedules • Occupancy schedules
Mechanical and Electrical (M&E) systems	• Cooling/Heating system type, including the source, distribution, and terminal units • Ventilation system type • Fan and pump inputs • Economizers and/or heat recovery systems • Domestic hot-water system • Specialty systems (e.g. fume hoods, exhausts) • Renewable-energy systems

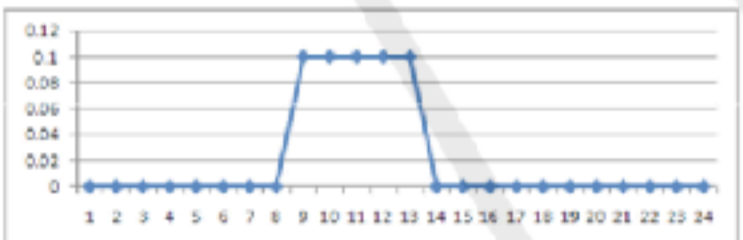
Commercial software have built-in industry standard default related to physical and technological properties, and benchmarks.

2st STEP: SET FUNCTIONAL DESTINATION

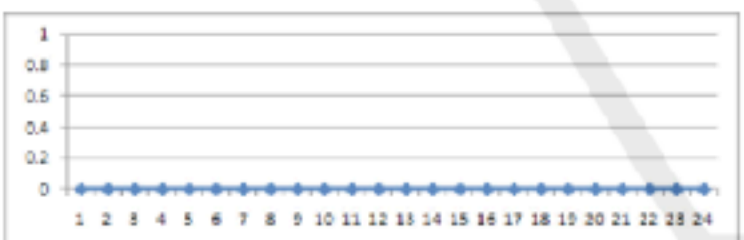
* eventually: specify Scheduling and Hourly Operational Profile



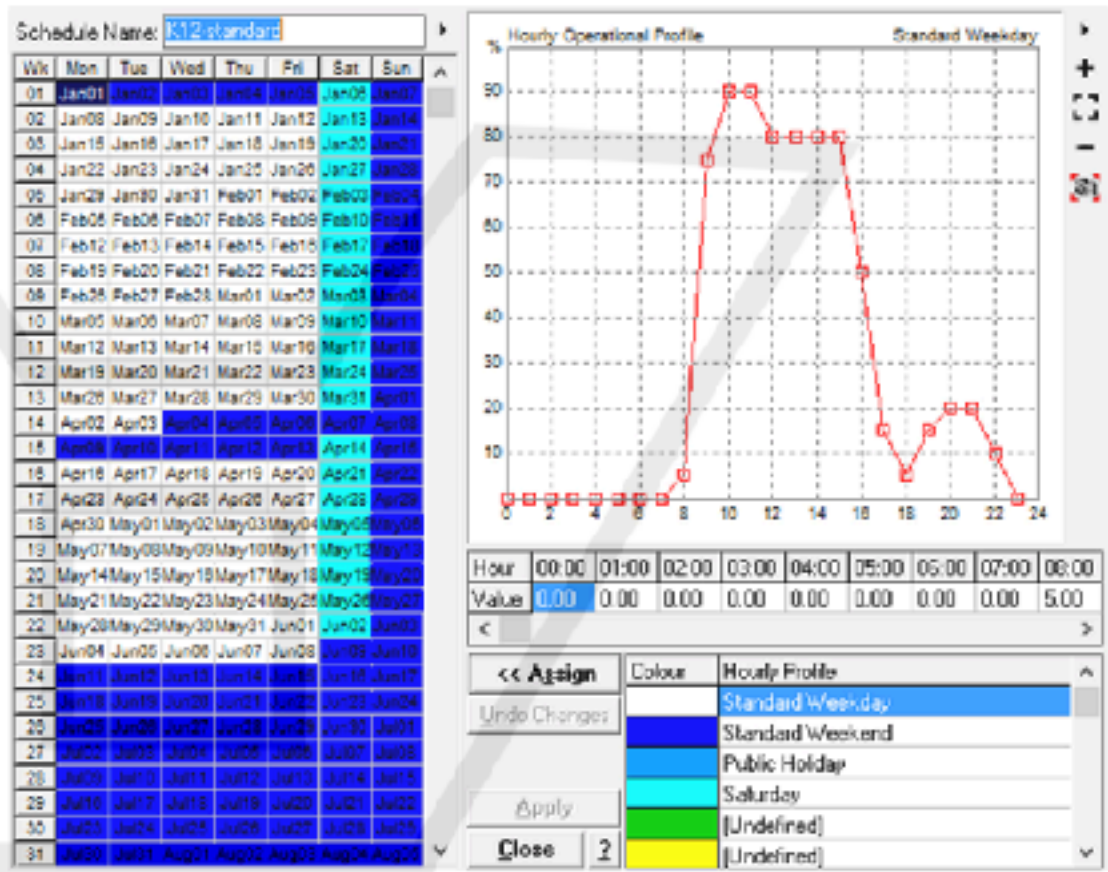
School schedule on weekdays



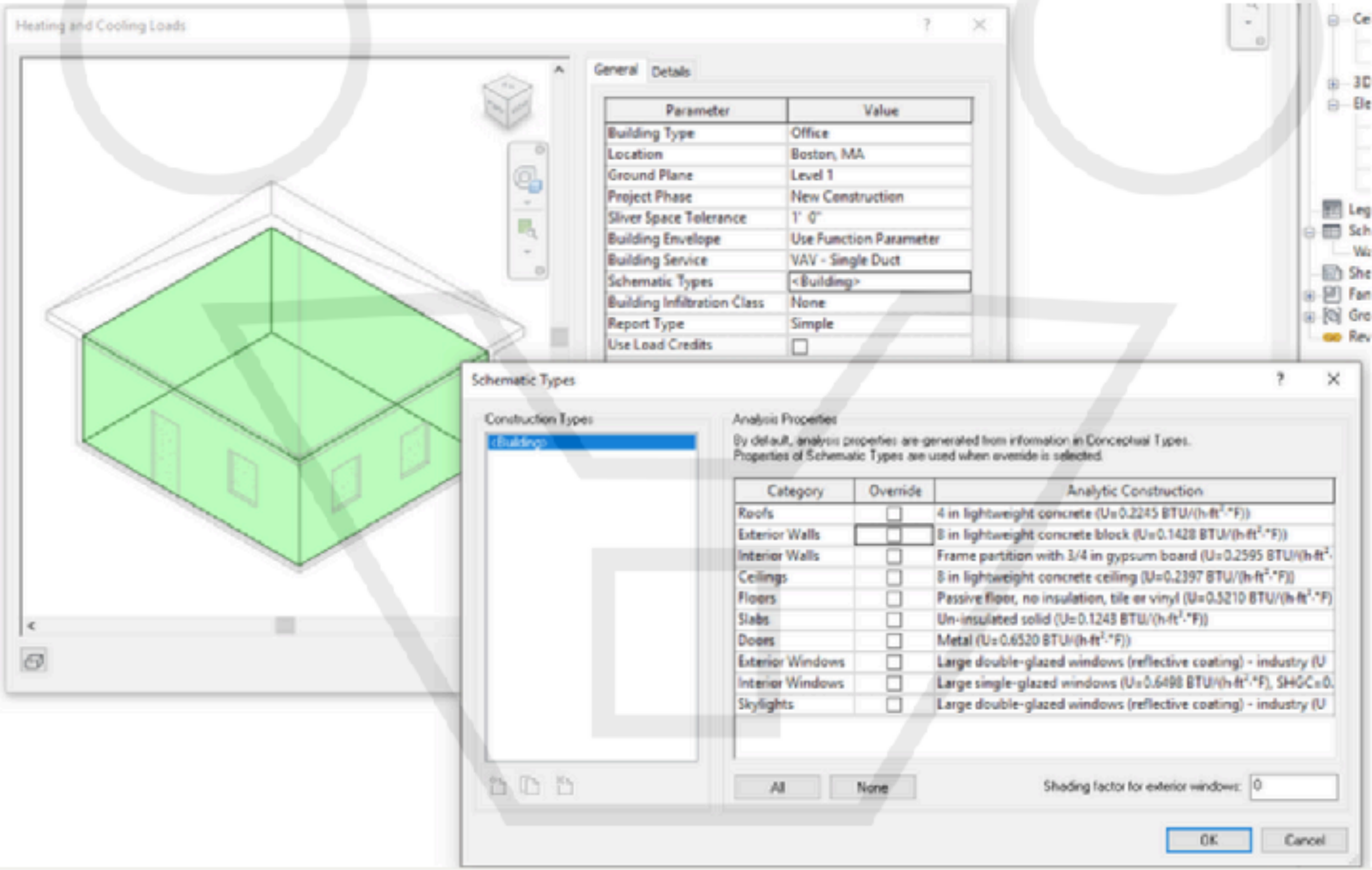
School schedule on Saturday



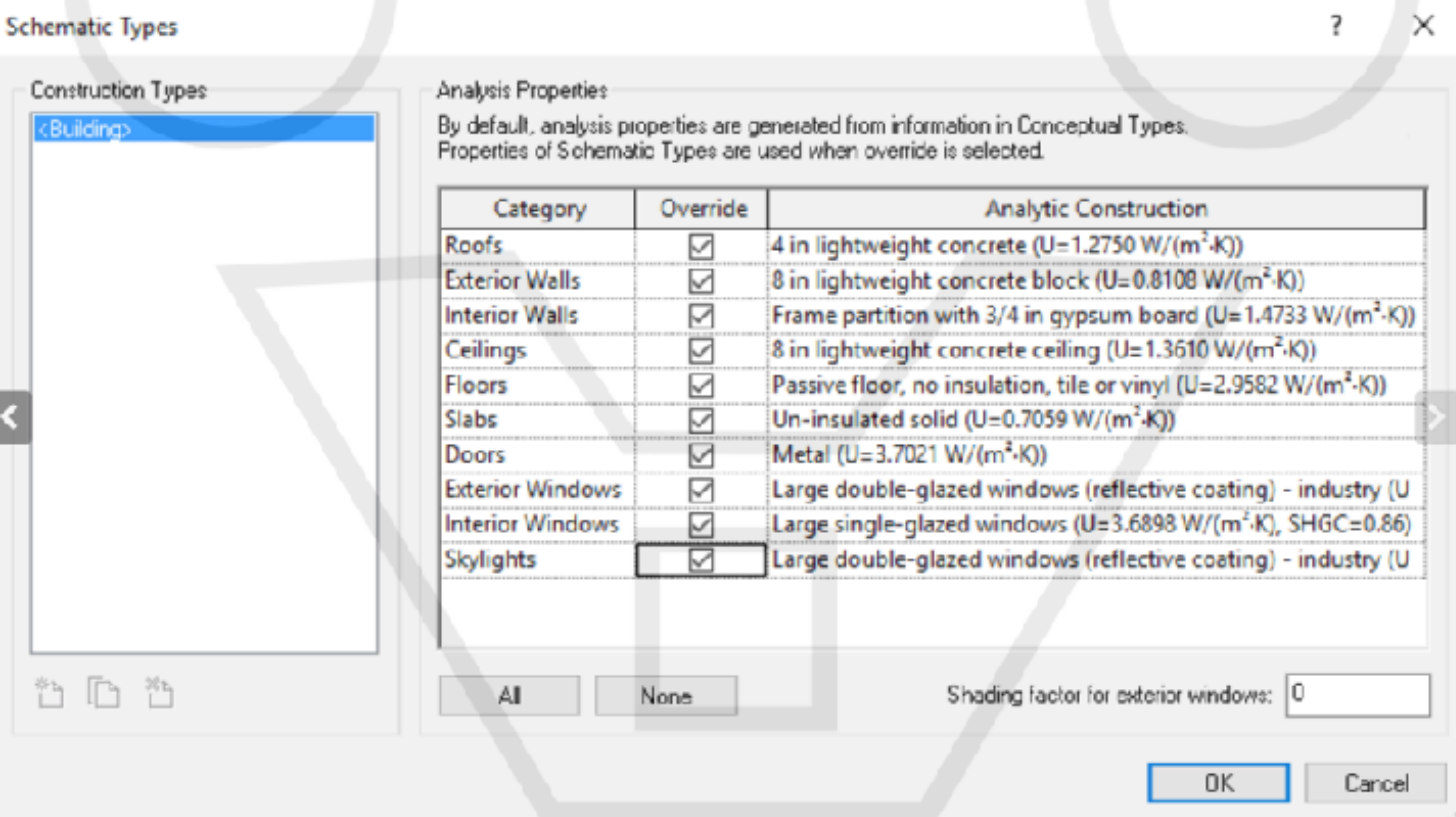
School schedule on Sunday



3st STEP: CHECK & SET DEFAULT CONSTRUCTION TYPES



3st STEP: CHECK & SET DEFAULT CONSTRUCTION TYPES



4st STEP: DEFINE DIFFERENT ALTERNATIVES

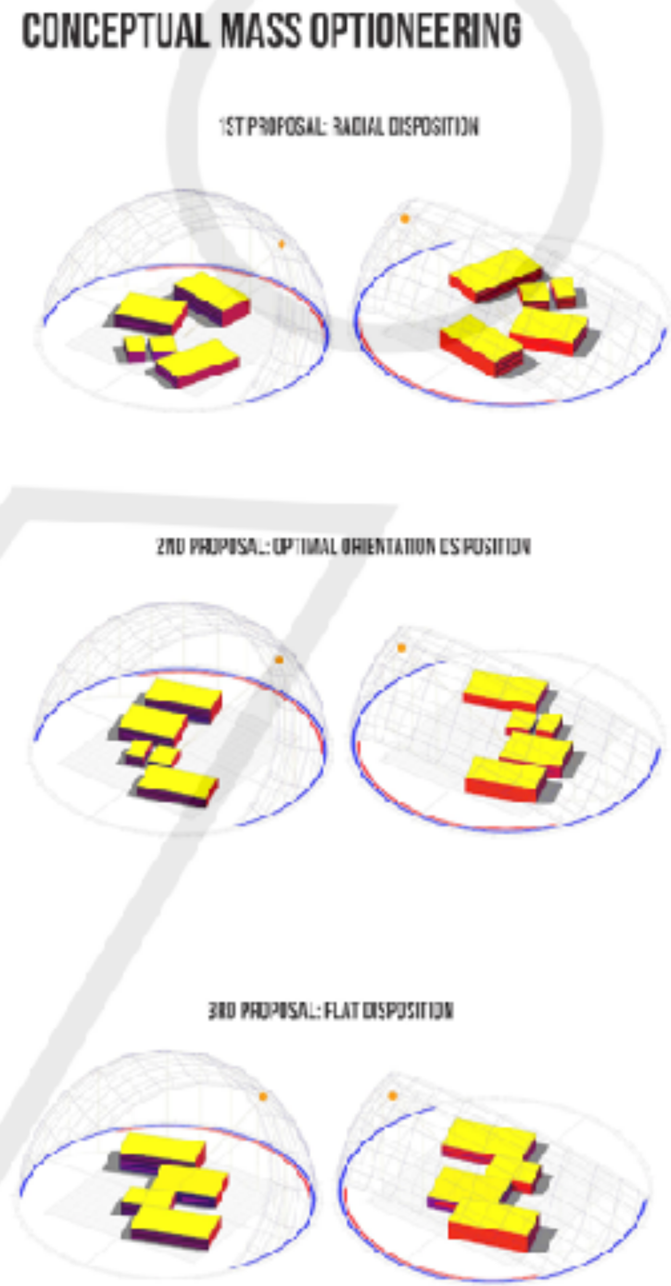
considering and evaluating:

-building orientation

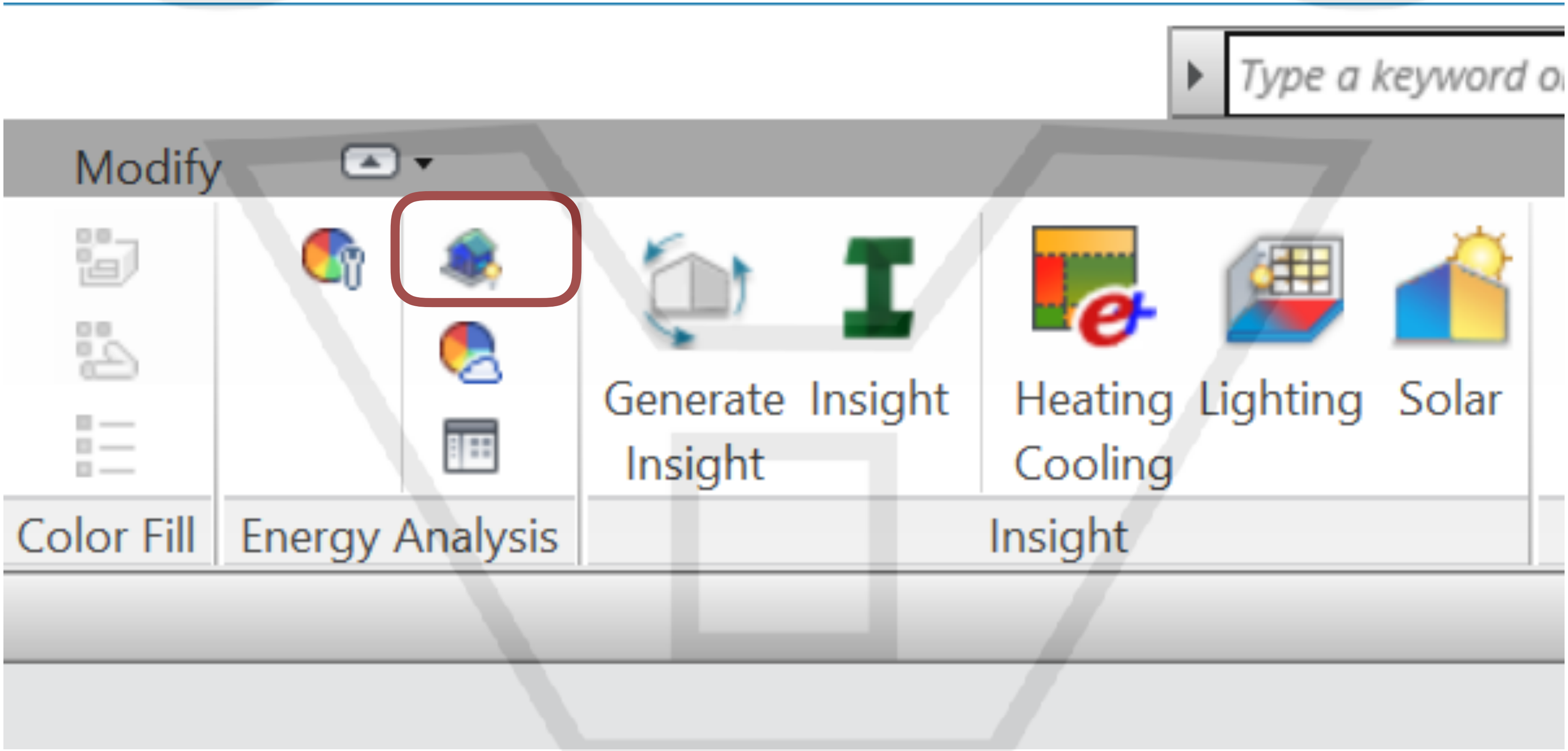
-compactness (footprint/volume)

-glazing ratio

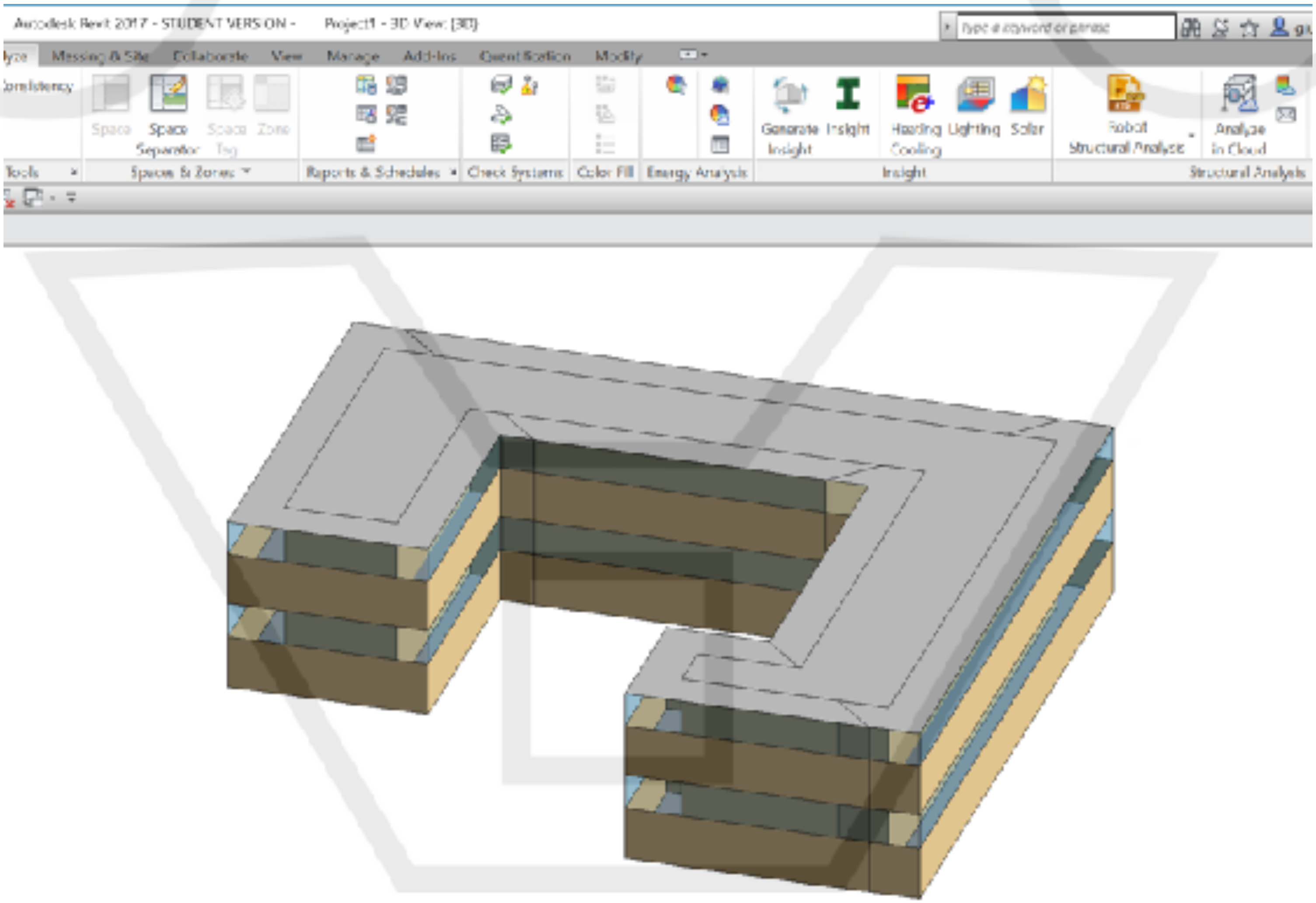
-...



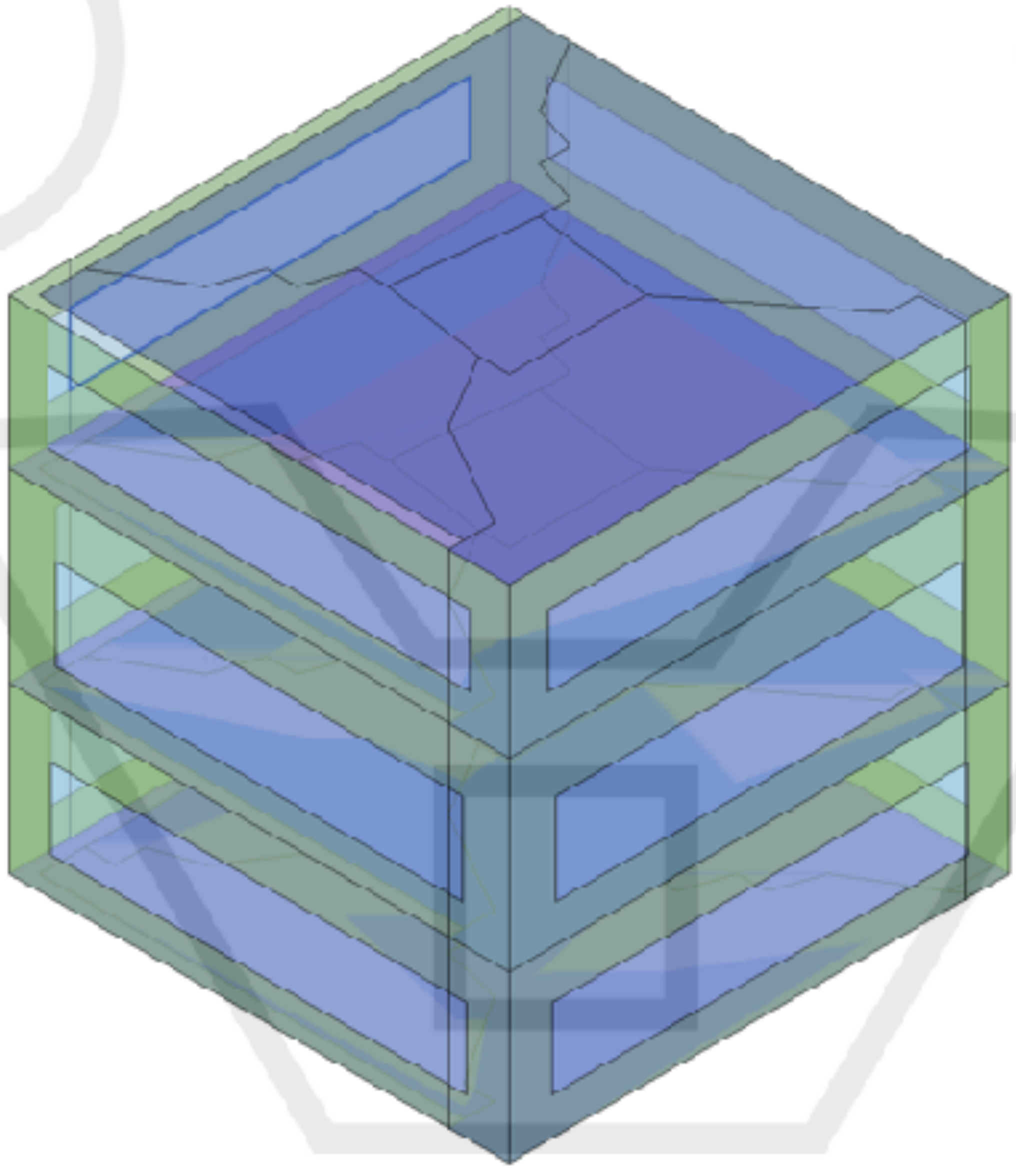
4st STEP: GENERATE THERMAL BLOCK



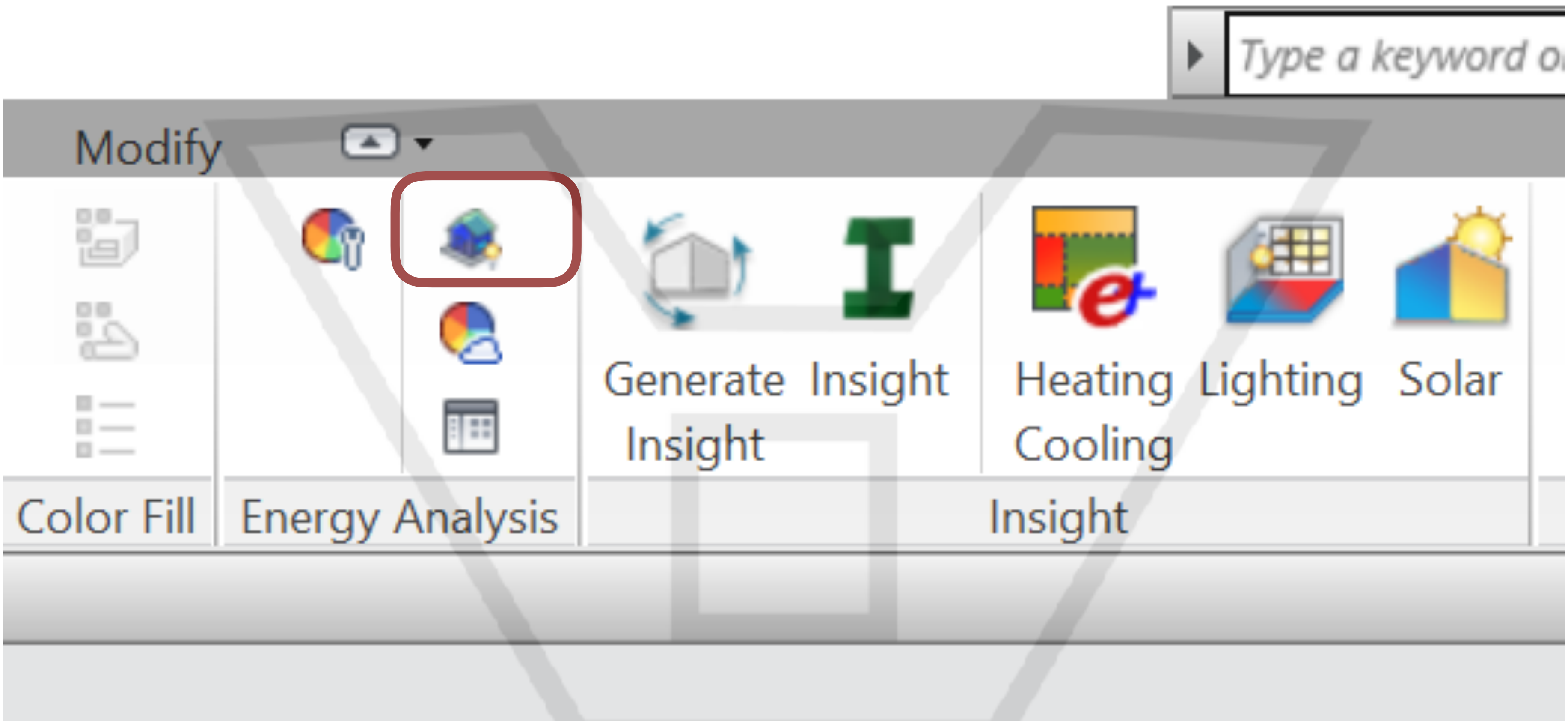
4st STEP: GENERATE THERMAL BLOCK



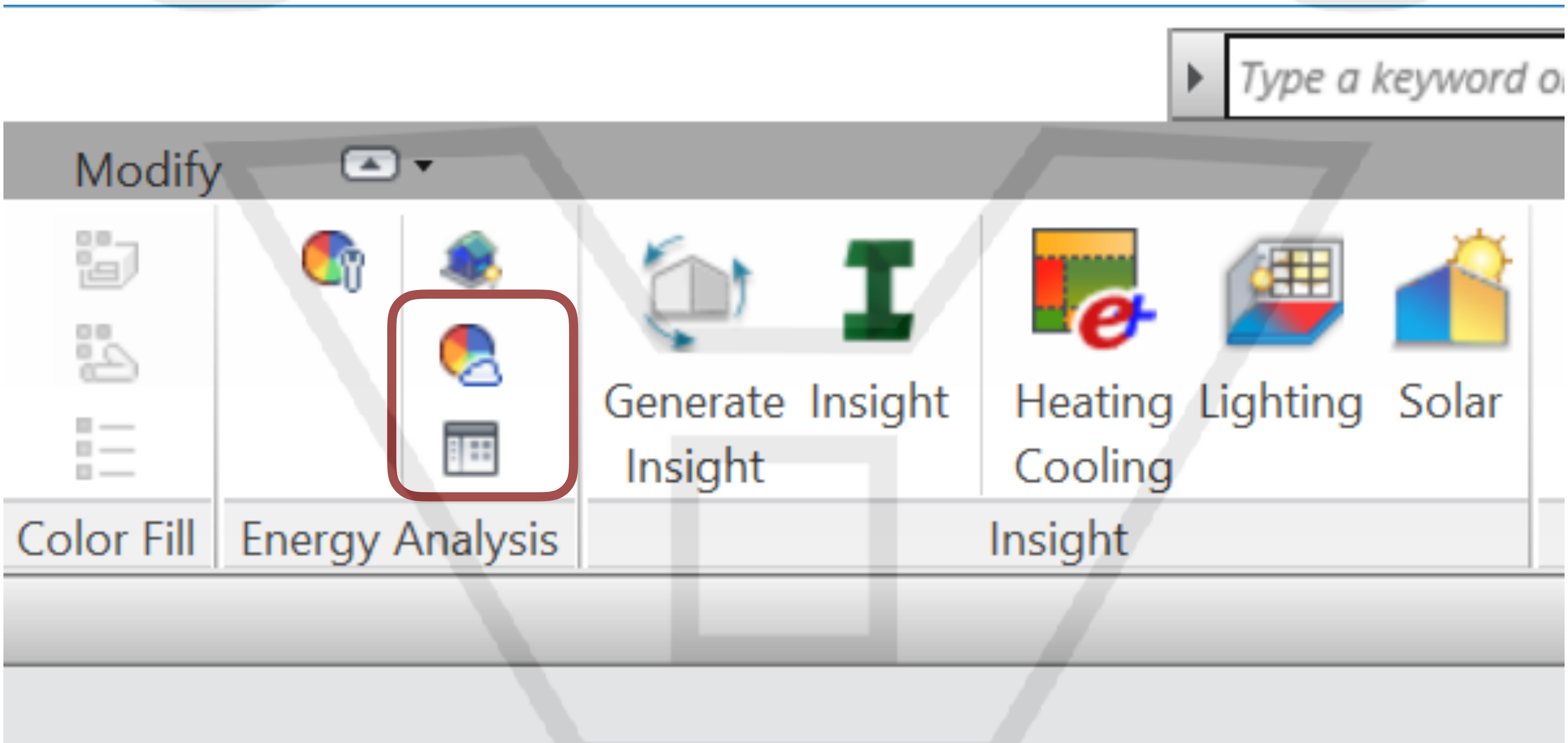
4st STEP: GENERATE THERMAL BLOCK



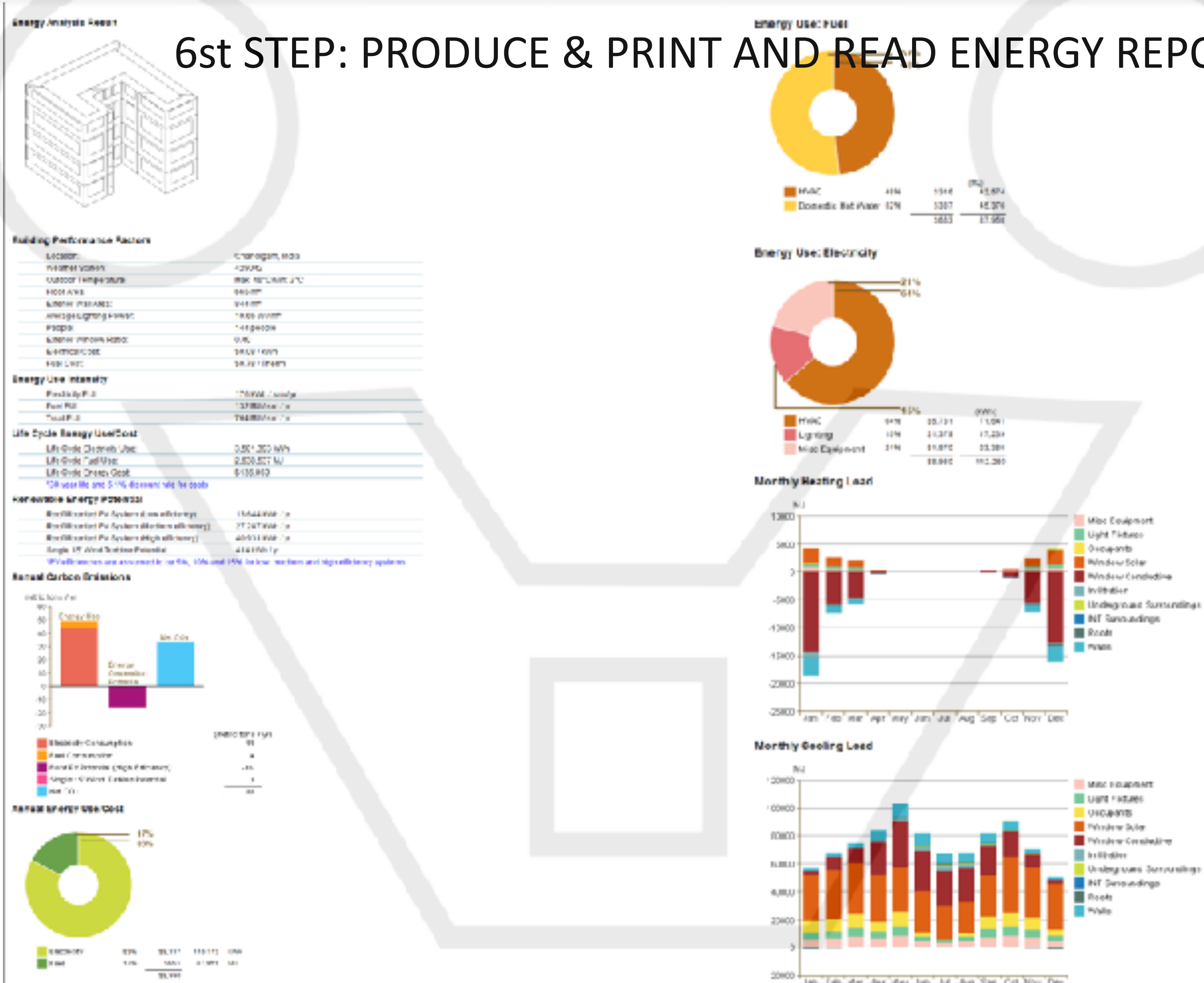
5st STEP: RUN ENERGY COMPUTATION



6st STEP: PRODUCE & PRINT AND READ ENERGY REPORT

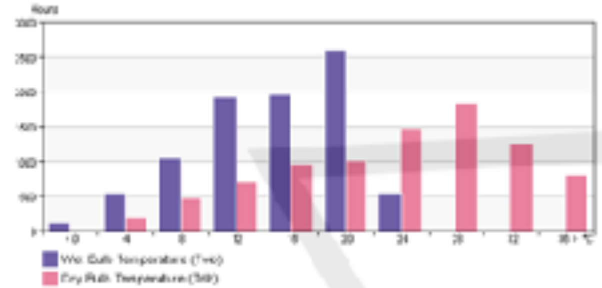


6st STEP: PRODUCE & PRINT AND READ ENERGY REPORT

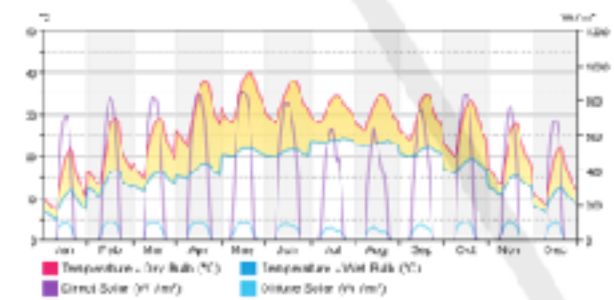


Monthly Design Data

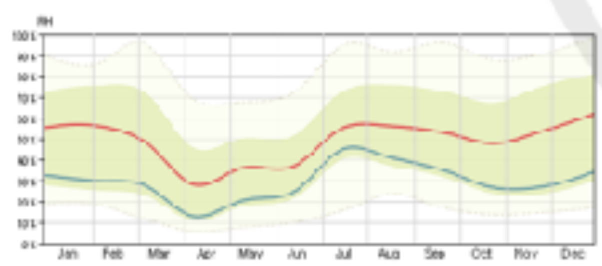
Annual Temperature Bins



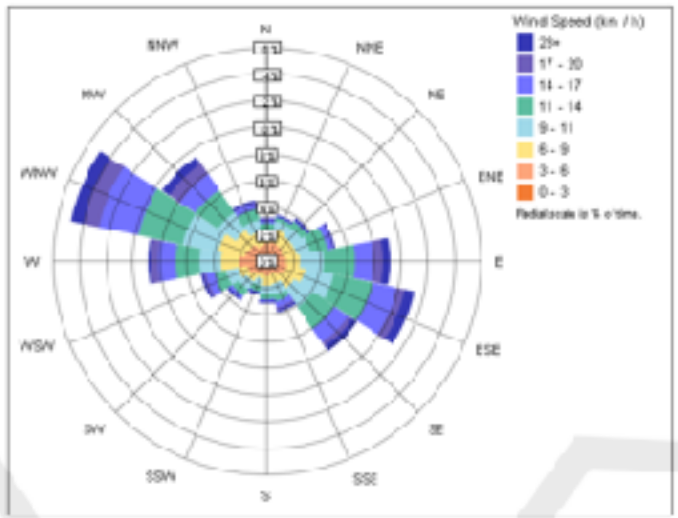
Diurnal Weather Averages



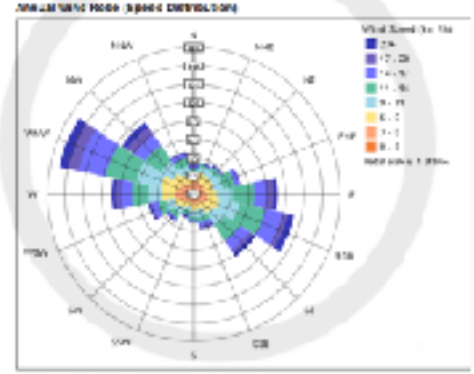
Humidity



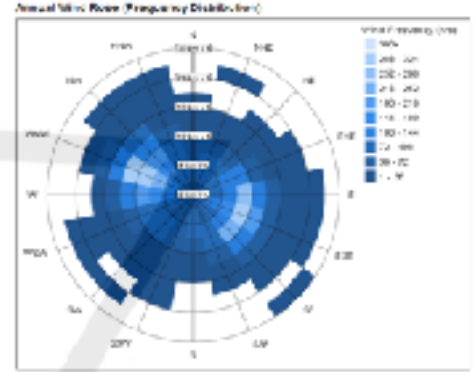
Annual Wind Rose (Speed Distribution)



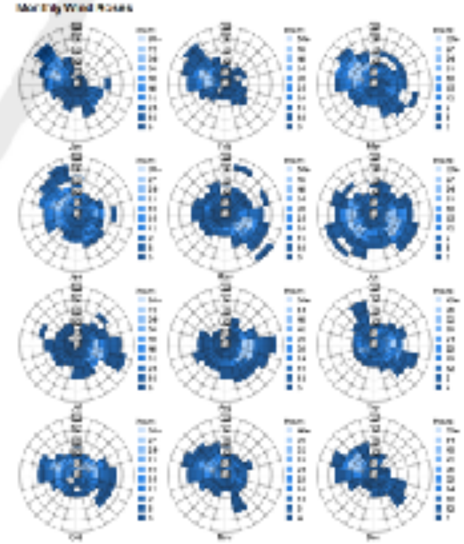
Annual Wind Rose (Speed Distribution)

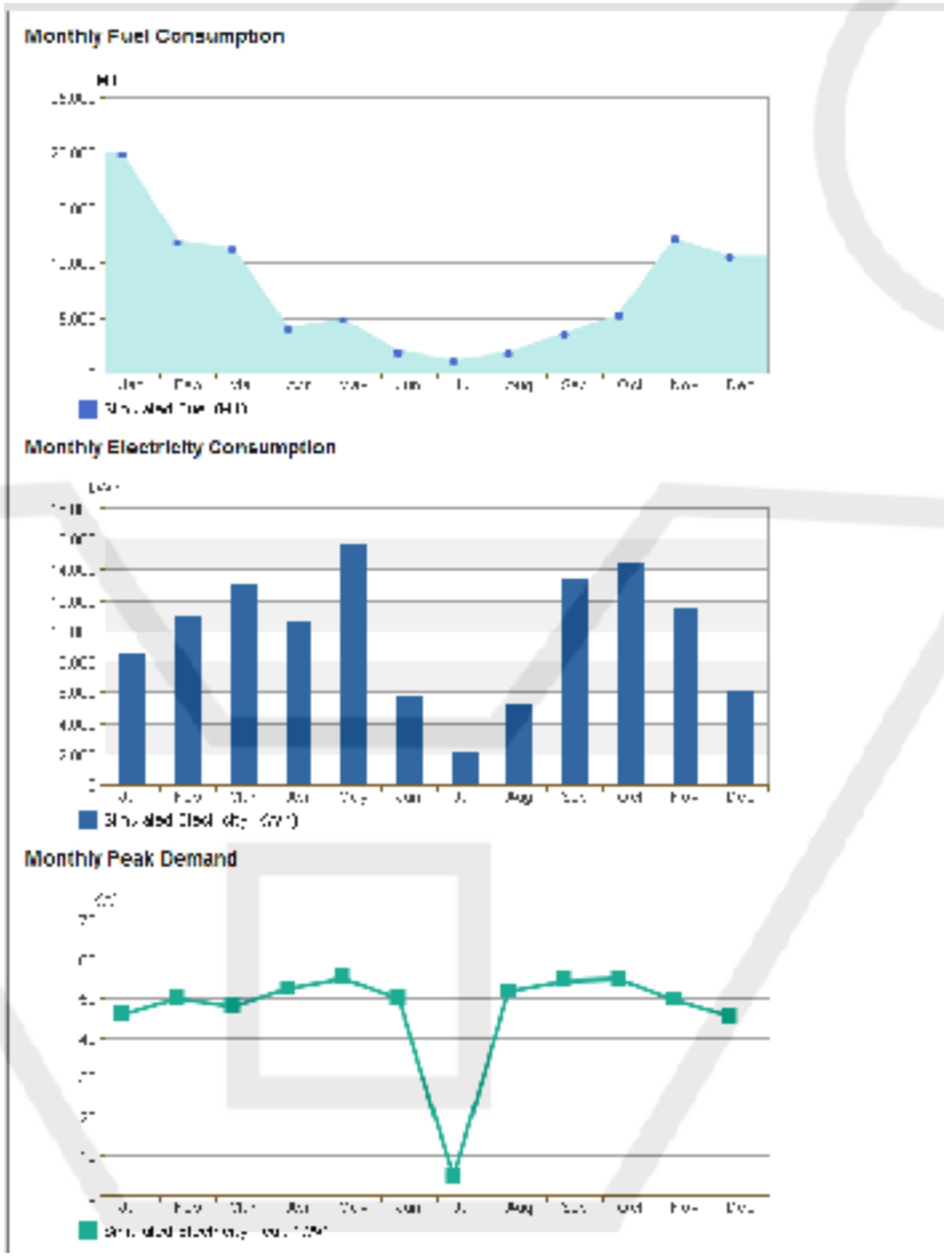


Annual Wind Rose (Frequency Distribution)



Monthly Wind Roses

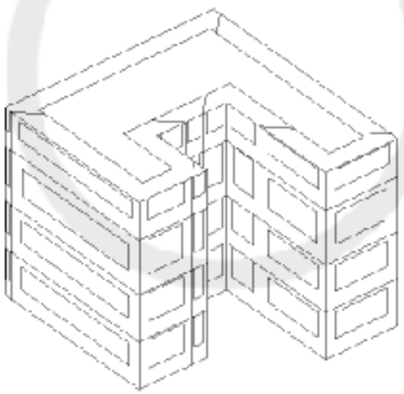



Monthly Fuel Consumption
Monthly Electricity Consumption
Monthly Peak Demand

6st STEP: PRODUCE & PRINT AND READ ENERGY REPORT

* subtract renewable energy contribution in order to have comparable alternatives

Energy Analysis Result



Building Performance Factors

Location:	Chandigarh, India
Weather Station:	429042
Outdoor Temperature:	Max: 46°C/Min: 3°C
Floor Area:	655 m²
Exterior Wall Area:	814 m²
Average Lighting Power:	10.66 W / m²
People:	144 people
Exterior Window Ratio:	0.40
Electrical Cost:	$0.08 / kWh
Fuel Cost:	$0.78 / Therm

Energy Use Intensity

Electricity EUI:	176 kWh / sm / yr
Fuel EUI:	132 MJ / sm / yr
Total EUI:	764 MJ / sm / yr

Life Cycle Energy Use/Cost

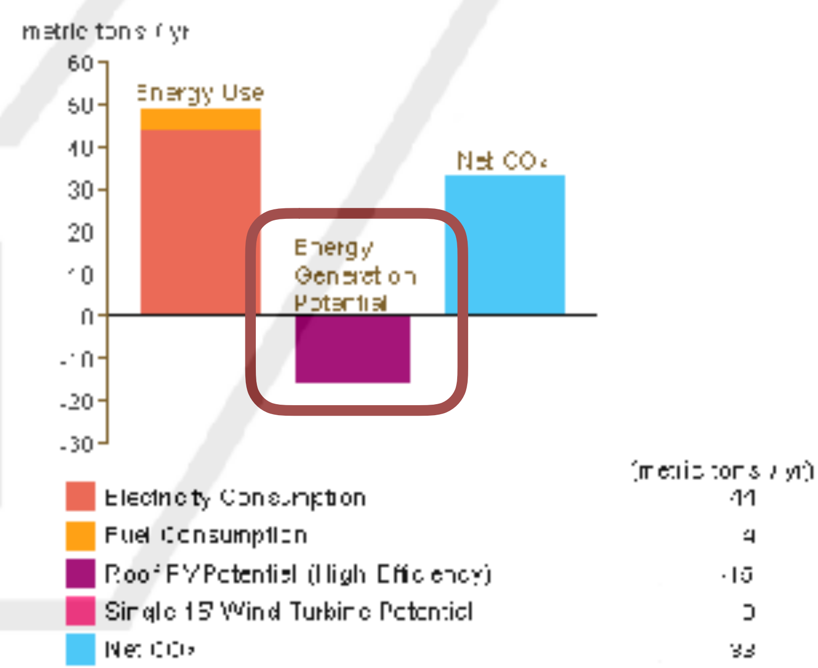
Life Cycle Electricity Use:	3,501,393 kWh
Life Cycle Fuel Use:	2,638,537 MJ
Life Cycle Energy Cost:	$135,069

Renewable Energy Potential

Roof Mounted PV System (Low efficiency):	13,644 kWh / yr
Roof Mounted PV System (Medium efficiency):	27,287 kWh / yr
Roof Mounted PV System (High efficiency):	40,931 kWh / yr
Single 15' Wind Turbine Potential:	414 kWh / yr

*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems

Annual Carbon Emissions



6st STEP: PRODUCE & PRINT AND READ ENERGY REPORT

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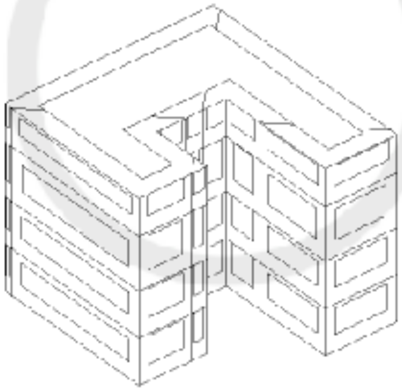
Energy Analysis Result



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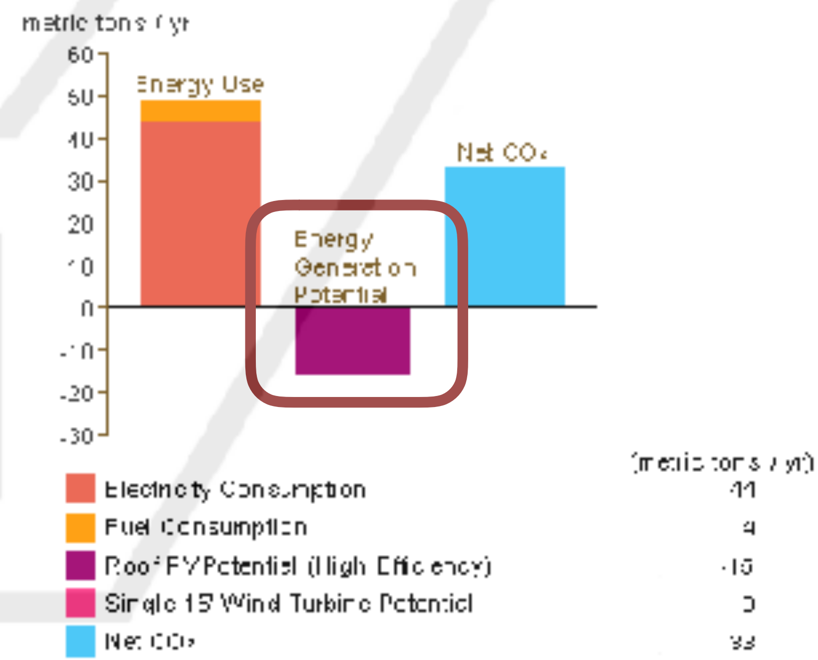
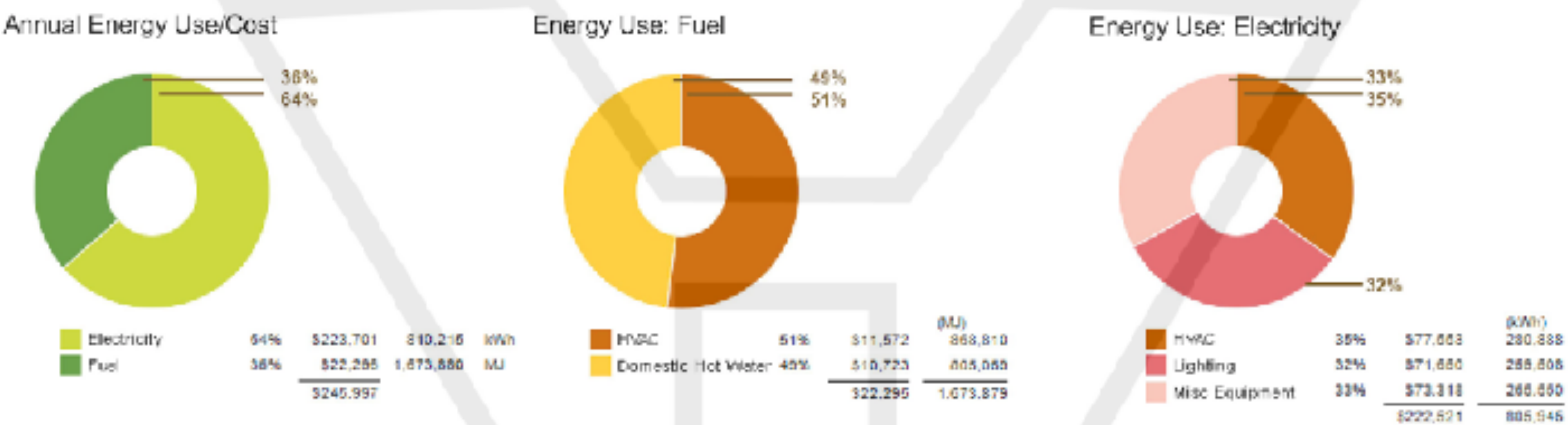
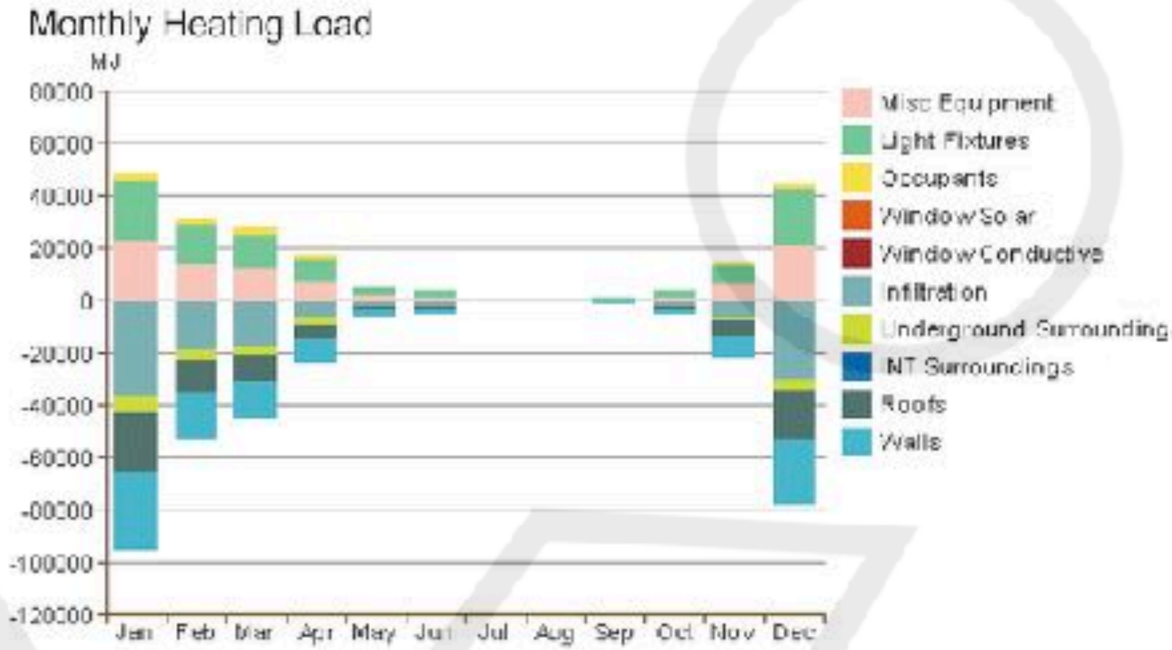


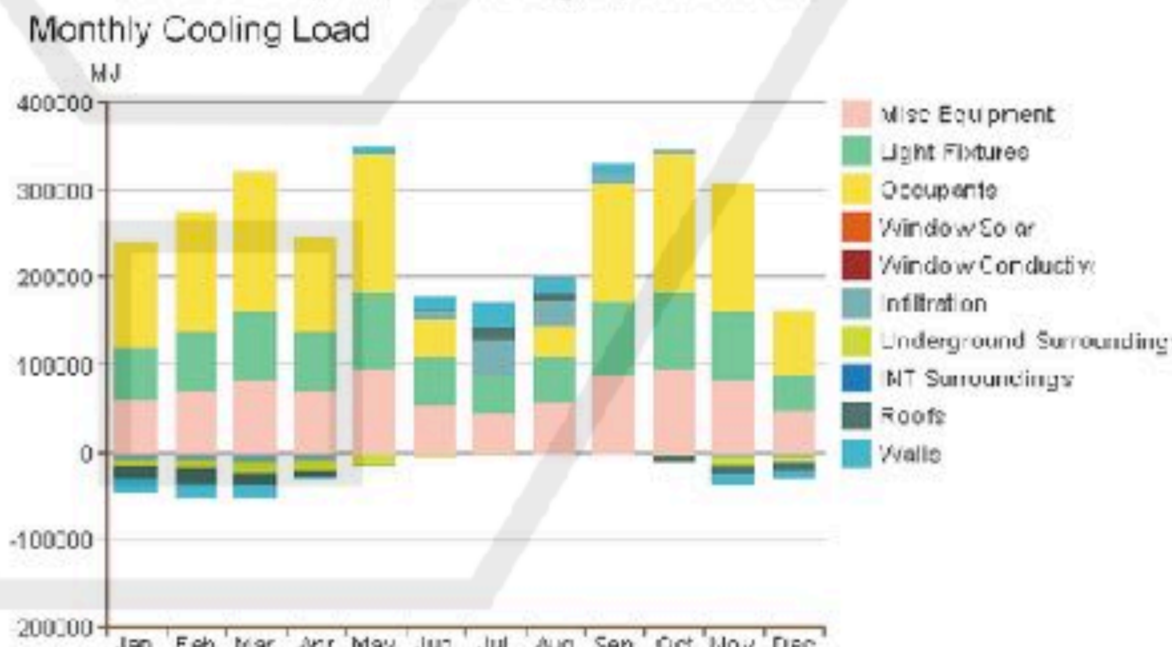
6st STEP: PRODUCE & PRINT AND READ ENERGY REPORT

* compare Fuel vs Electricity (HVAC/Lighting) in order to understand if the building is mainly that or to cool



* pay attention to Energy Loads in order to understand:
-the biggest concern for gains/losses





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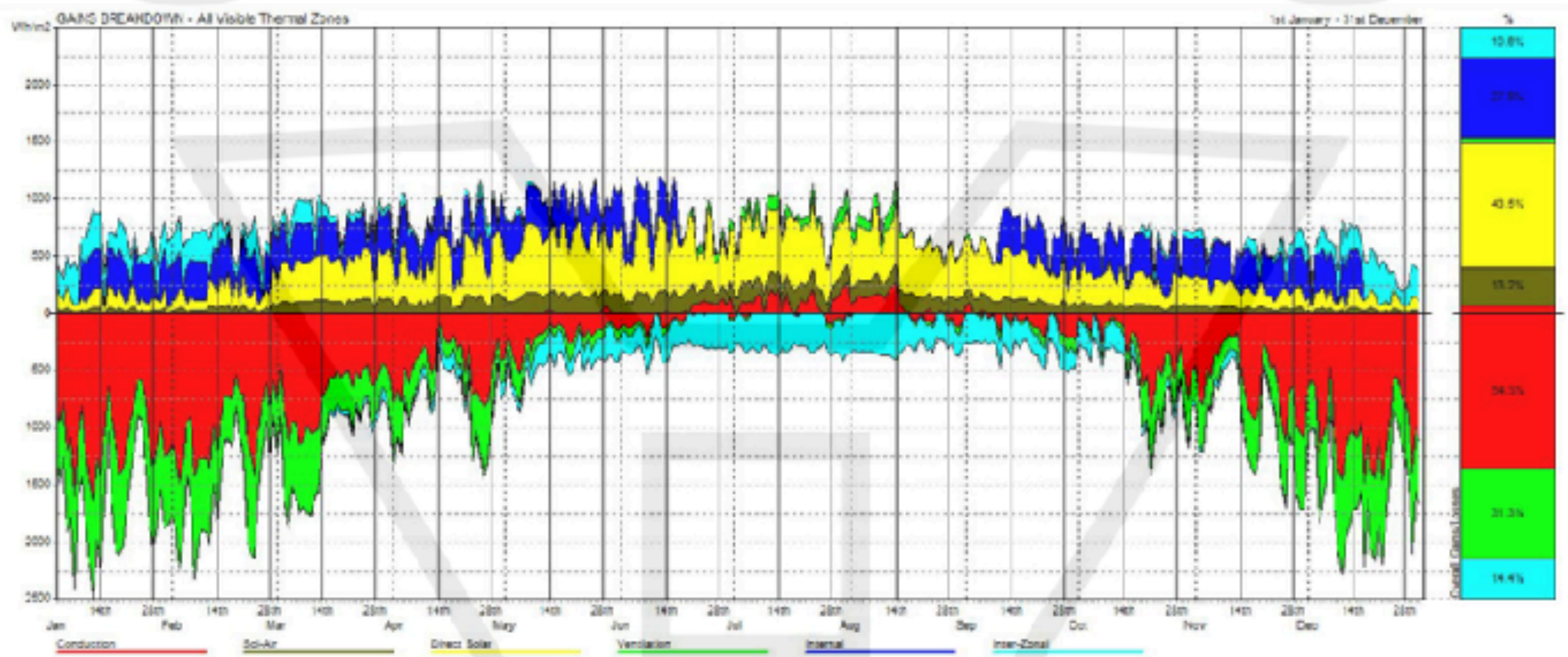


Passive Gains Breakdown

This analysis will show us the areas of biggest concern for gains/losses in our building.

Here we can see that heat loss through the external fabric is the largest contributor.

Internal vs. External Loads in Energy Analysis Output

Internal Loads
Heat generated from within the building.

- Misc Equipment — Includes plug loads like computers and office equipment.
- Lighting
- Occupants

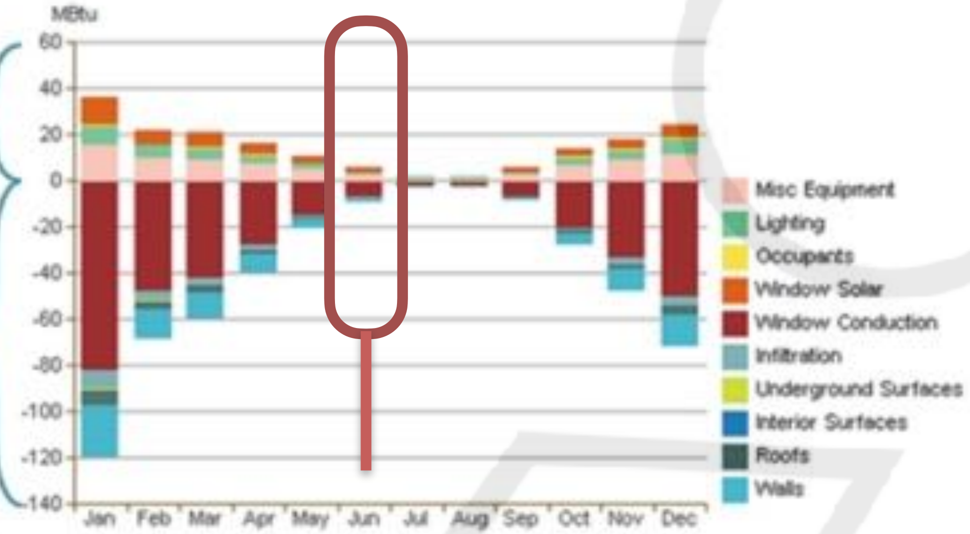
External Loads
Heat gain or loss due to conduction, convection, and radiation through the envelope.

- Window Solar
- Window Conduction
- Infiltration
- Underground Surfaces
- Interior Surfaces
- Roofs
- Walls

Monthly Heating Loads

Heat gains that offset the heating loads.

Heat energy being lost.
Heat must be added to maintain thermal comfort.

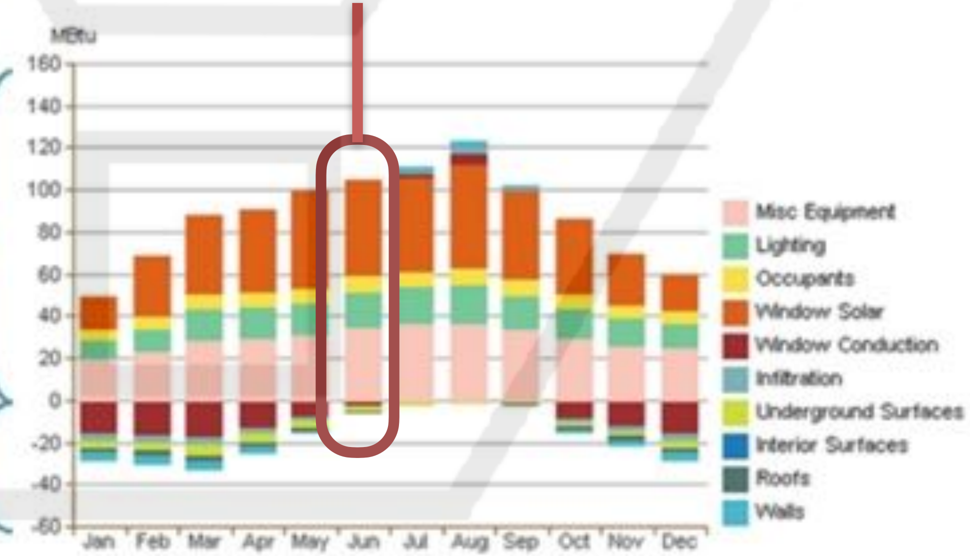


WHY DO WE HAVE DIFFERENT LOADS IN THE SAME PERIOD?

Monthly Cooling Loads

Heat energy being gained.
Heat must be removed to maintain thermal comfort.

Heat losses that offset cooling loads.

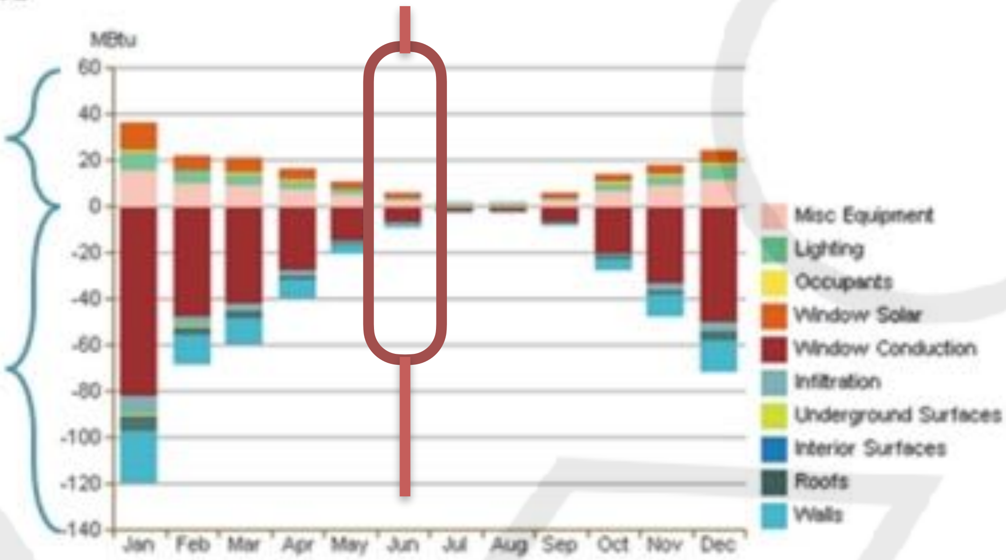


Monthly Heating Loads

Heat gains that offset the heating loads.

Heat energy being lost.
Heat must be added to maintain thermal comfort.

Hottest hours >> Day Hours

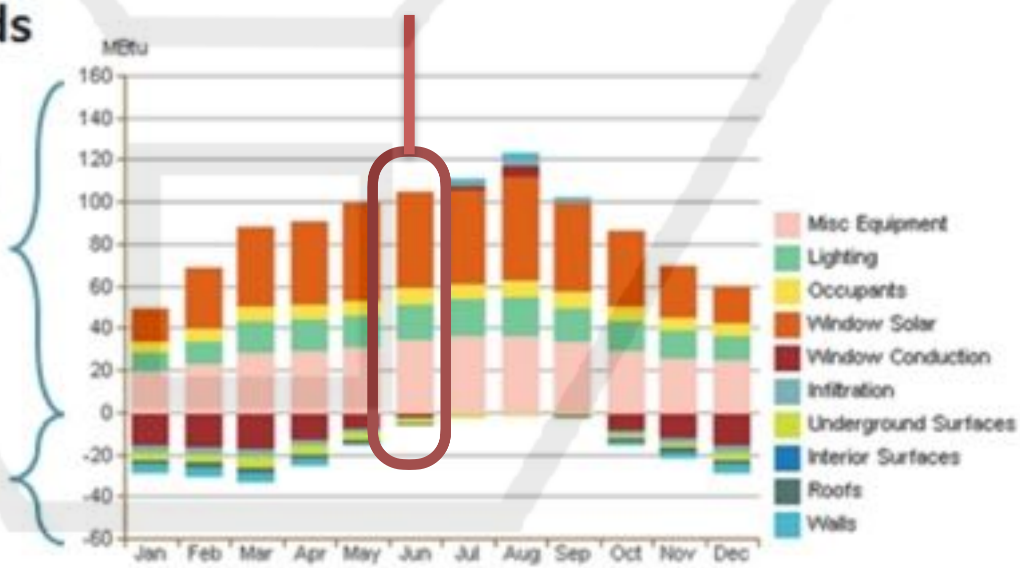


Monthly Cooling Loads

Heat energy being gained.
Heat must be removed to maintain thermal comfort.

Heat losses that offset cooling loads.

Coldest hours >> Night Hours



Peak Heating Load

The peak heating load represents the amount of heat lost to the outdoor environment at design outdoor and indoor conditions, which must be made up by the HVAC system to maintain occupant comfort (Figure 5). There is one relatively straightforward and uncomplicated heat loss calculation procedure used in ACCA MJ8. The components of the heating load calculation are covered in depth in Section 4 of the ACCA MJ8. The total estimated heat loss is a combination of the sensible heat loss through conduction, infiltration, and ventilation loads. No credit is taken for solar gains or internal loads in calculating the heating load because the peak heat loss occurs at night during periods of occupant inactivity.

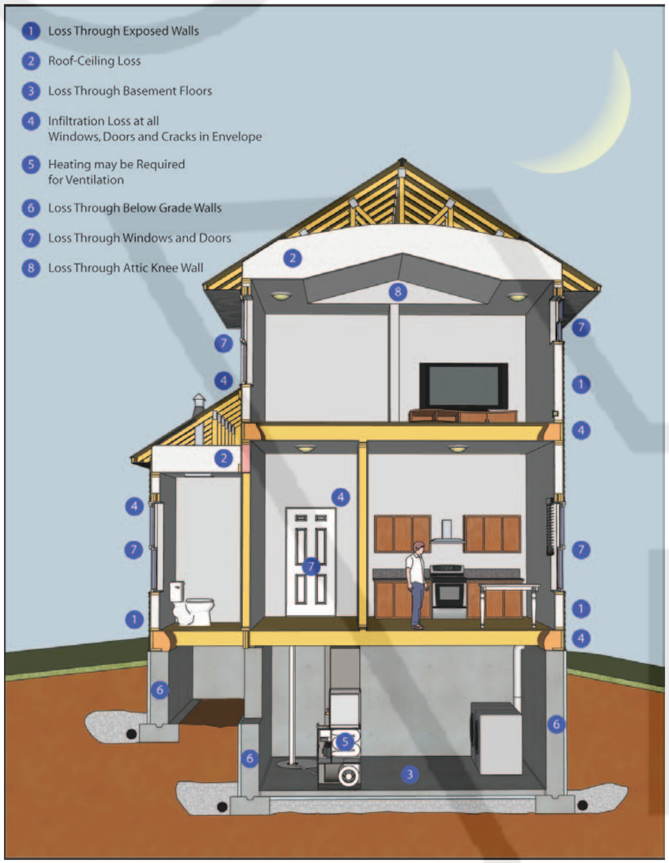


Figure 5. Heat Loss Locations

Peak Cooling Load

Peak cooling loads represent the amount of heat gained by the house from the outdoor environment at design conditions, which must be removed by the HVAC system to maintain occupant comfort. Cooling loads are made up of the sensible and latent heat gains. The mechanisms of heat gain are conduction, infiltration, ventilation, and radiation (Figure 6). The components of the cooling load calculation are covered in depth in ACCA MJ8.

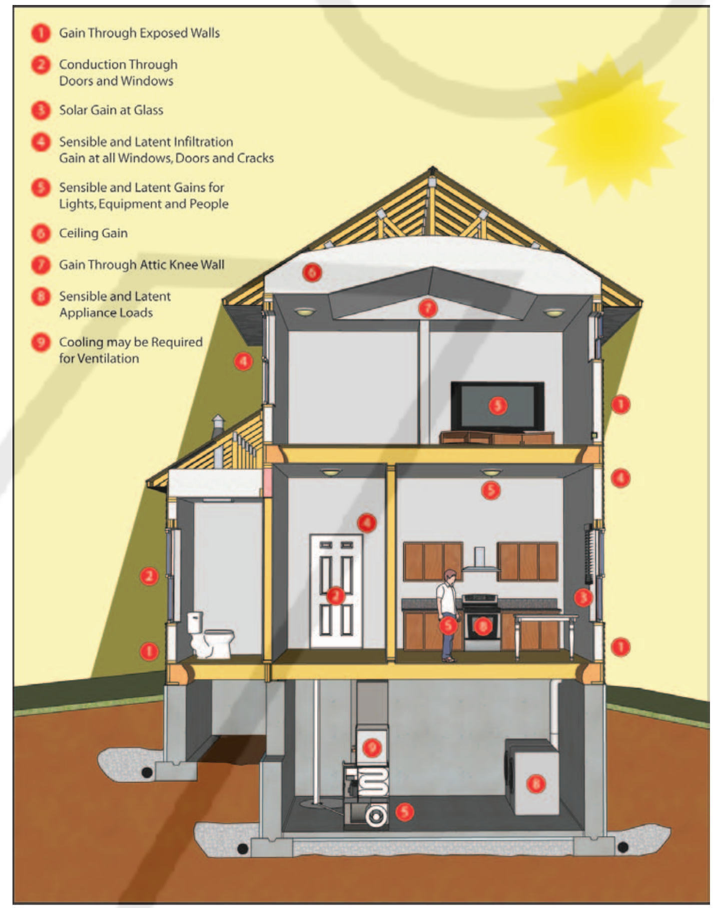
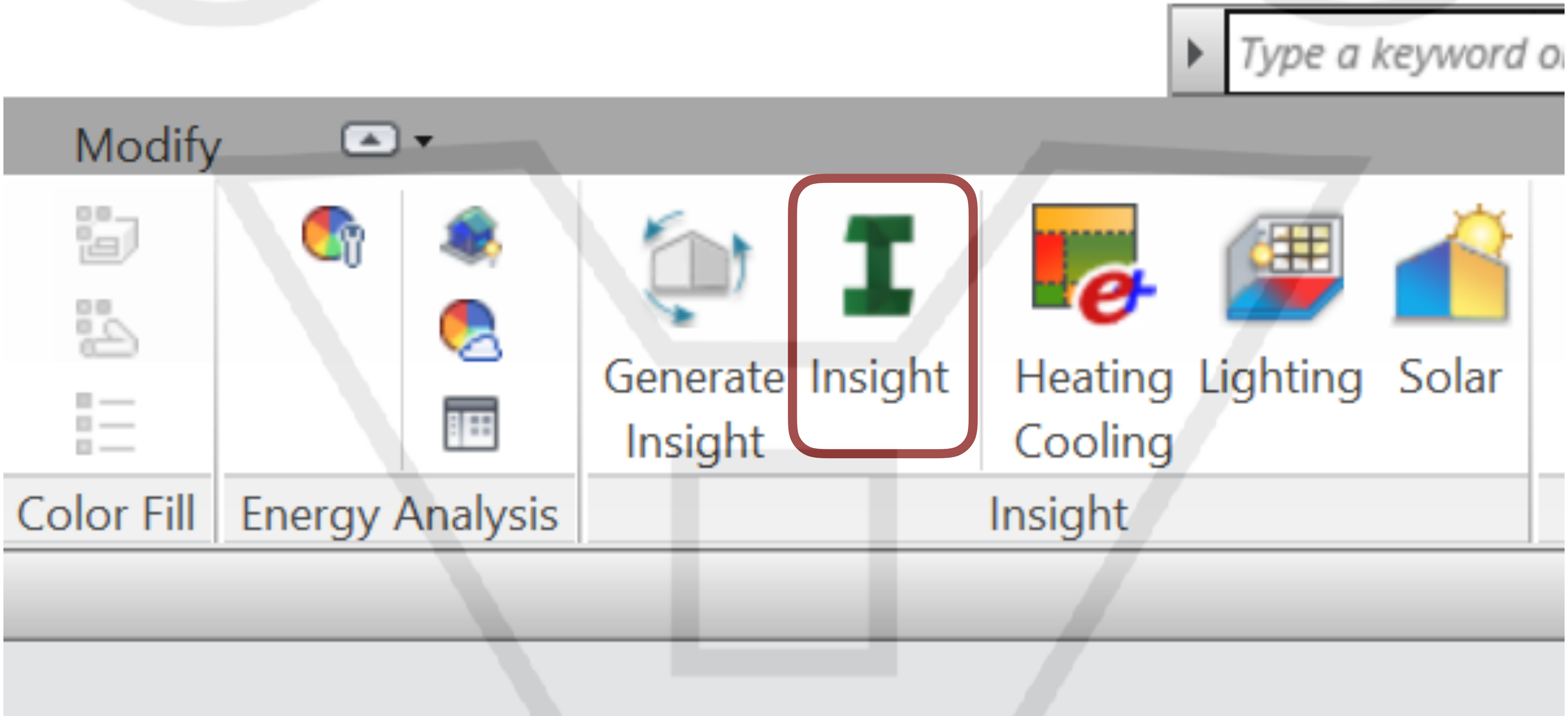


Figure 6. Heat Gain Locations

<no sun / no occupants contribution>

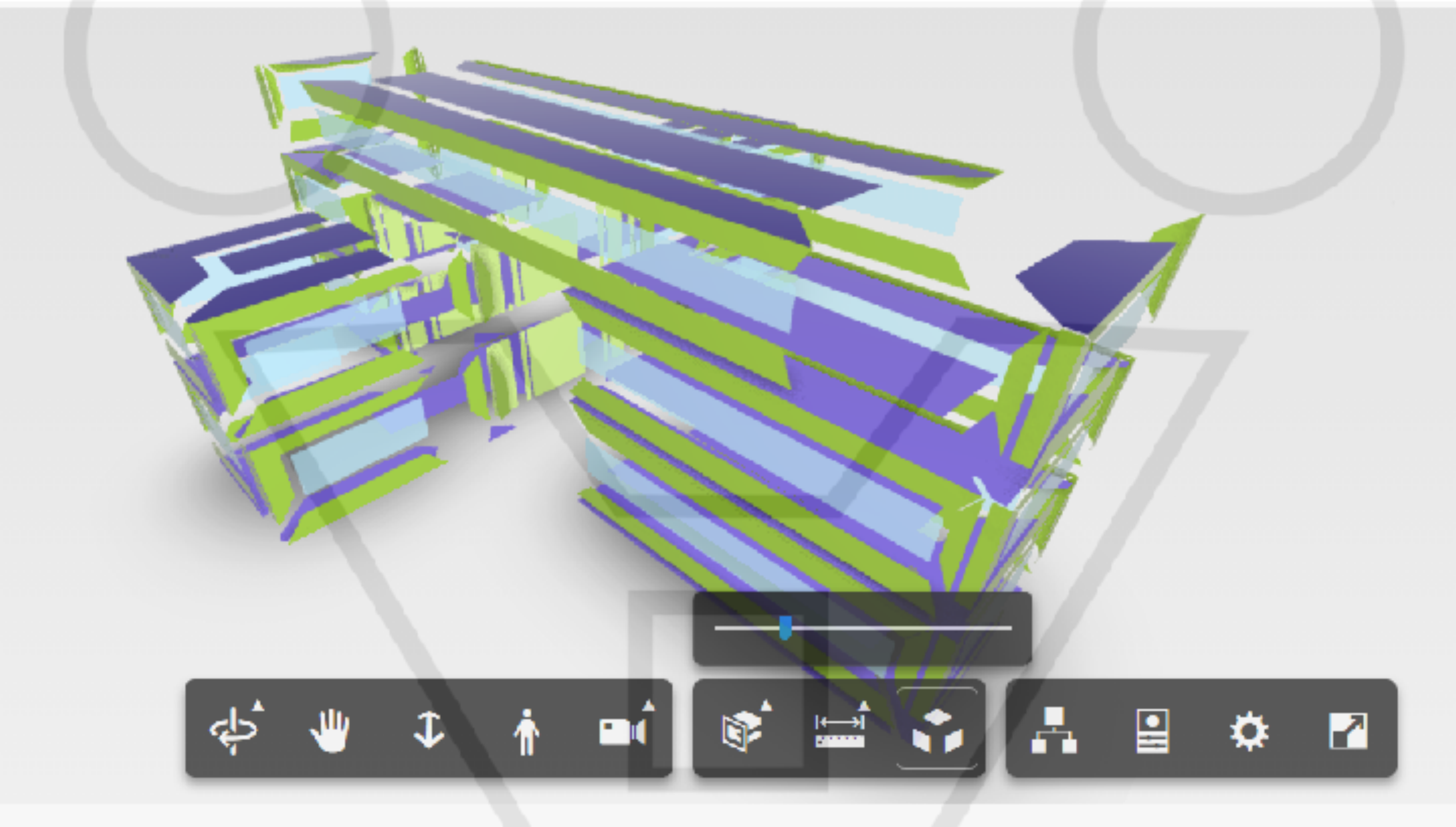
7st STEP: BENCHMARKING OPTIONS AND TUNING SOLUTIONS WITH AUTODESK INSIGHT



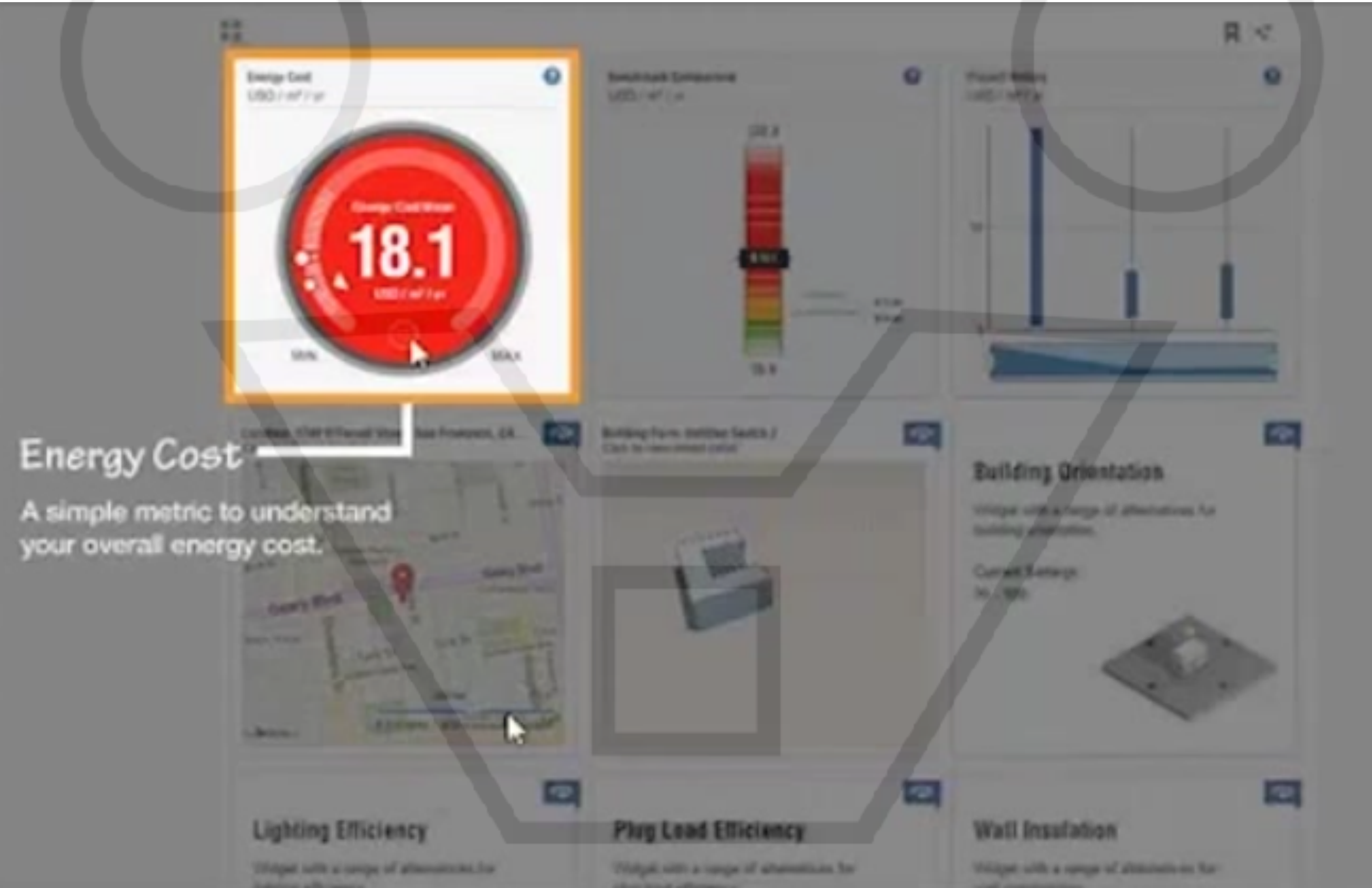
Early Targeting & Feasibility

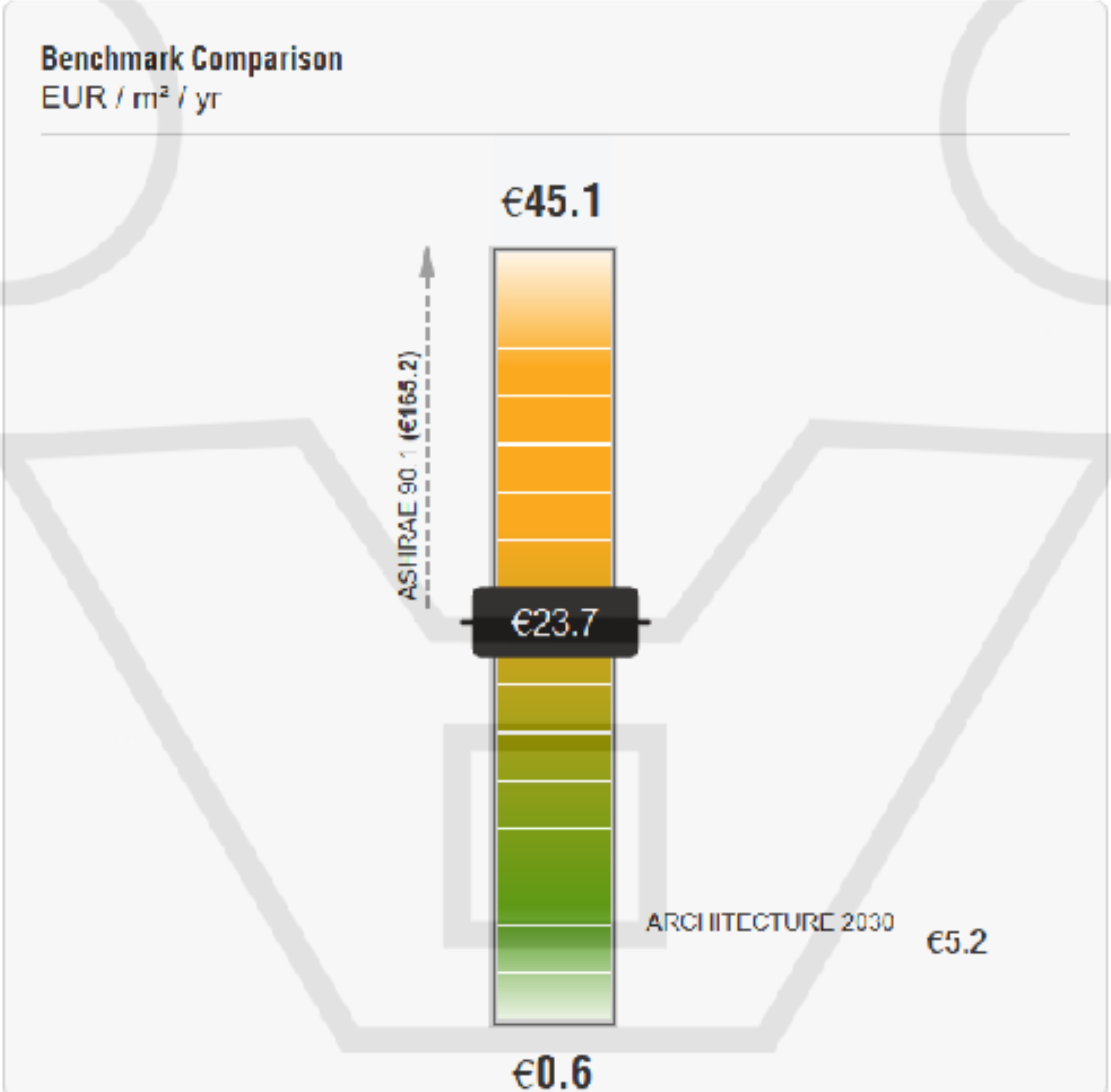
Energy Cost Range, Benchmarks, Factors & History


23.7
Location
Bing
Benchmark Comparison
€45.1
€23.7
€0.6
Model History
Operating Schedule
The typical hours of use by building occupants.
Current Setting:
24/7 - 12/7




14.6
MIN
MAX
$23.8
$7.1
Building Orientation
Widget with a range of alternatives for building orientation
Current Settings
315 - 0


Energy Cost
A simple metric to understand your overall energy cost.
18.1
Building Orientation
Lighting Efficiency
Plug Load Efficiency
Wall Insulation

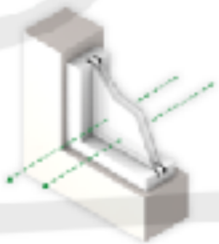

Benchmark Comparison
EUR / m² / yr
€45.1
ASHRAE 90.1 (€165.2)
€23.7
ARCHITECTURE 2030
€5.2
€0.6


13.2
Project History
Track your project performance over the lifecycle of the design.

Window Glass - West

Glass properties control the amount of daylight, heat transfer & solar heat gain into the building, along with other factors.

Current Setting:
Dbl LoE - Trp LoE



Window Shades - West

Shades can reduce HVAC energy use. The impact depends on other factors, such as window size and solar heat gain properties.

Current Setting:
BIM

Window Shades - East

Shades can reduce HVAC energy use. The impact depends on other factors, such as window size and solar heat gain properties.

Current Setting:
BIM - 2/3 Win Height

Building Orientation

Rotates a building clockwise from 0 degrees, e.g. 90 degrees rotates the North side of the building to face East.

Current Setting:
270

Daylighting & Occupancy Controls

Represents typical daylight dimming and occupancy sensor systems.

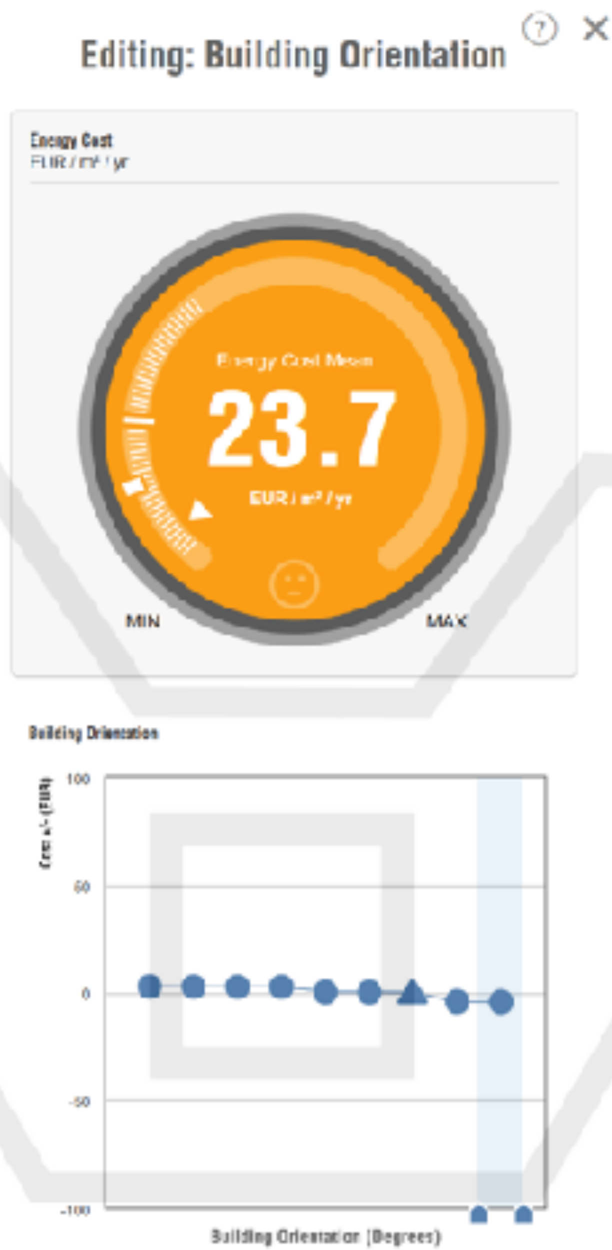
Current Setting:
None - Daylighting & Occupancy Controls

Window Shades - South

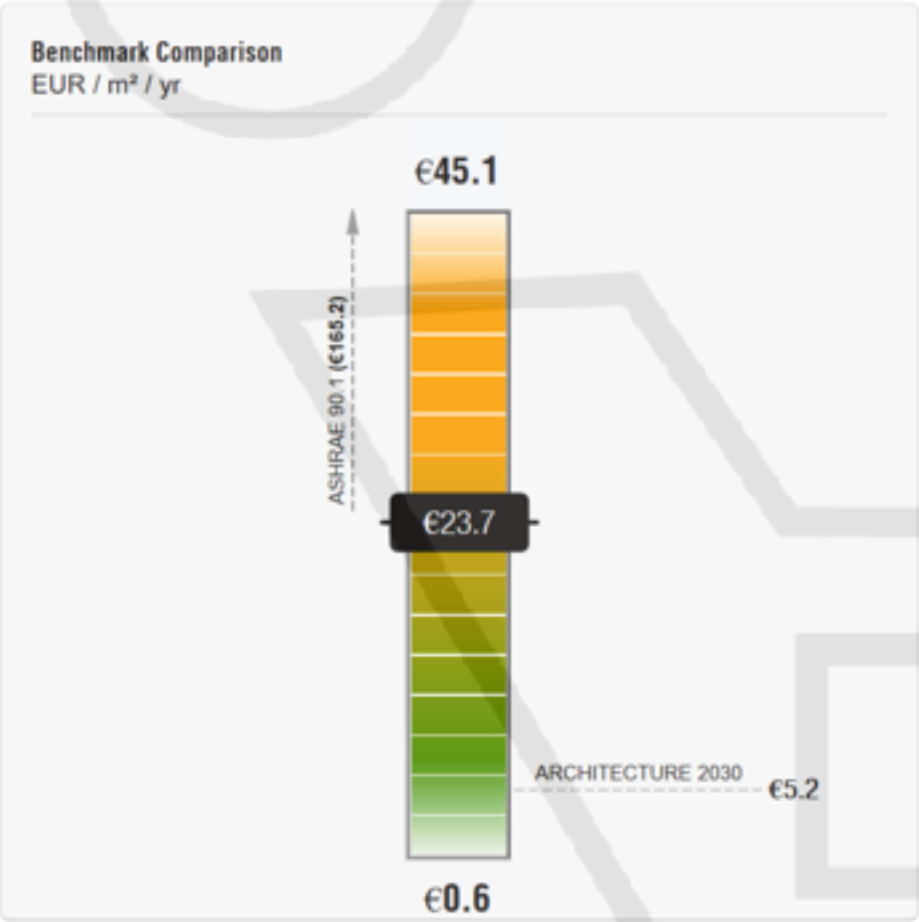
Shades can reduce HVAC energy use. The impact depends on other factors, such as window size and solar heat gain properties.

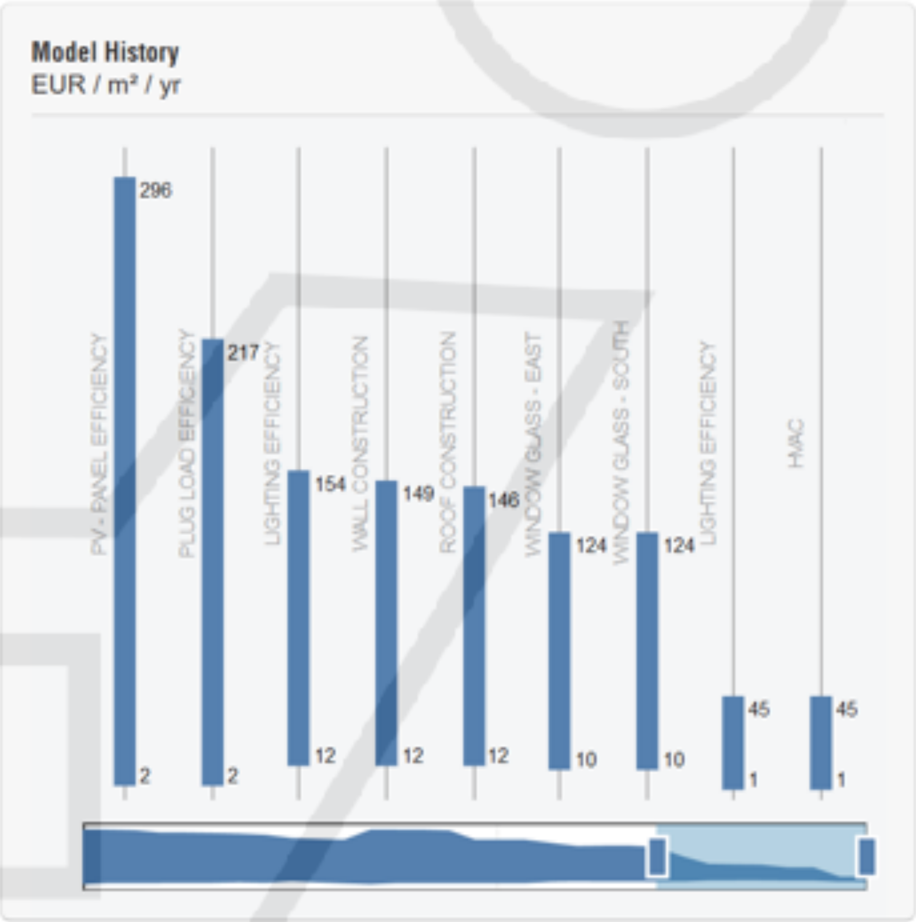
Current Setting:
1/6 Win Height - 2/3 Win Height


6.40
Factors
Tune parts of the building design or operation to improve building performance and achieve project goals.
6.38
Factors
Tune parts of the building design or operation to improve building performance and achieve project goals.

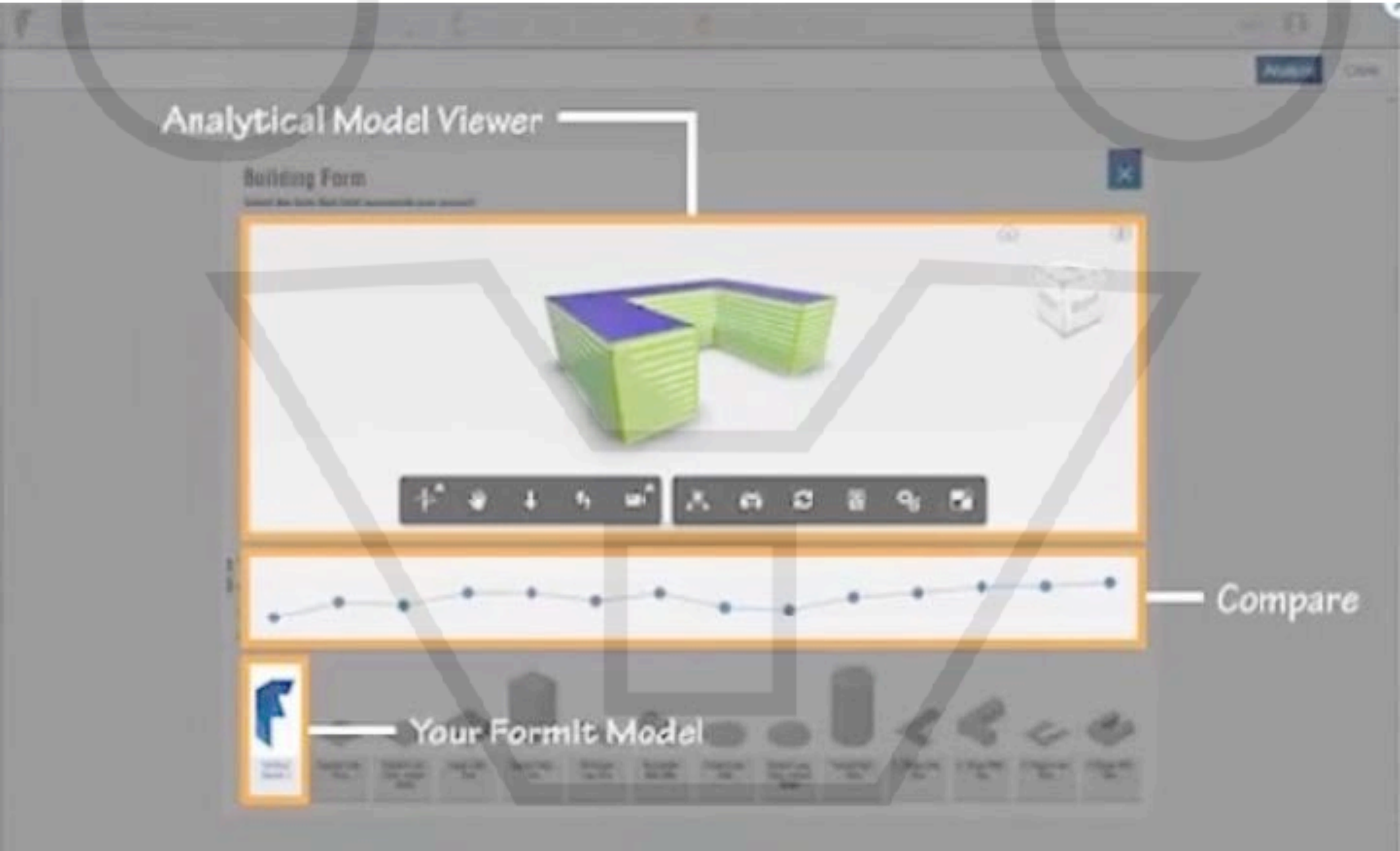

Editing: Building Orientation
Energy Cost
Energy Cost Mean
23.7
EUR / m² / yr
MIN
MAX
Building Orientation
100
50
0
-50
-100
Building Orientation (Degrees)

Introduction to To... The solar envelope: h... File CAD NF (AFNOR) :...





8st STEP: COMPARE OPTIMIZED ALTERNATIVE SOLUTIONS



9st STEP: FIND HOTTEST AND COLDEST BLOCKS/SURFACES IN ORDER TO VERIFY THE CONSISTENT ALLOCATION OF SPACES AND ENVELOPE SOLUTIONS