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

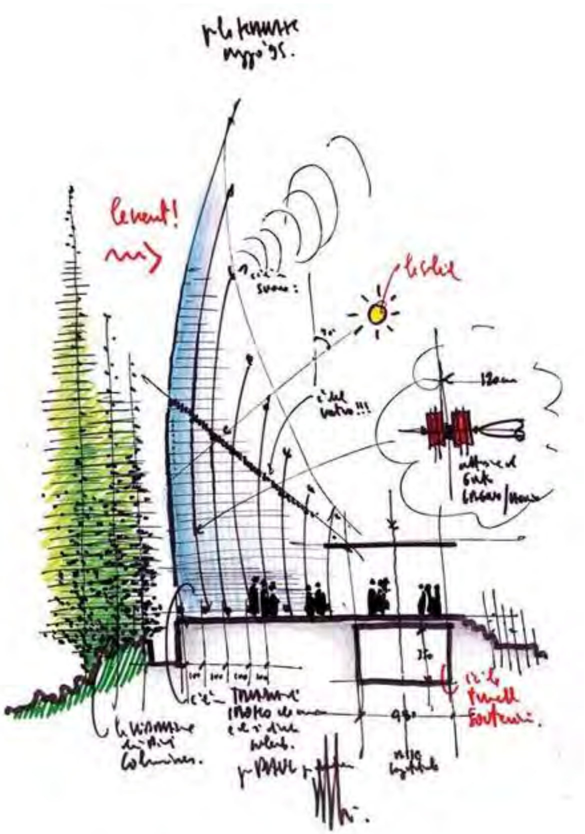
WHAT IS MODELING

SKETCHING • DRAWING • DRAFTING

DESIGNING - MODELING

RE-PRESENTATION

SKETCHING



Renzo Piano, Tjibaou Cultural Centre, Nouméa, New Caledonia, 1998

Picasso, Studio for Guernica, 1937

Sketching is a freehand drawing representing the preliminary phase of a drawing. It has a gestural character, based on immediate actions without corrections and few details intended to capture an idea or an experience. It expresses approximative essentiality.

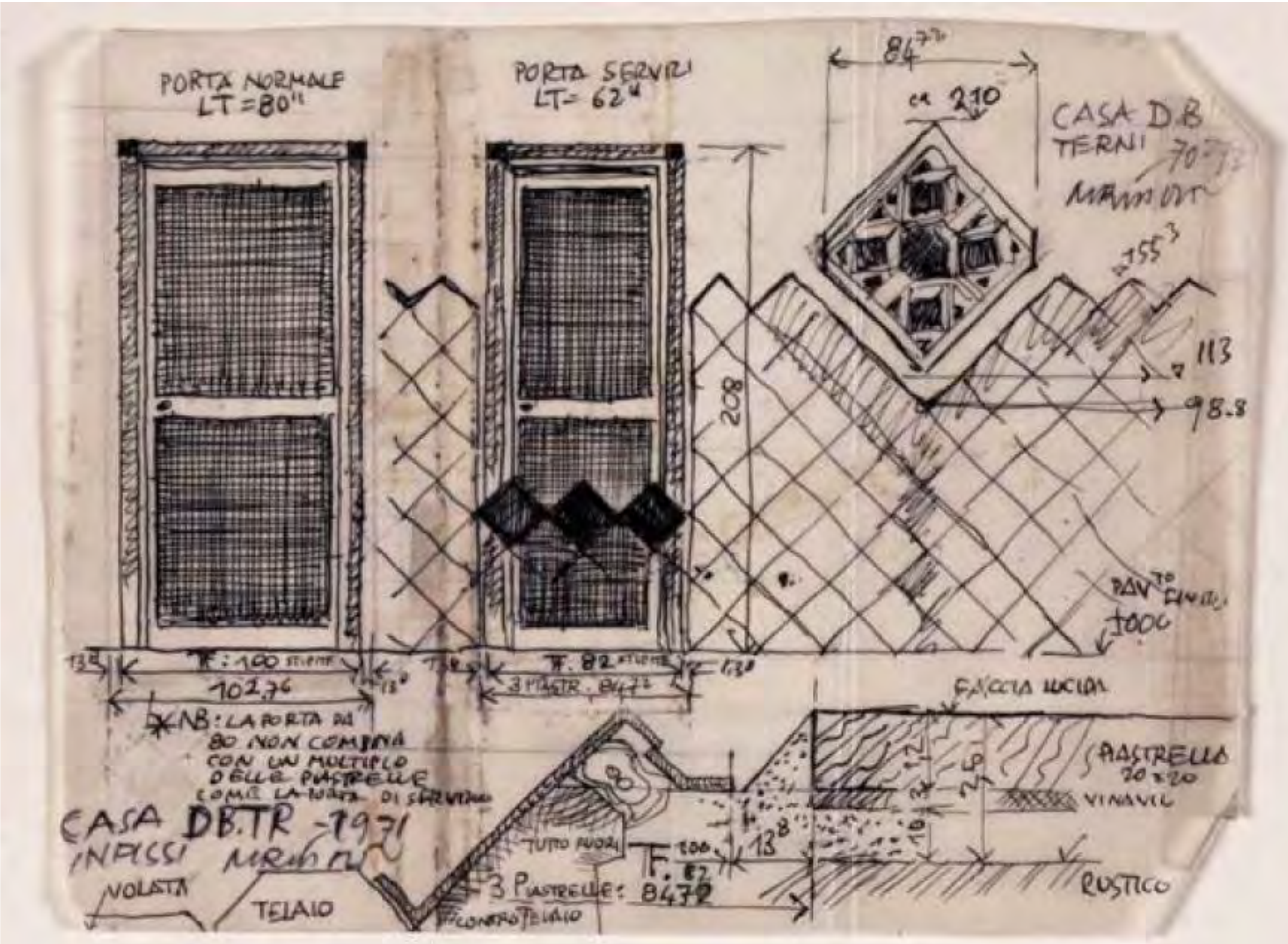
Van Gogh's Studies

Vincent van Gogh Drawing, Pencil, black chalk
Saint-Rémy: March - April, 1890

Henri Matisse Nu assis les bras étendus Print, Lithograph, Expressionist 1925

Gauguin's Sketchbook

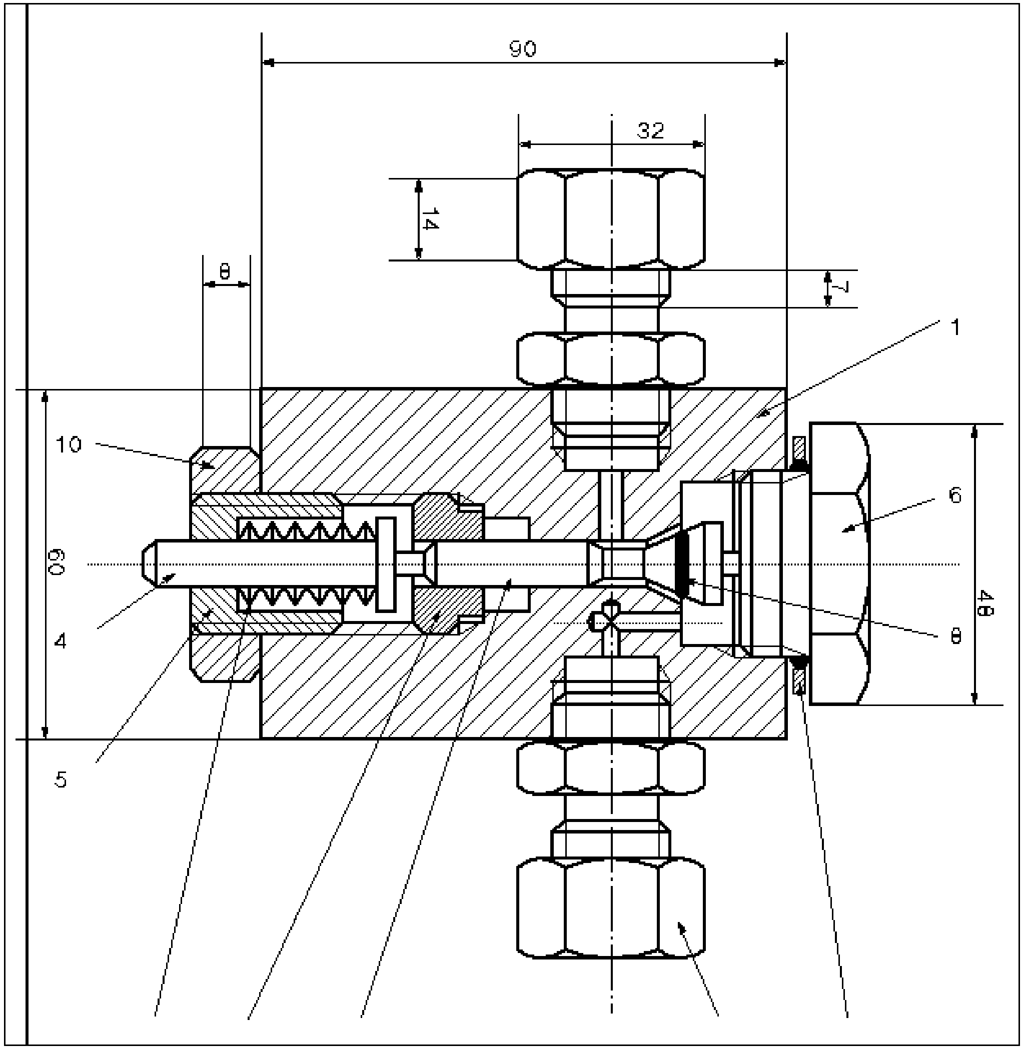
DRAWING



Drawing has a more thoughtful character and its excecution is based on a form of planning represented by the use of construction lines. It is detailed although it can be freehand

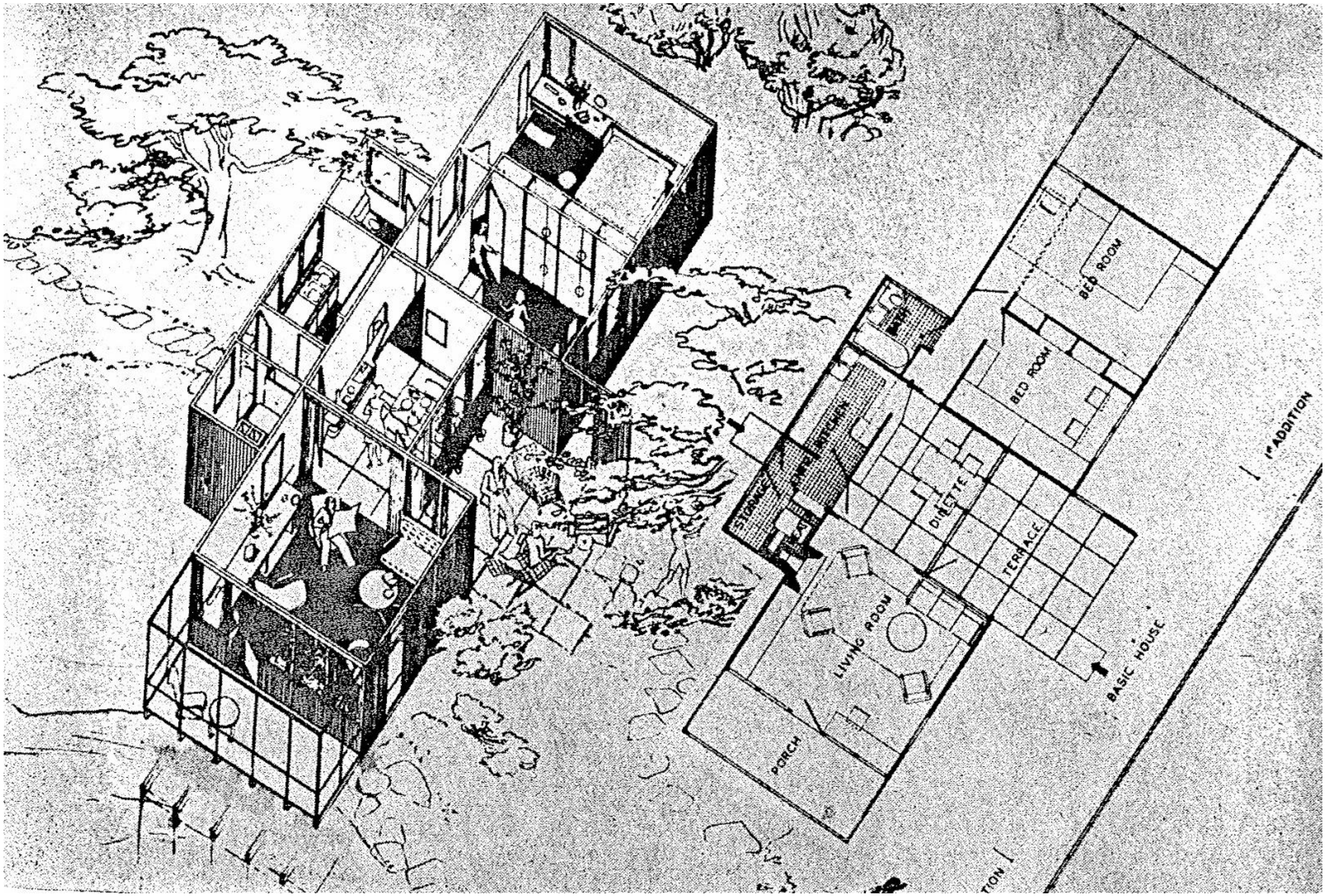
Mario-Ridolfi-Casa-De-Bon

DRAFTING



Drafting is the act of producing drawings based on calculation, measure, and precision. It is a technical activity in which the design idea come alive in an accurate and formal representation intended for the production of the conceived objects.

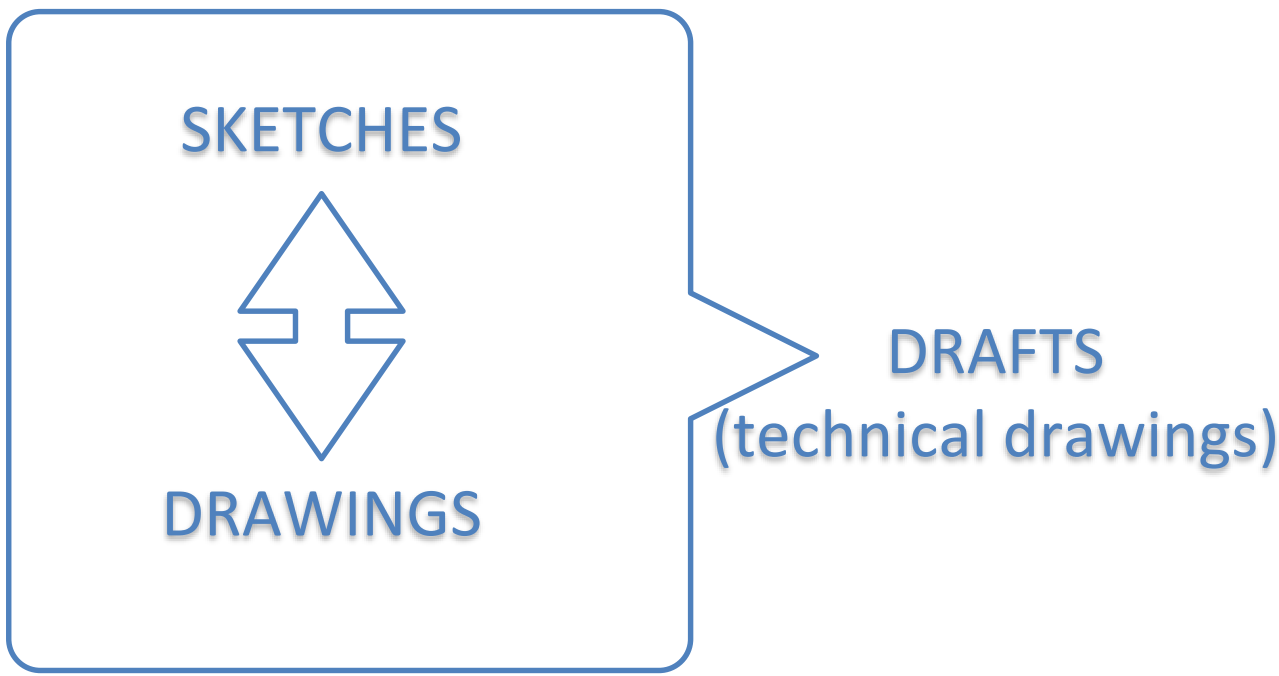
DESIGNING

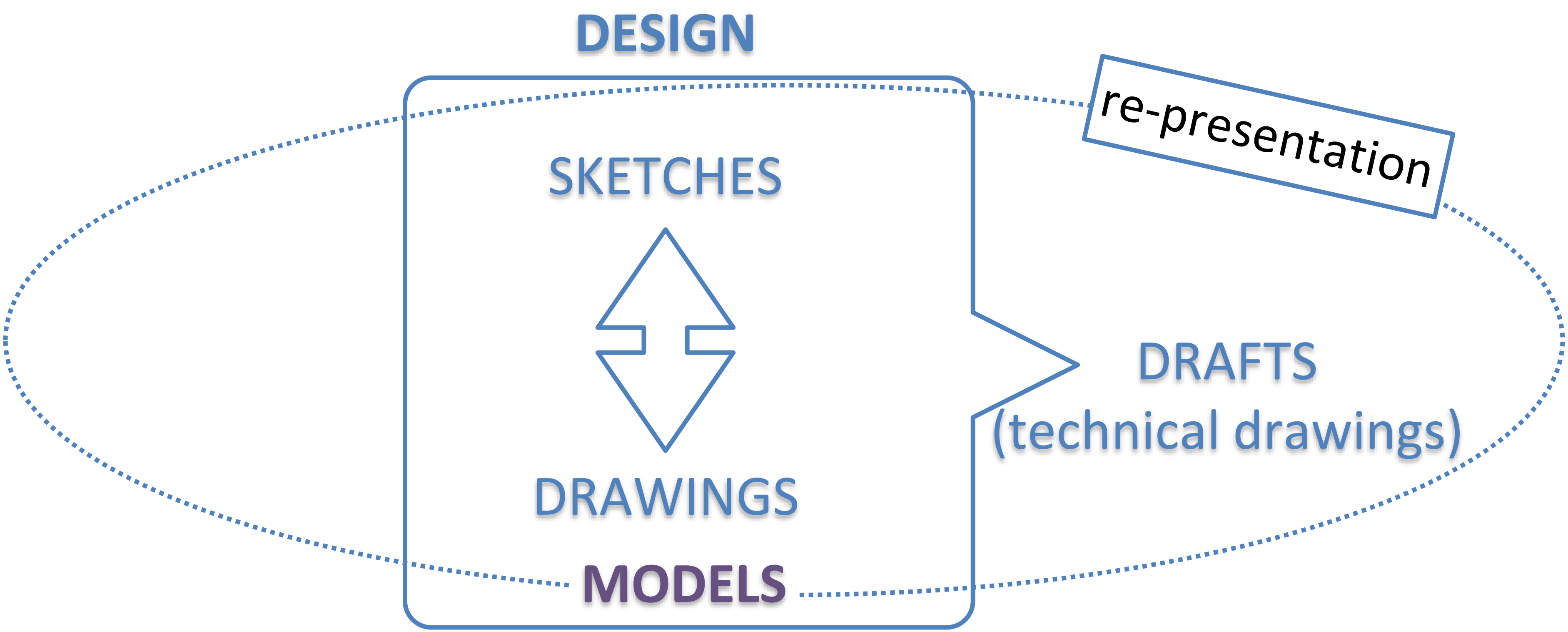


Design is the process of generating and presenting ideas and projects through forms and tools of the visual language fitting expectd goals and requirements.

Walter Gropius «the Expansible House»

DESIGN




DESIGN
re-presentation
SKETCHES
DRAWINGS
DRAFTS
(technical drawings)
MODELS

ISOMORPHIC MODELS

Morfological Model or
“Depictional” representation

Simulation in order
to understand
how it looks

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

A SCALED MODEL AS AN EXPERIMENT
to understand how reality behaves

The simulation differentiate itself from experiments where experiments are conducted on reality iteslef, using the same matter while simulation operates through the interposition of other and different materials. Traditionally models and simulations are mainly representative, experiments are descriptive.

Massimo Ricci, Modello in scala della
Cupola di S. Maria del Fiore in Firenze

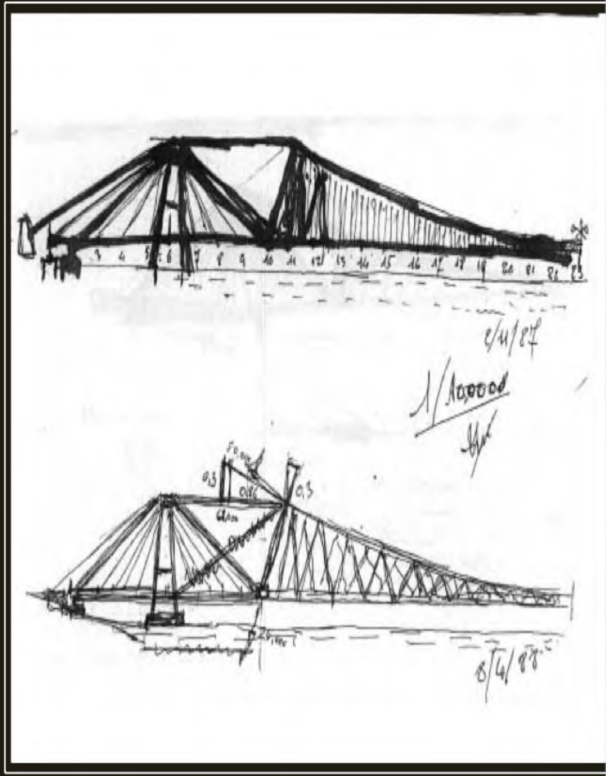
SIMULATION IS ANOTHER WAY TO UNDERSTAND REALITY BASED ON ABSTRACTION: THIS ABSTRACTION IS THE MODEL

MODELING: the Language of Design

Simulation to understand how reality behaves and how it works

Leonardo da Vinci. Anatomical drawings (around 1510)

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

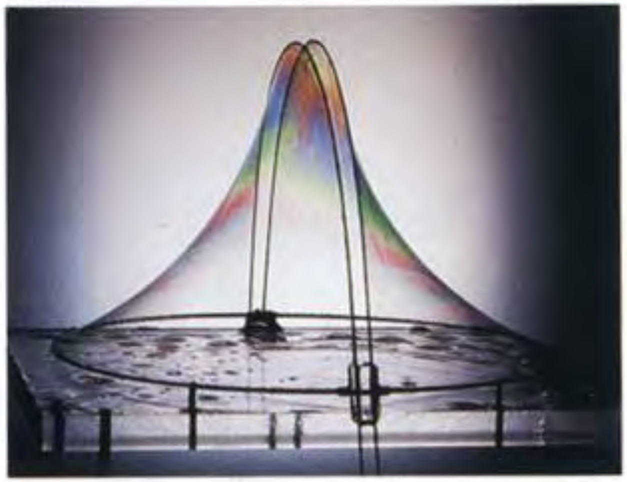


Riccardo Morandi. Bridge studies (1987/89)

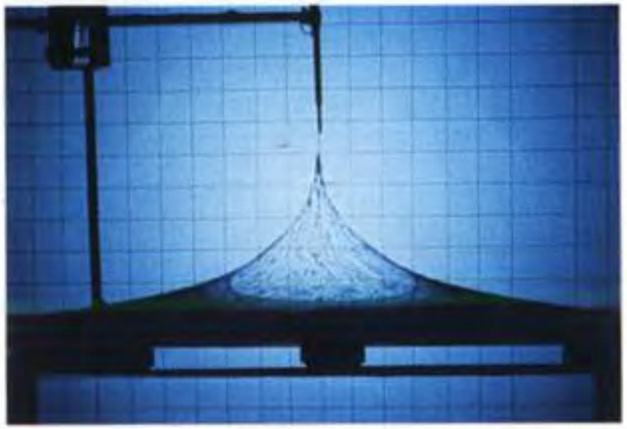
MODELING: the Language of Design

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

S. Jobs (1955-2011)



1



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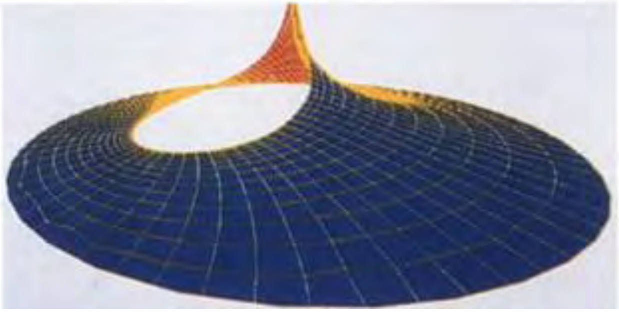


MODELS TO VISUALIZE MATTER BEHAVIOURS

Functionality and Performance Design

Frey Otto's studies & researches

1 Soap film model of an arch-supported membrane.

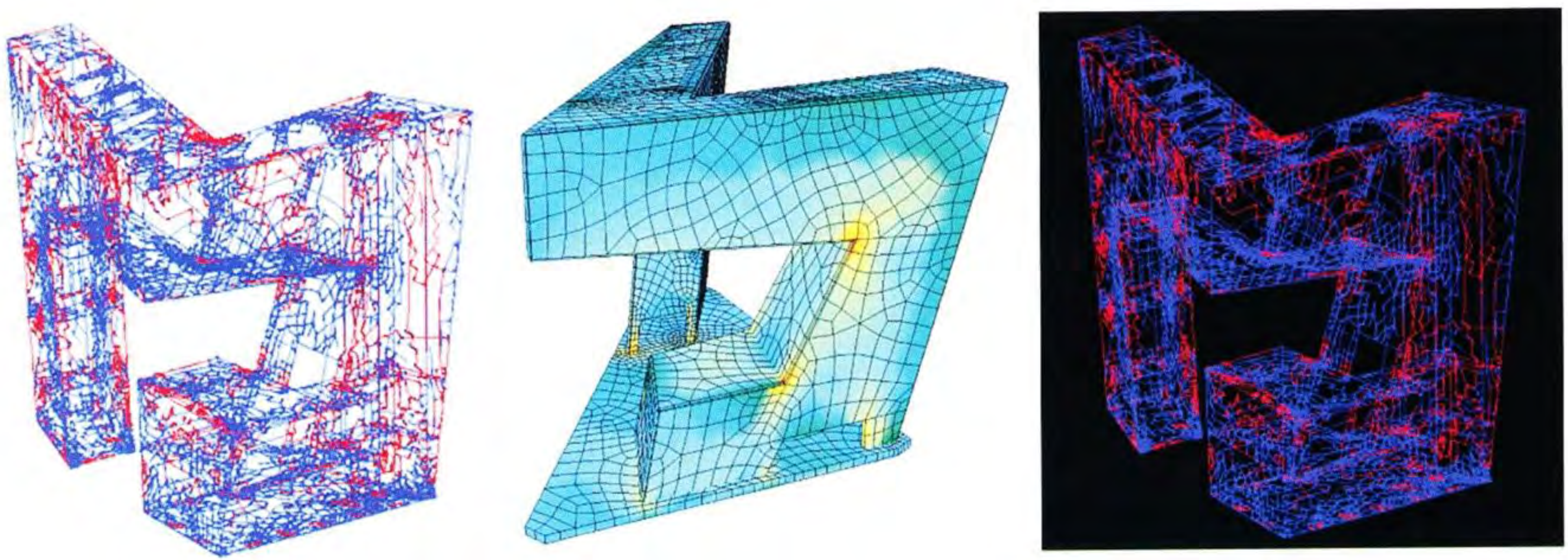
2 Soap-film model of a membrane surface with rope loop as its high point.

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).

DYNAMIC MODELS & PARAMETRIC SIMULATION

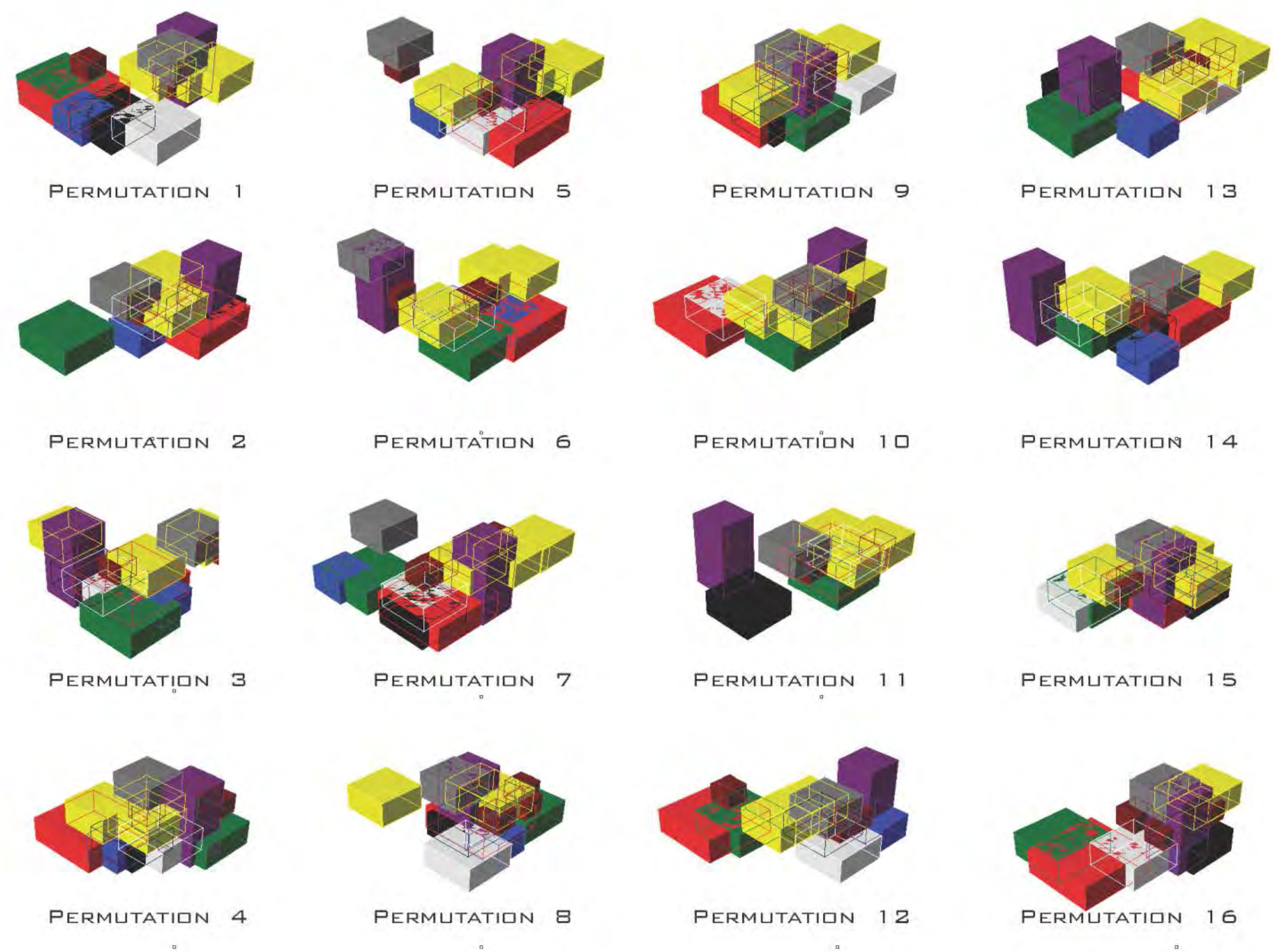
Static (informative) vs **Dynamic (performative)** Model

Antique map of the medioeval Florence

Monopoly Game Board

DYNAMIC MODELS & PARAMETRIC SIMULATION

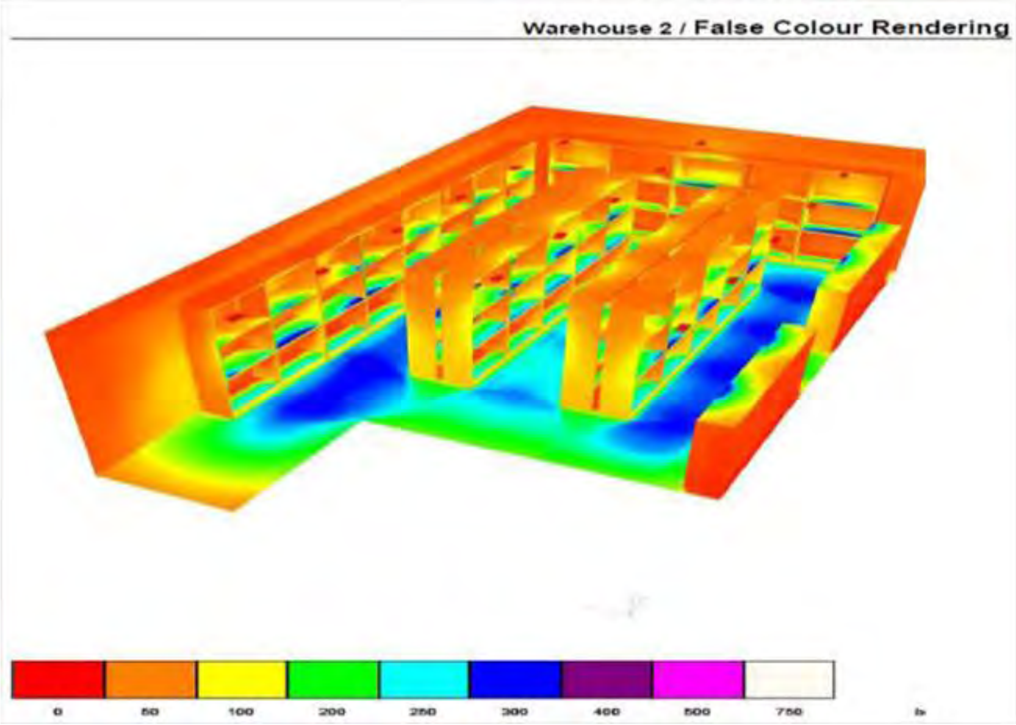
PERMUTATIONAL OUTPUTS FROM A PARAMETRIC MODEL



DYNAMIC MODELS & PARAMETRIC SIMULATION

MANY DIFFERENT BEHAVIOURS FROM A PARAMETRIC MODEL

"... 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



DYNAMIC MODELS & PARAMETRIC SIMULATION

Designing as a scientific process

(*Decision making testing – through different simulations – variable conditions*)

What if ?

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

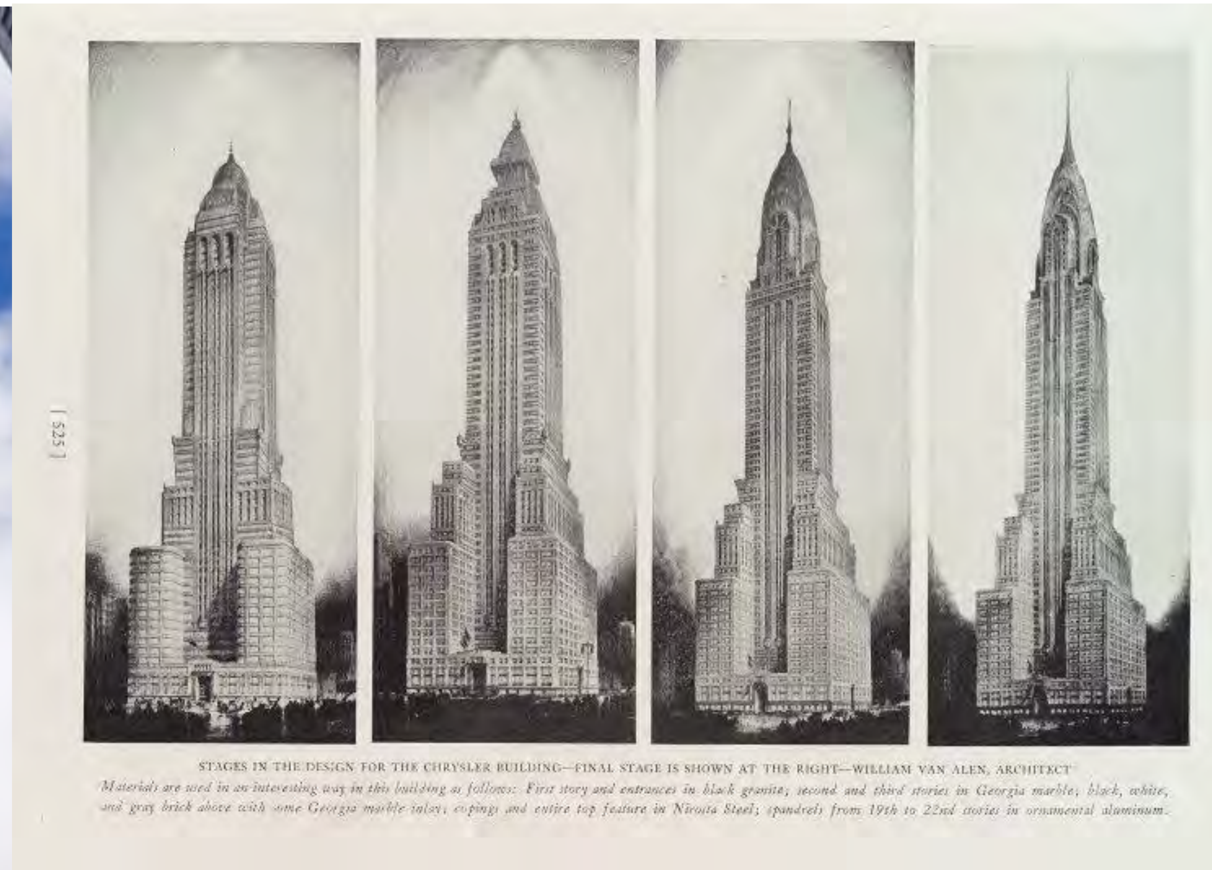
1929-30 The race for the sky

70 floors, 282.5 m high

completed in 1930 (11 months)

Manhattan Bank, then Trump Building

H. Craig Severance



77 floors, 319 m high

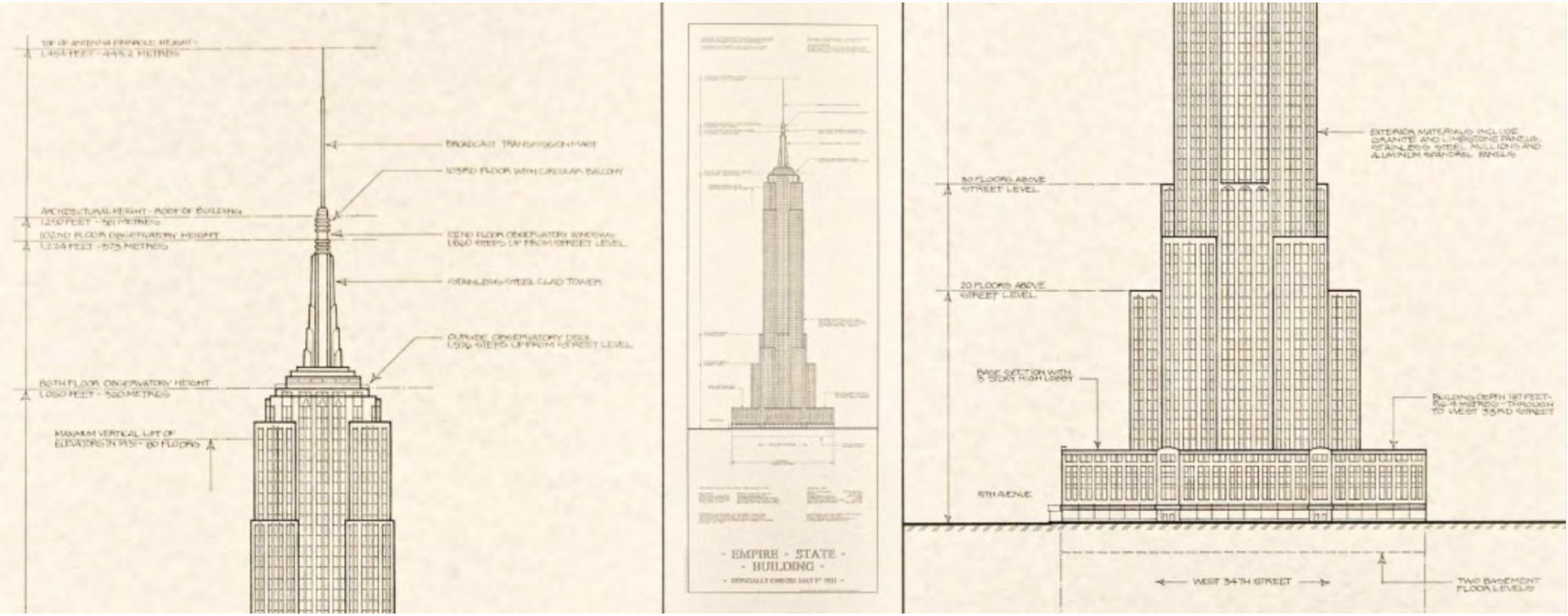
completed in 1930 (20 months including 2 months of demolition)

Chrysler Building William Van Alen

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

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

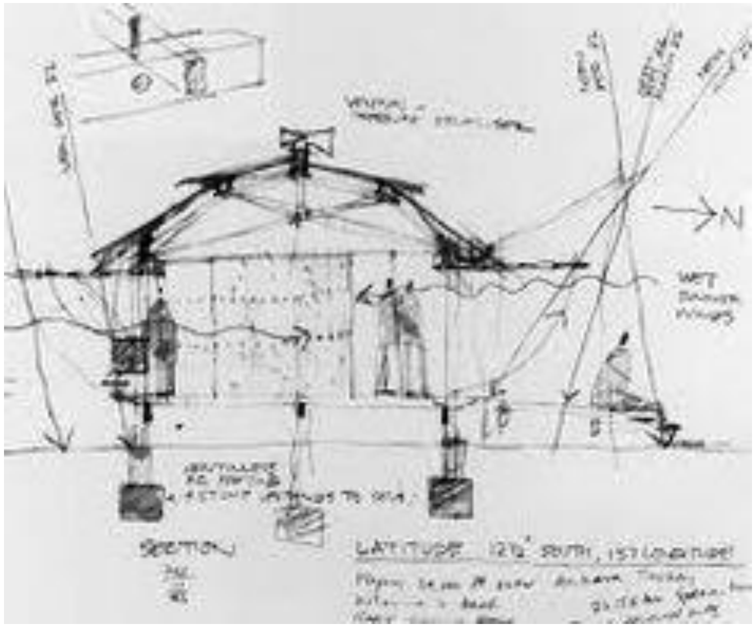


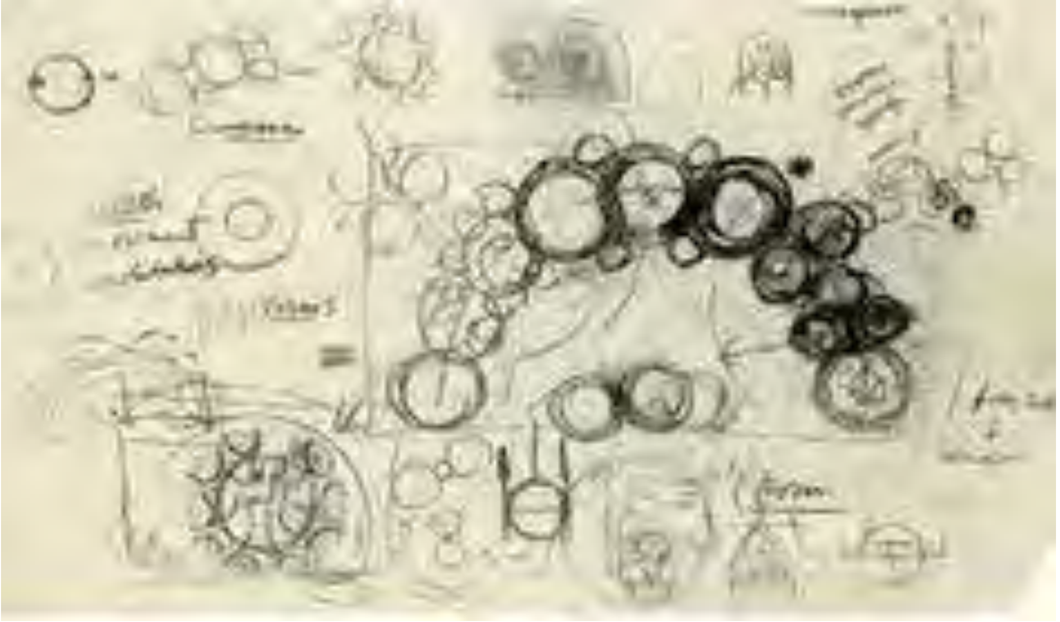
From Sep. the 16th to October the 3d, 1929
16 alternatives (2 by day) were delivered and compared.

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

Modeling & Performance Simulation using Computational Design

TRADITIONAL APPROACH





louis kahn sketches

Decision-Making through:

-rules of thumb

-individual intuition

-experience & tacit knowledge

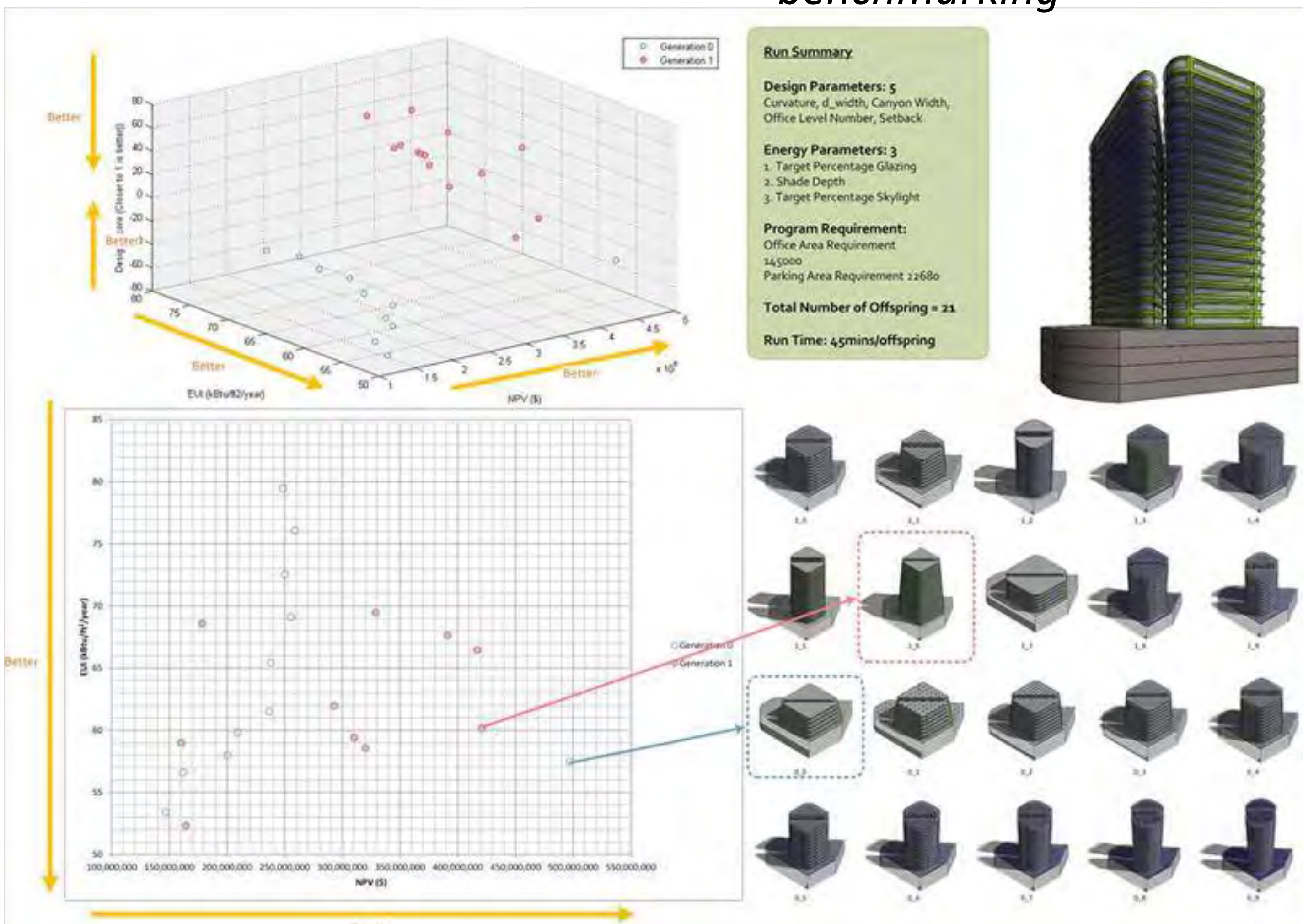
COMPUTATIONAL MODELING FOR SIMULATION

" 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

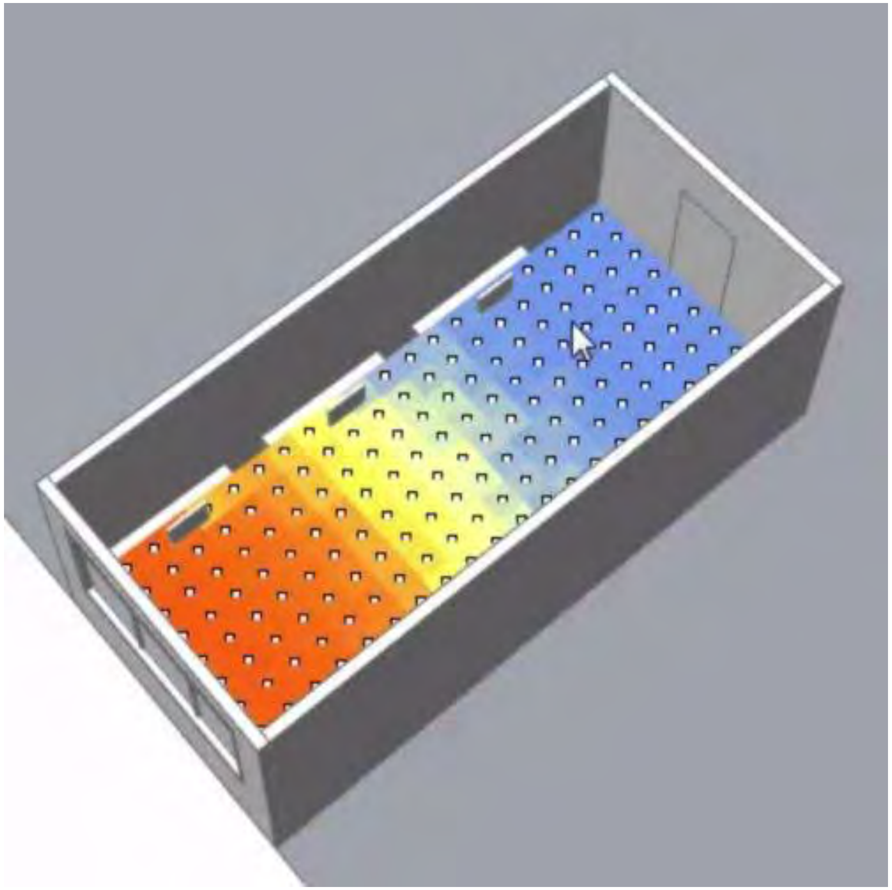
Decision-Making through:
- *formal procedures*
- *evidence-based observation*
- *benchmarking*

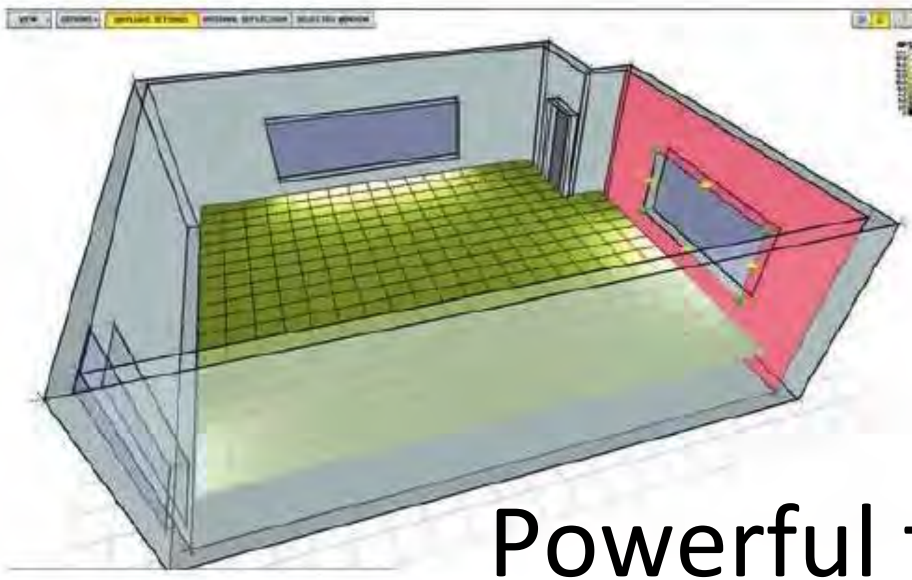


MODELING FOR SIMULATION NUMERICALLY PERFORMANCE BASED

features:

precision
objectivity
replicability
communicability



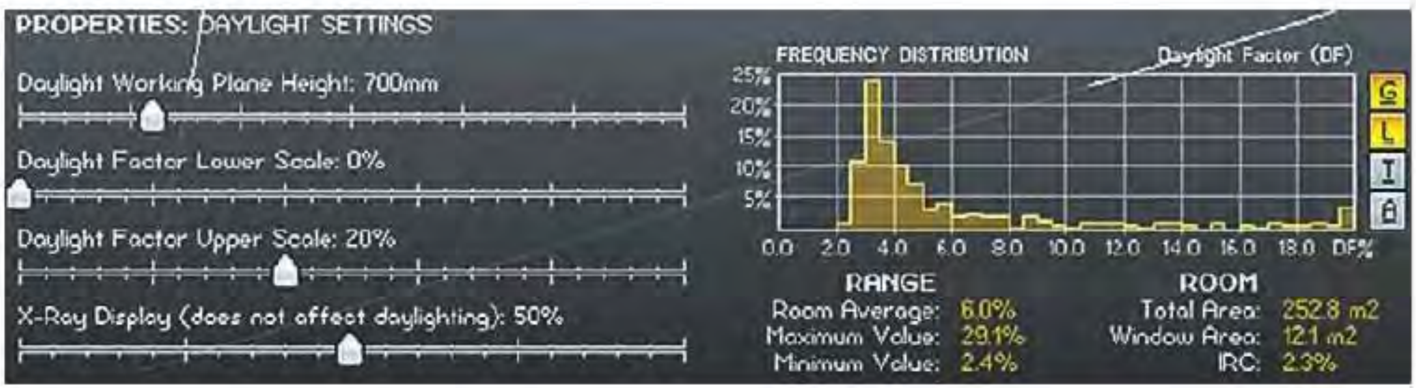


2.3 and 2.4

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.

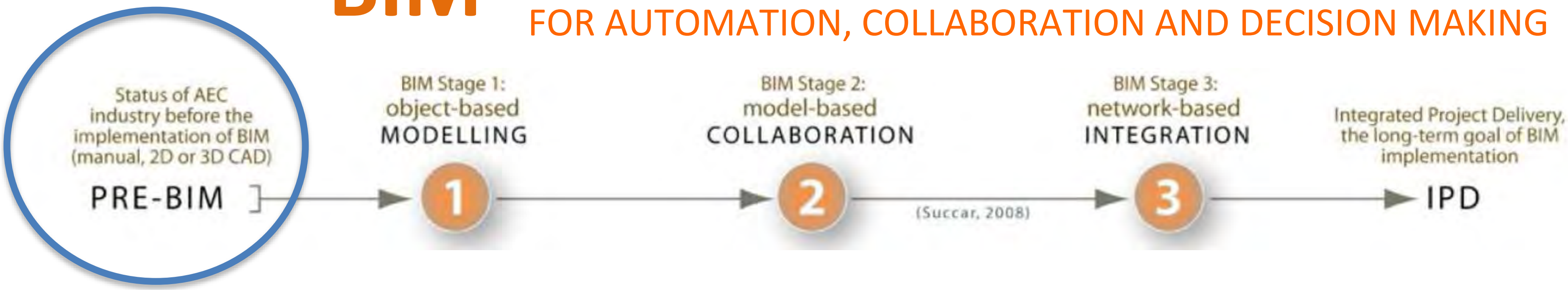
Powerful tools for gamers



PLAYING OPTIONS
AND
UNDERSTANDING
CAUSALITY

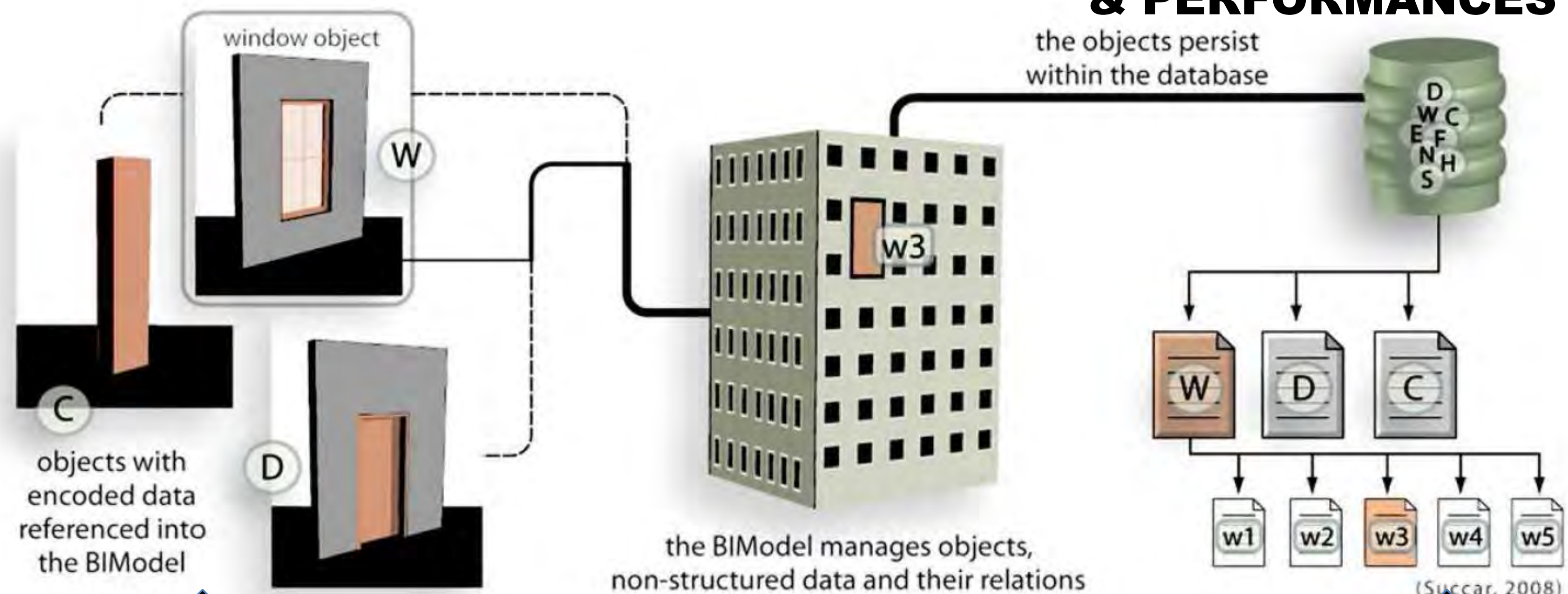
http://andrewmarsh.com

BIM DIGITAL OBJECTS PARAMETRICALLY INTERRELATED FOR AUTOMATION, COLLABORATION AND DECISION MAKING



ELEMENTS / LIBRARIES

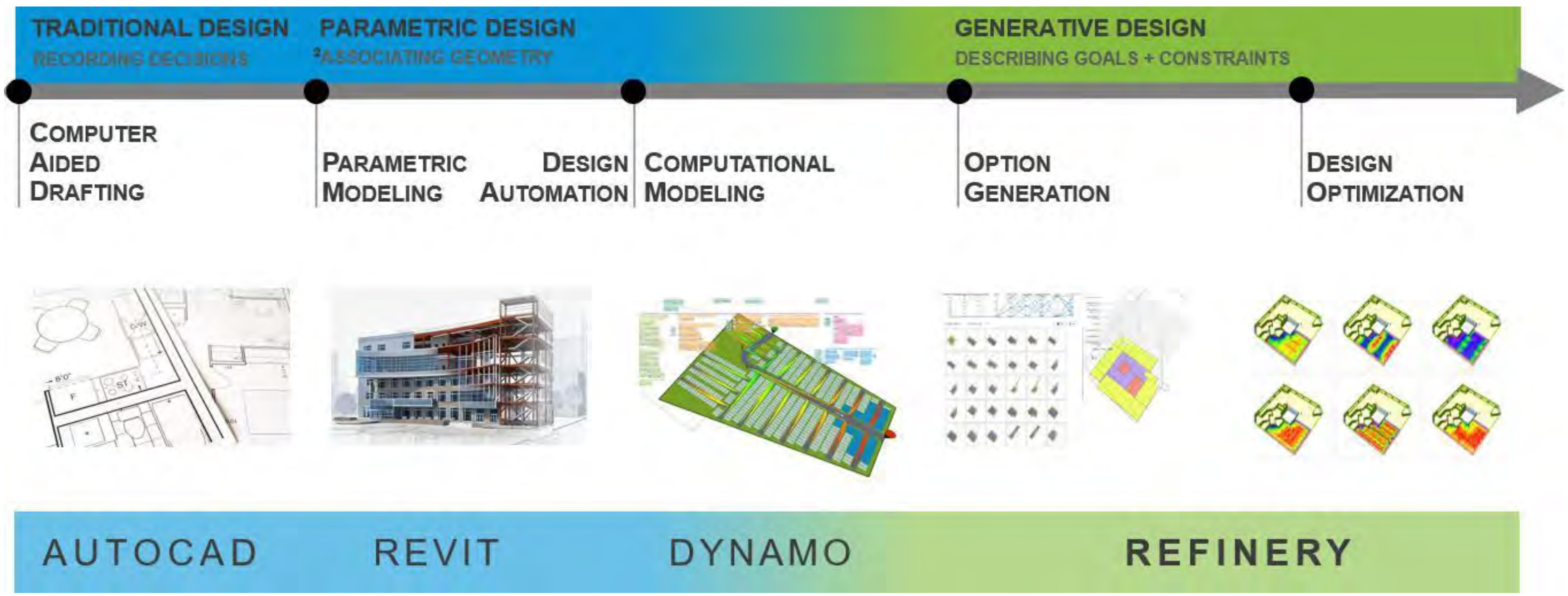
DATASET OF FACTS & PERFORMANCES



THE WHOLE MODEL AS A SYSTEM WHERE THE INTERACTION TAKES PLACE

In **Parametric Design** the user defines relationships between traditionally drawn or sculpted elements.

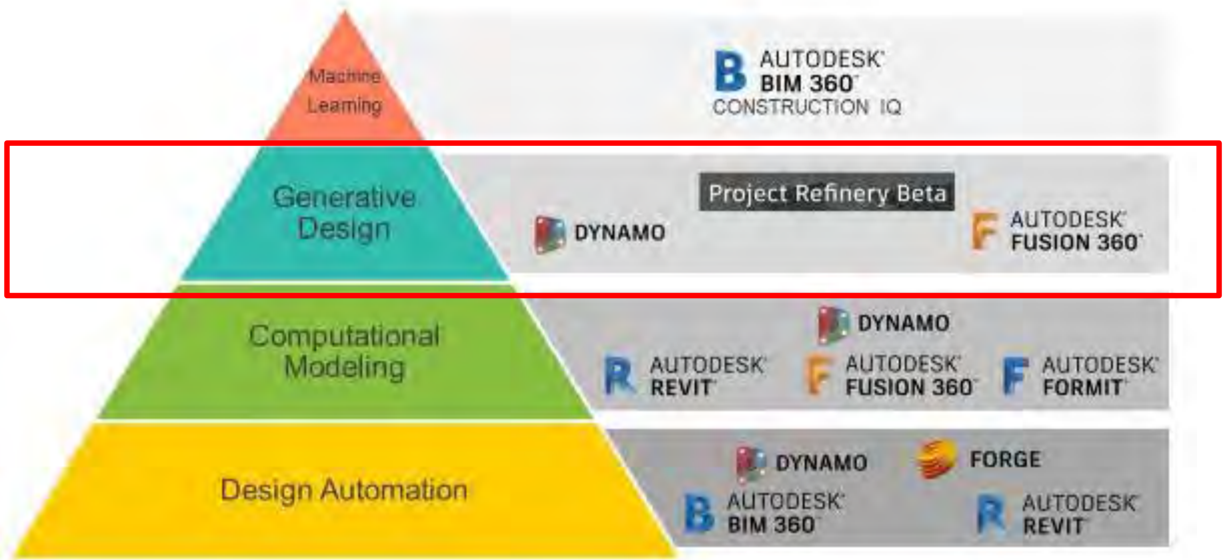
With **Design Automation** the user gets the ability to automate tasks within parametric models, by driving the parameters with automated scripts.



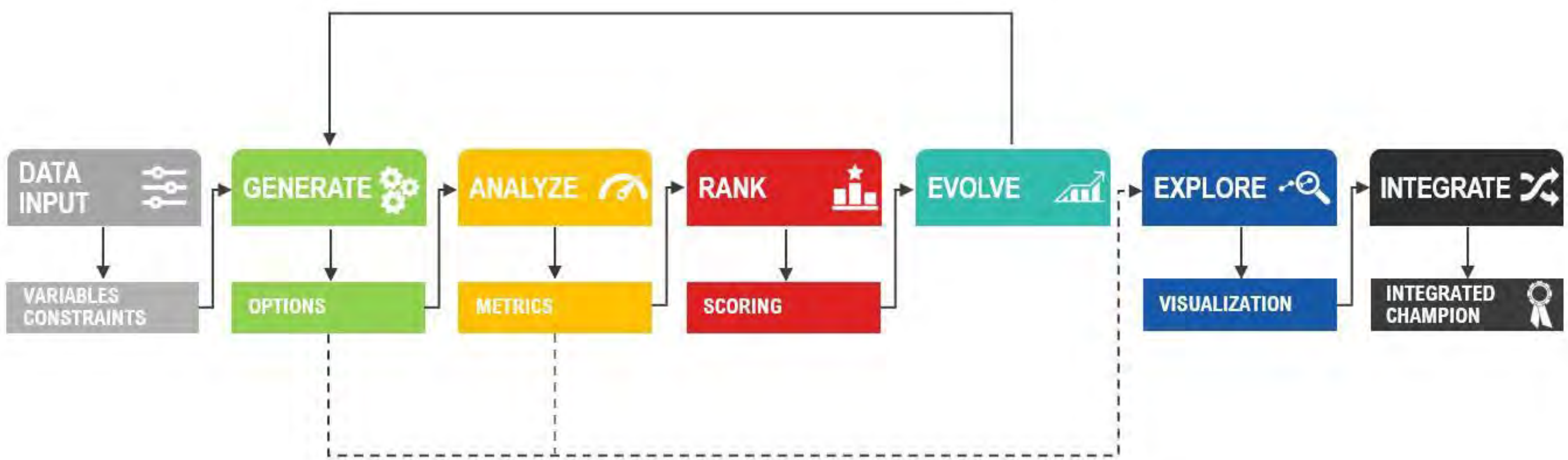
In **Computational Modelling**, the user explicitly describes a process to create a design outcome.

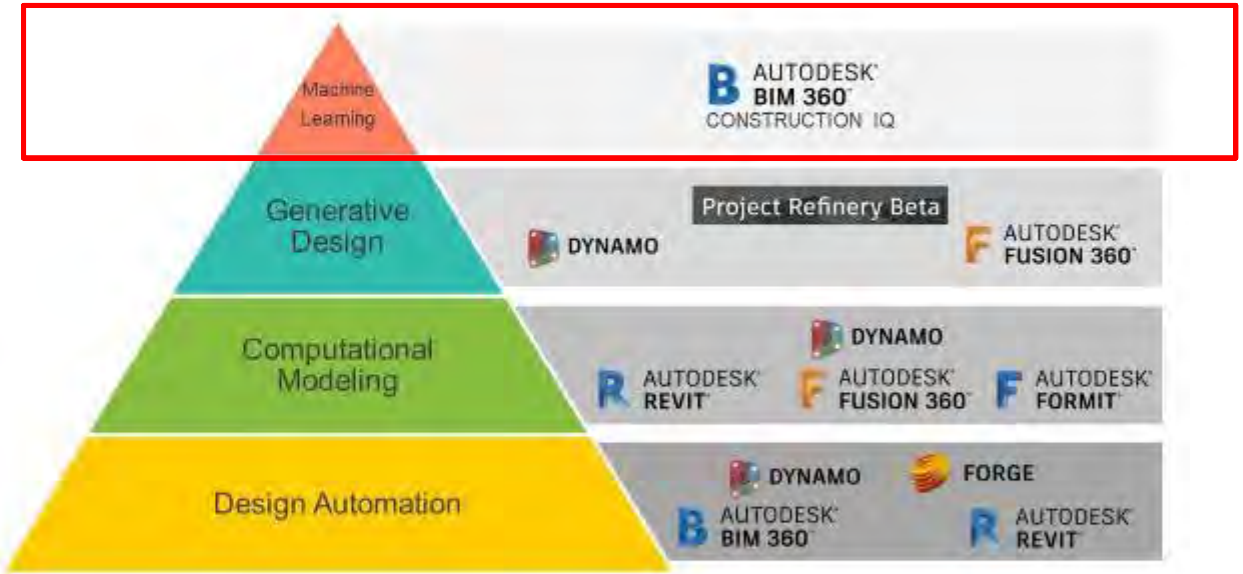
With **Option Generation**, the user explores of variations of computed rules given different starting points for the calculations

With **Design Optimization**, the user defines explicit goals and a computational or parametric model is automatically explored for states that fit those goals



A goal-driven approach using automation where users set specific parameters and goals and the machine generate and evaluate many potential solutions that, under designer guide, fits better.





Ultimately, with **Machine Learning** (ML), the user states outcomes and the system returns conforming results based on historical data.

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

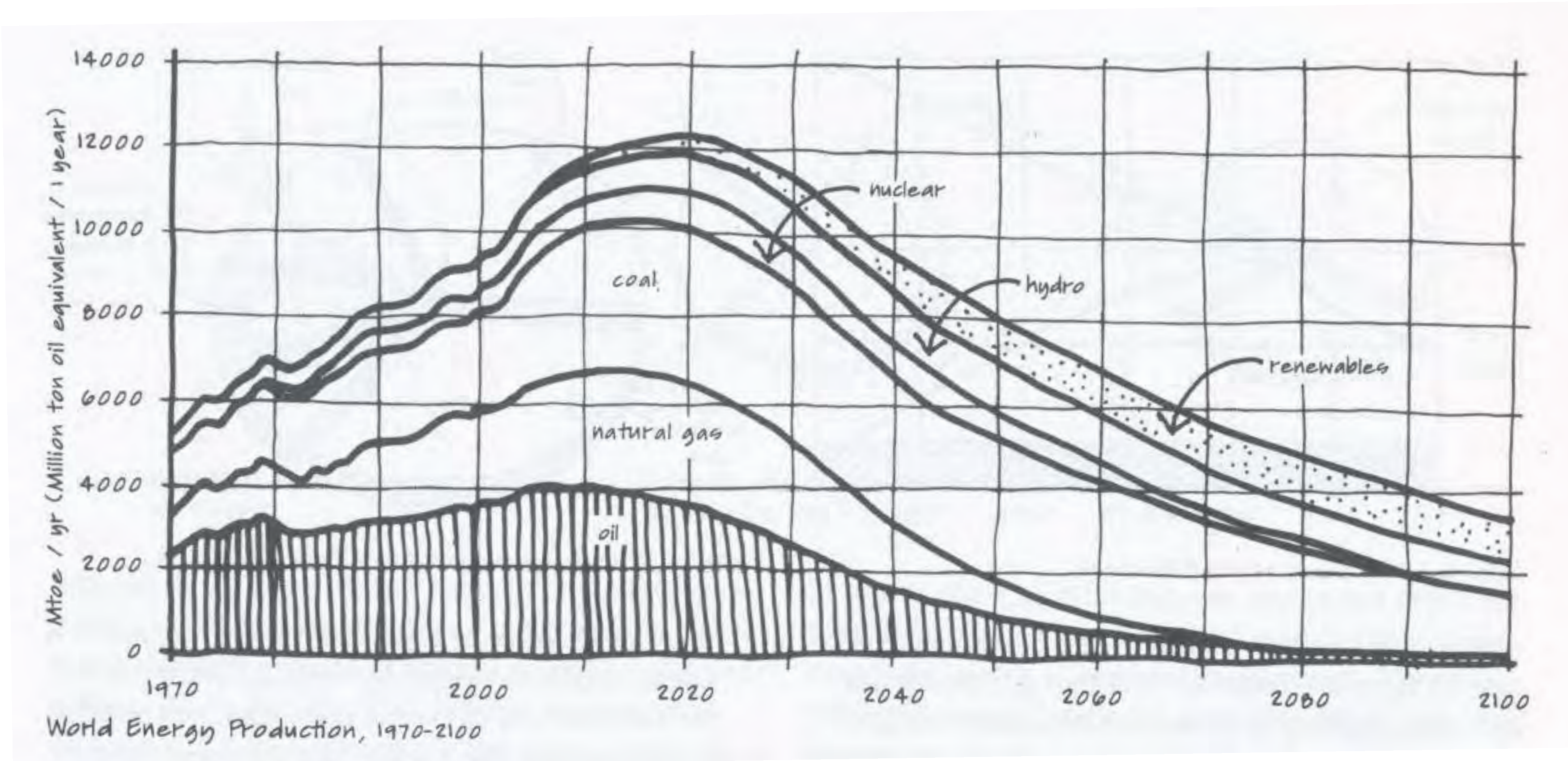
Testing the trade-off in order to be aware of how configurations and elements can affect behaviours and produce differente results

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

Ethical responsibility about us and the environment we live

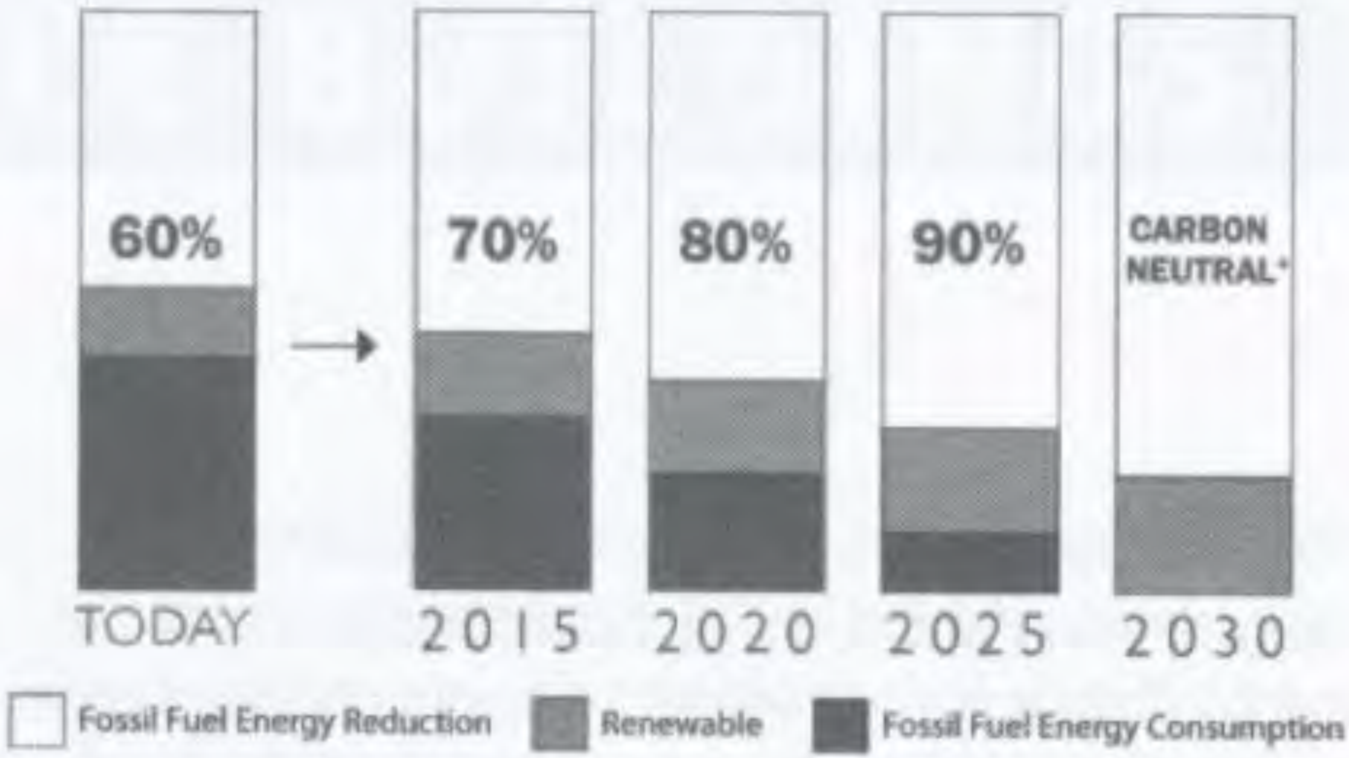
Because the built environment and constructions are one of the largest factor that affect our living

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



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.

GREEN BUILDINGS

GREEN BUILDINGS

Building with nearly zero emission and consumption

HOW TO EVALUATE ENERGY PERFORMANCE

GREEN METRICS & CERTIFICATIONS

ZEPHIR

PASSIV HAUS ITALIA

Affiliato iPHA

iPHA Affiliate

is a voluntary standard based on EUI

GREEN METRICS & CERTIFICATION

HOW TO EVALUATE ENERGY PERFORMANCE

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

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/ft^2	=	3.16 Watts/m^2 (instantaneous power incident on a surface)
1 Btu/ft^2	=	3.16 Watts* hours/m^2 (units of energy on a surface over time)
1 Btu	=	.293 Wh (unit of energy)
kBtu/ft^2/year	=	11.352 MegaJoules/m^2/year (Energy Use Intensity, annual measure of energy use per unit area)
1 W/ft^2	=	.093 W/m^2 (Plug Load or Lighting Power Density, usually per room area)
U value (Btu/ft^2/h/°F)	=	5.678 U value (W/m^2/°C) (conductivity of a material or assembly, where U = 1/R)
1 ft^2/minute	=	.000472 m^2/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

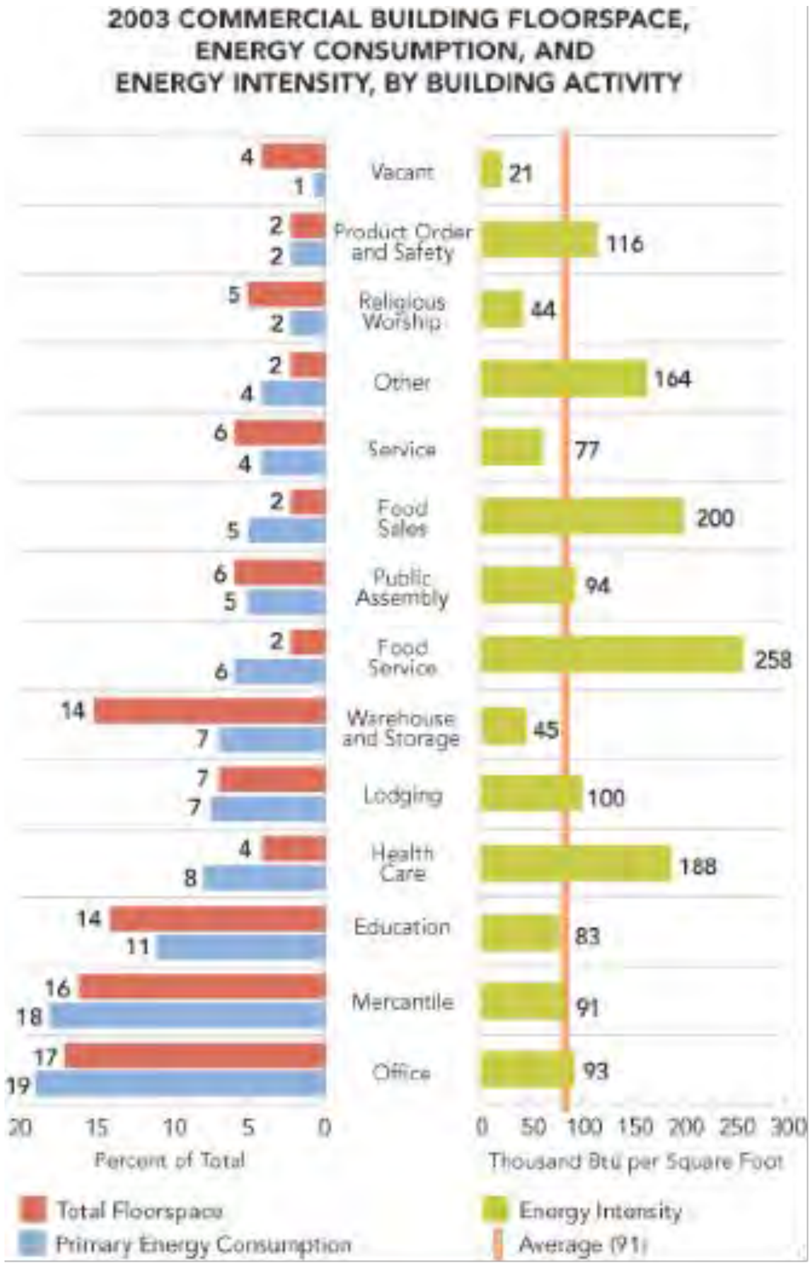
Definition: Energy Use Intensity is a building's annual energy use per unit area. It is typically measured in thousands of BTU per square foot per year (kBTU/ft2/yr) or kWh/m2/yr. EUI can measure "site" energy use (what the building consumes) or "source" energy use (the amount of fuel the power plant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

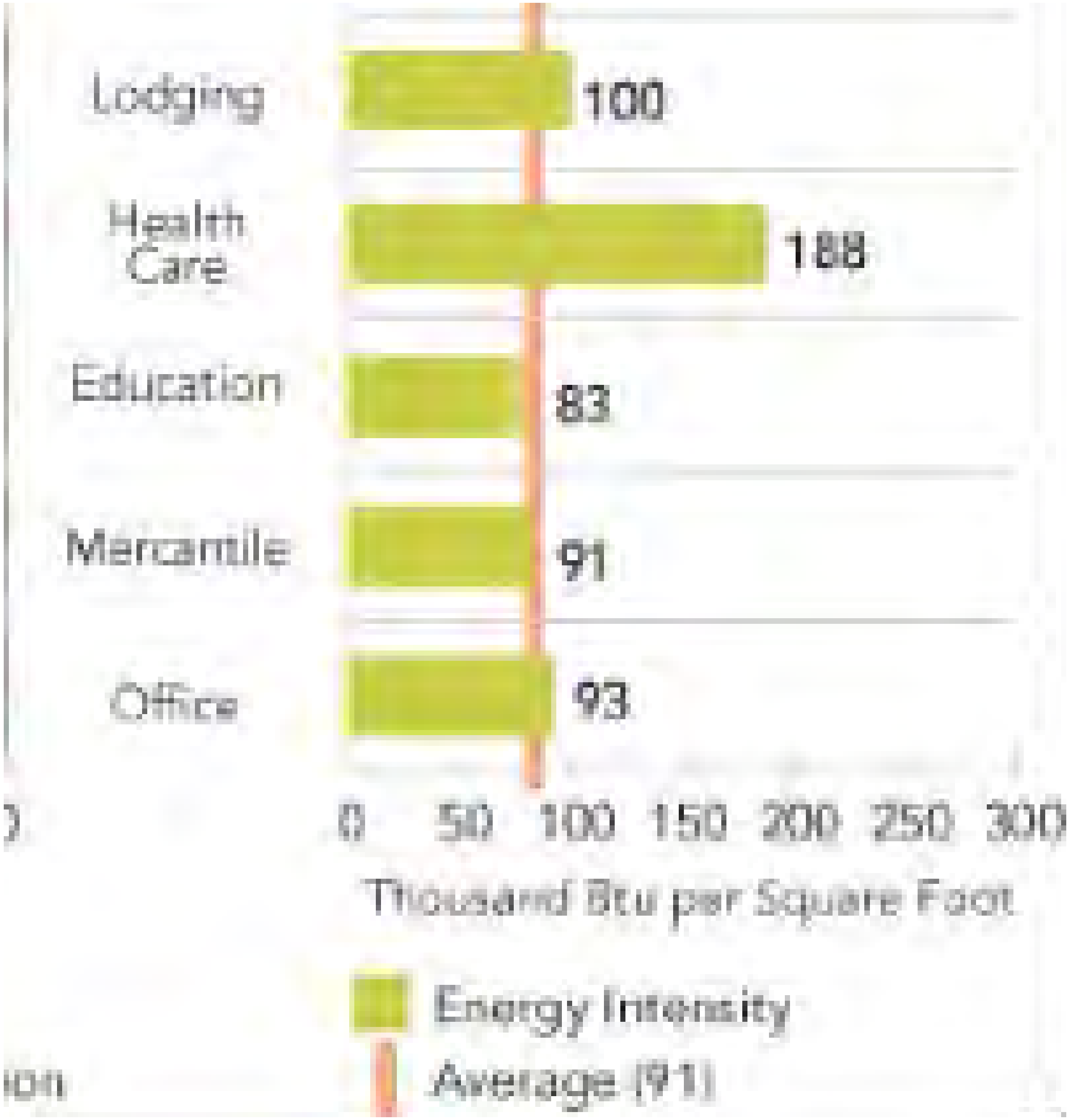
Typical values: Below are some average EUIs for three building types in the US. (These are meant to give a rough idea of EUI ranges; actual values can vary widely based upon location & specific space uses.)

	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

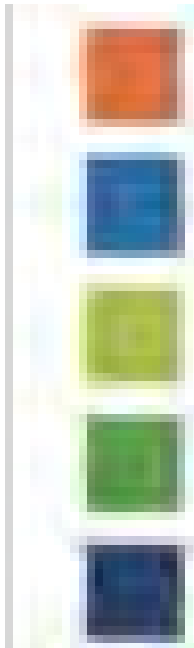
EVALUATION IN RELATIONSHIP WITH BASELINE SOLUTION based on current average benchmark



EVALUATION IN RELATIONSHIP WITH BASELINE SOLUTION based on current average benchmark



ELEMENTS THAT AFFECT ENERGY CONSUMPTION



HEATING

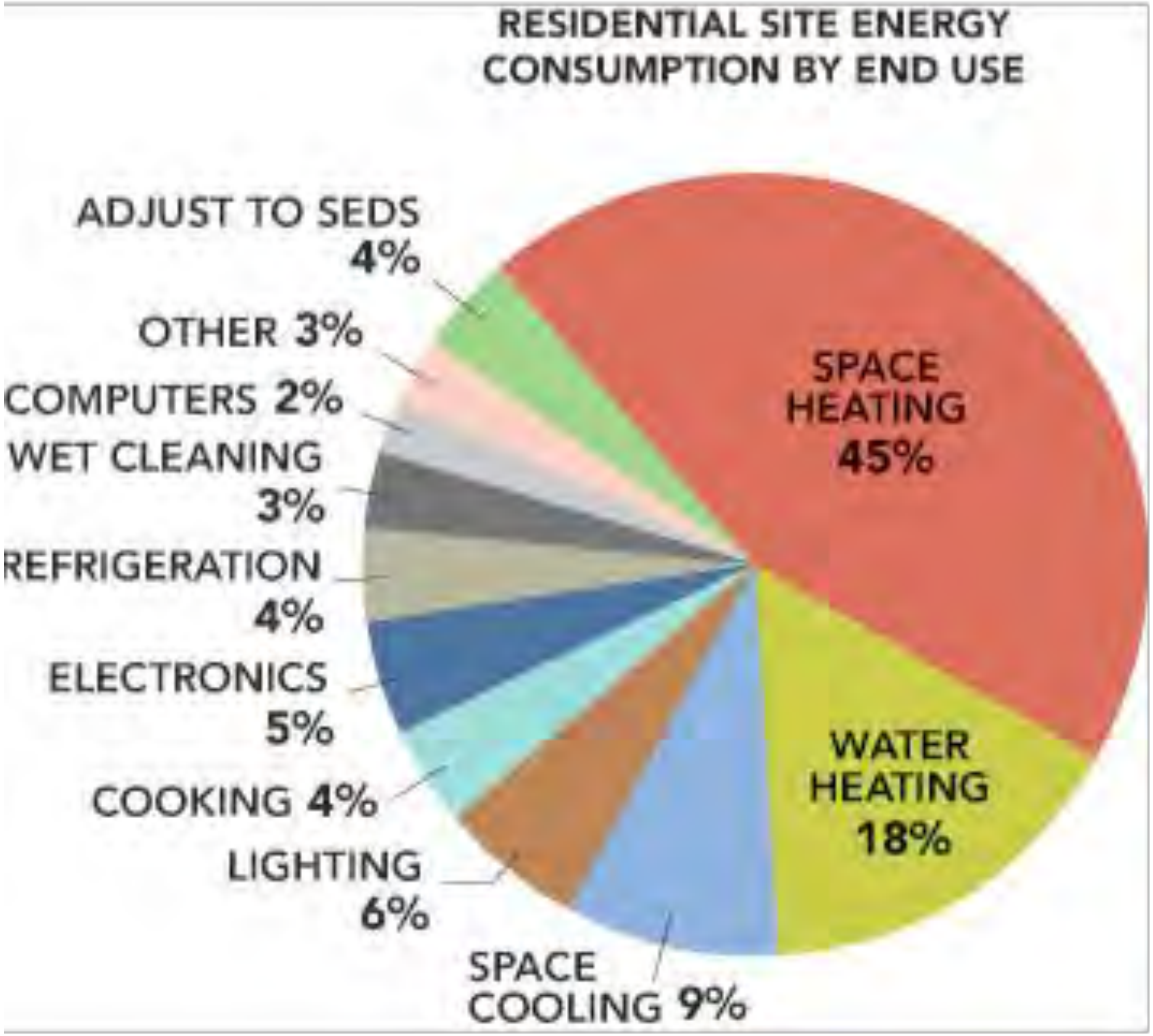
COOLING

APPLIANCES

HOT WATER

LIGHTING

EVALUATION IN RELATIONSHIP WITH BASELINE SOLUTION
based on current average benchmark



Primary Space / Building Type	Ave. % Electric	Site EUI med	70%	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

Targets based on
U.S. Commercial Building National Average

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 / 1story			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 20,025 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	16	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	19	27	8	3	51	15	5	172	52	17	105	32	11	56	17	6
1A	Miami, FL	63	19	6	89	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	59	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	305	92	31	163	49	16	89	27	9
3A	Atlanta, GA	57	17	6	84	25	8	99	30	10	95	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	65	20	7	84	25	8	108	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	60	18	6	247	74	25	123	37	12	64	19	6
4A	Baltimore, MD	59	18	6	85	26	9	101	30	10	91	27	9	60	18	6	58	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	Ketchican, AK	66	20	7	93	28	9	109	33	11	97	29	10	55	17	6	72	22	7	246	74	25	138	41	14	89	27	9
6A	Minneapolis, MN	77	23	8	108	32	11	126	38	13	121	36	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	98	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	108	32	11	114	34	11	85	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	148	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"

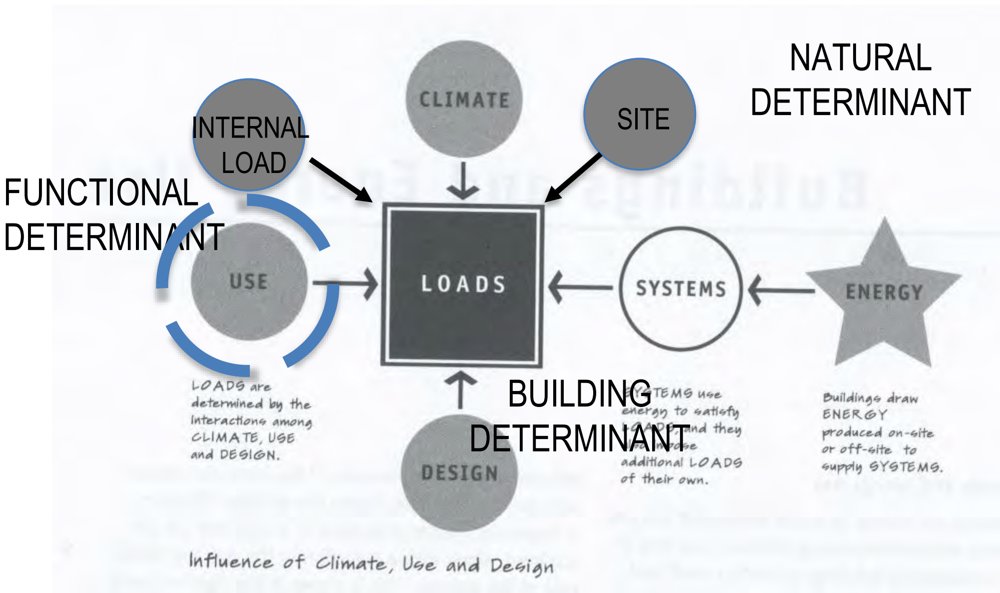
EVALUATION IN RELATIONSHIP WITH
BASELINE SOLUTION based on Code* compliant element as a basic benchmark

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

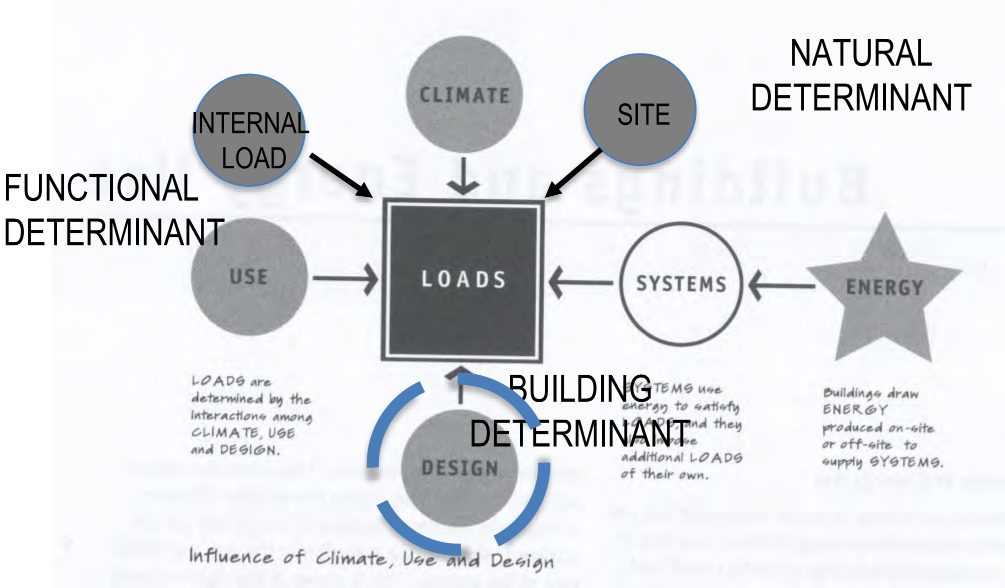
City	Miami	Houston	Phoenix	Atlanta	Los Angeles	Las Vegas	San Francisco	Baltimore	Albuquerque	Seattle	Chicago	Denver	Minneapolis	Helena	Duluth	Fairbanks
Medium Office	39	42	40	41	33	37	38	45	38	42	48	41	54	48	57	77
Stand-alone Retail	62	63	60	61	44	56	50	72	61	65	81	69	93	83	104	145
Quick Service Restaurant	535	549	538	561	496	541	524	609	567	575	657	604	713	663	765	949
Large Hotel	99	108	100	116	105	105	113	127	119	124	138	131	150	144	163	196
Mid-Rise Apartment	39	39	38	38	31	36	33	42	37	38	47	41	54	48	59	76

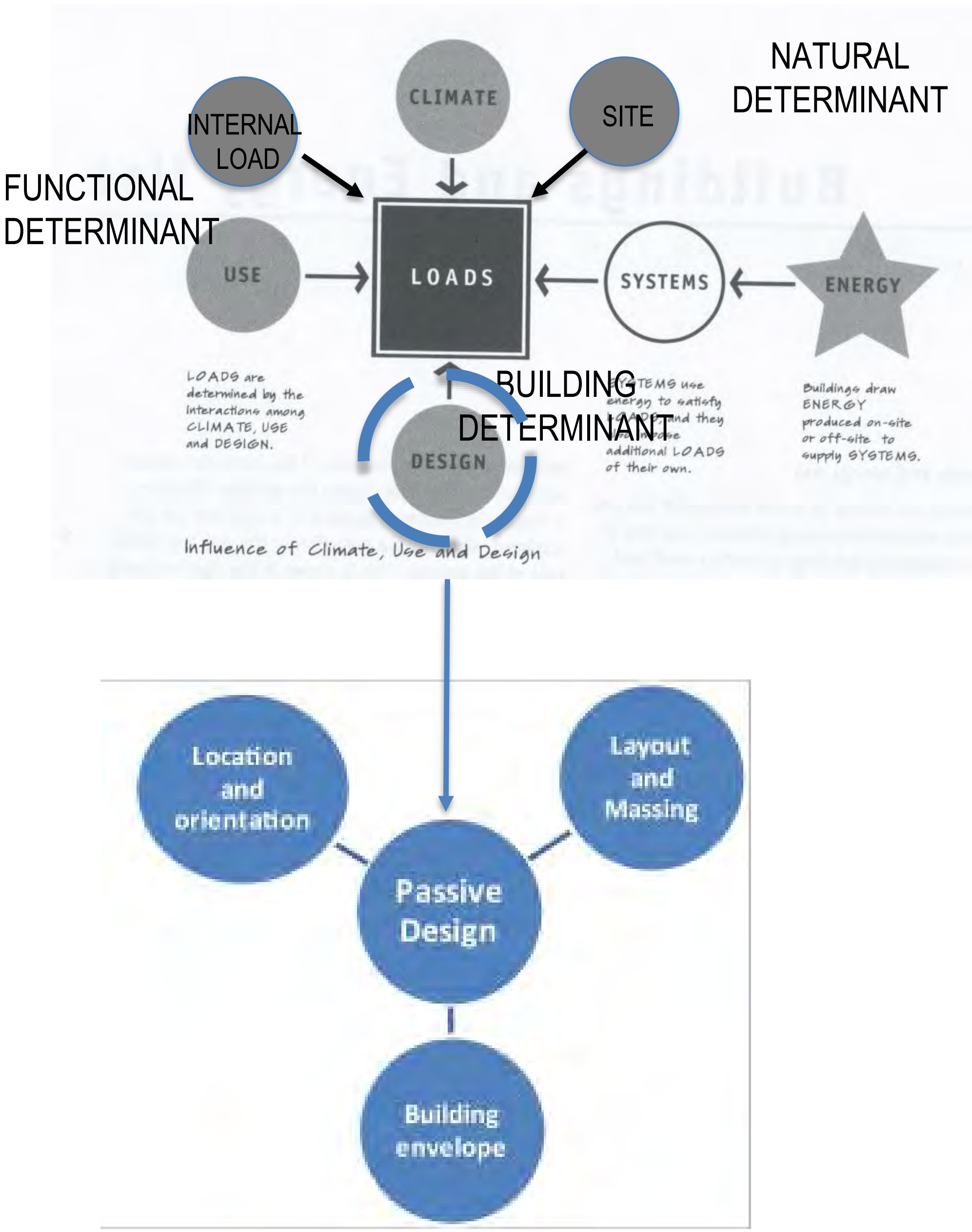
WHY, AS ARCHITECTS, WE NEED TO DEAL WITH ENERGY SIMULATION?

ENVIRONMENTAL SYSTEM DETERMINANTS



ENVIRONMENTAL SYSTEM DETERMINANTS



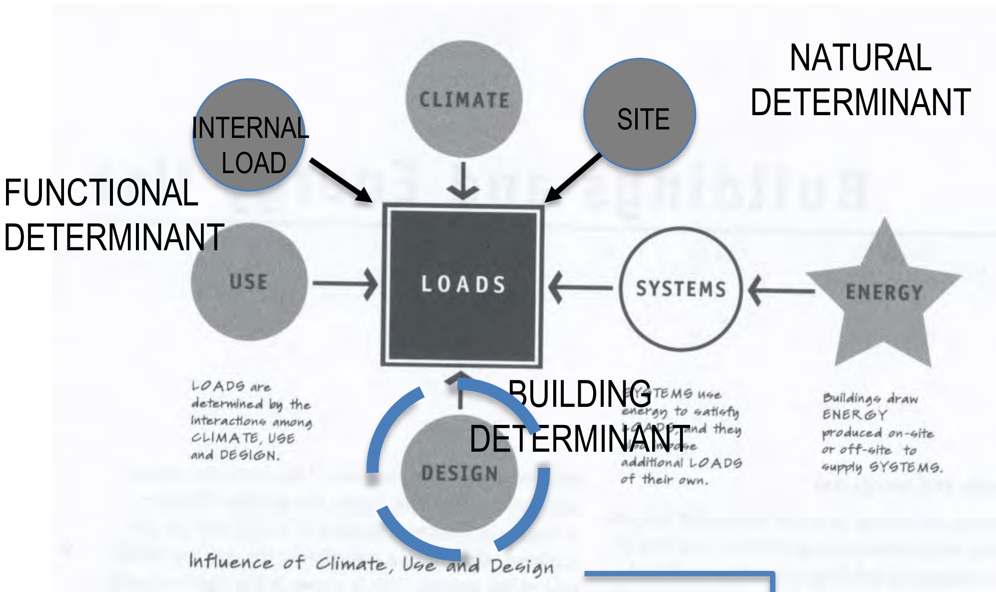


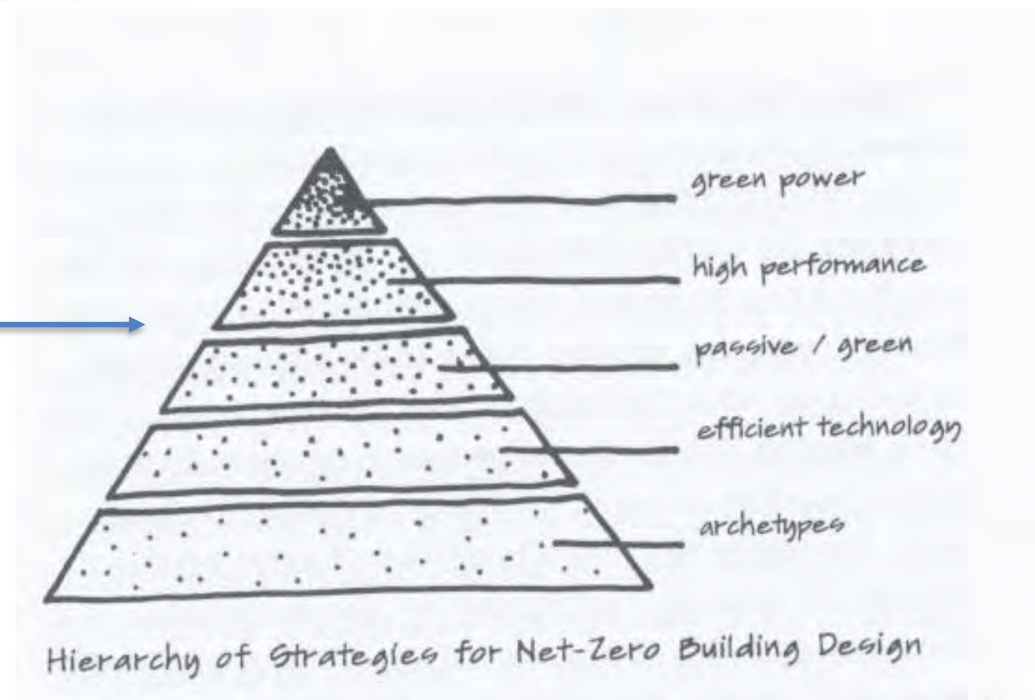
MODELING FOR PASSIVE DESIGN

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:

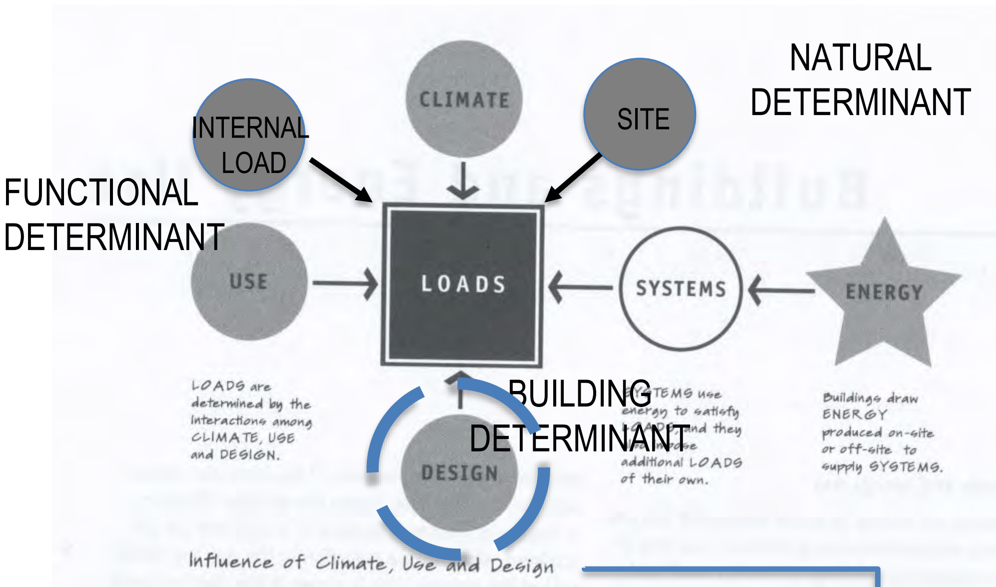
- Day lighting: can reduce the energy used for artificial lighting but excessive and improper exposure may result in glare and other forms of visual discomfort
- Natural ventilation: can reduce mechanical ventilation energy to move air around but can result in hygiene issues and over-cooling in cold 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.

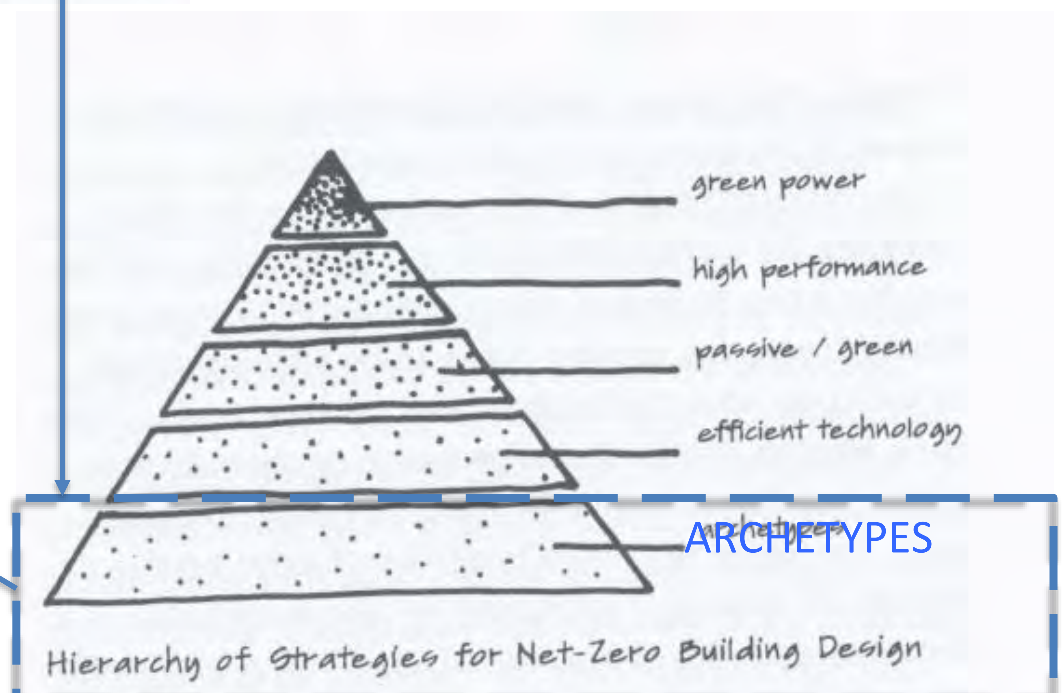
MODELING FOR PASSIVE DESIGN



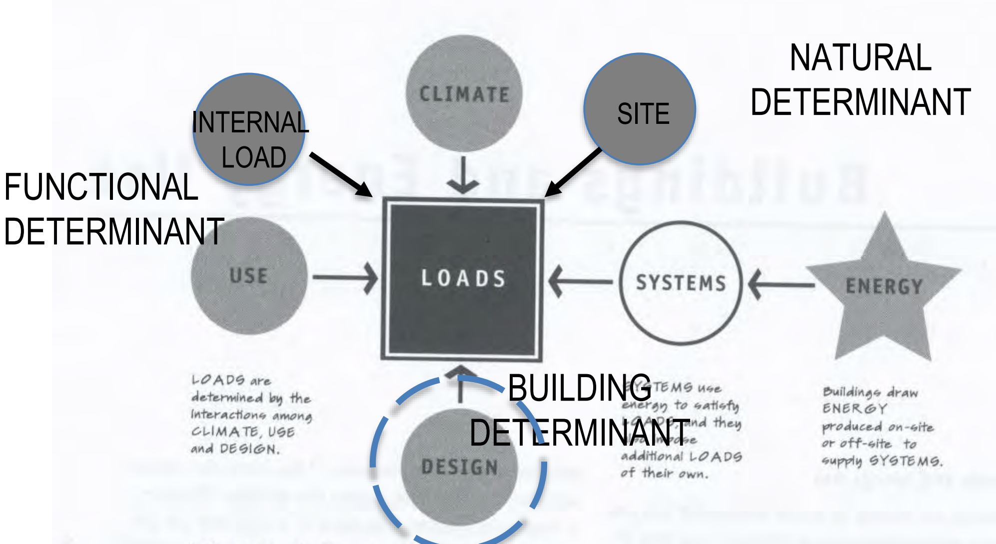


MODELING FOR PASSIVE DESIGN



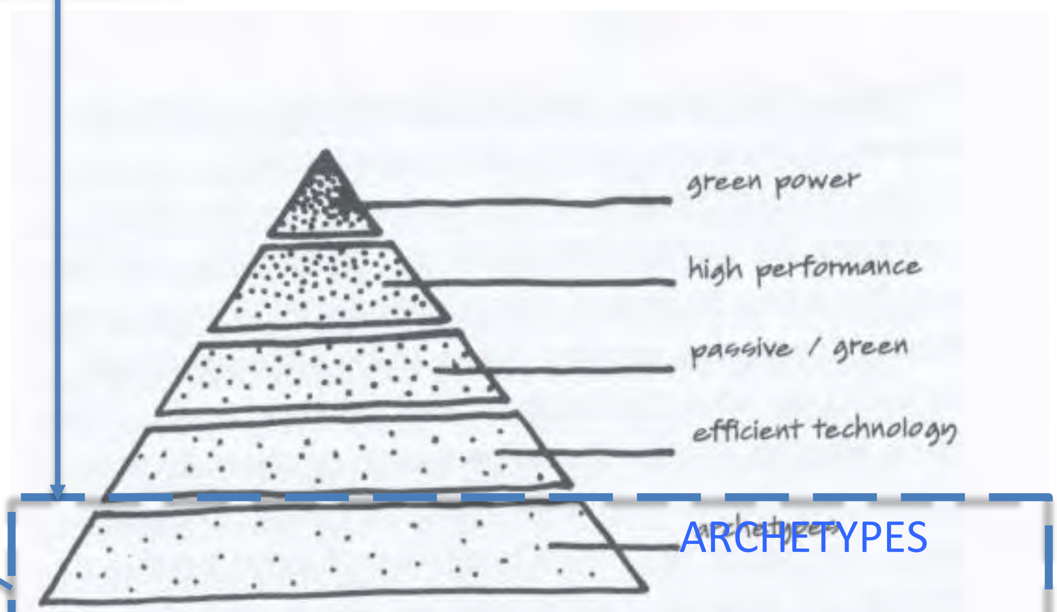


MODELING FOR PASSIVE DESIGN



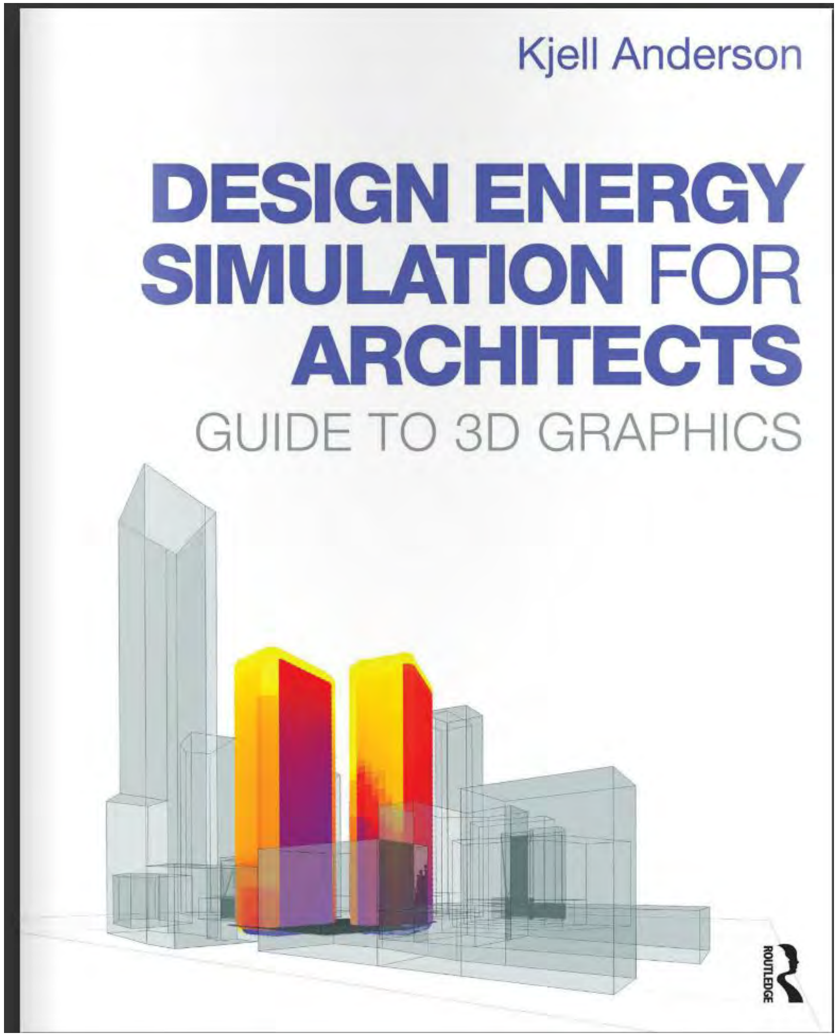
Influence of Climate, Use and Design

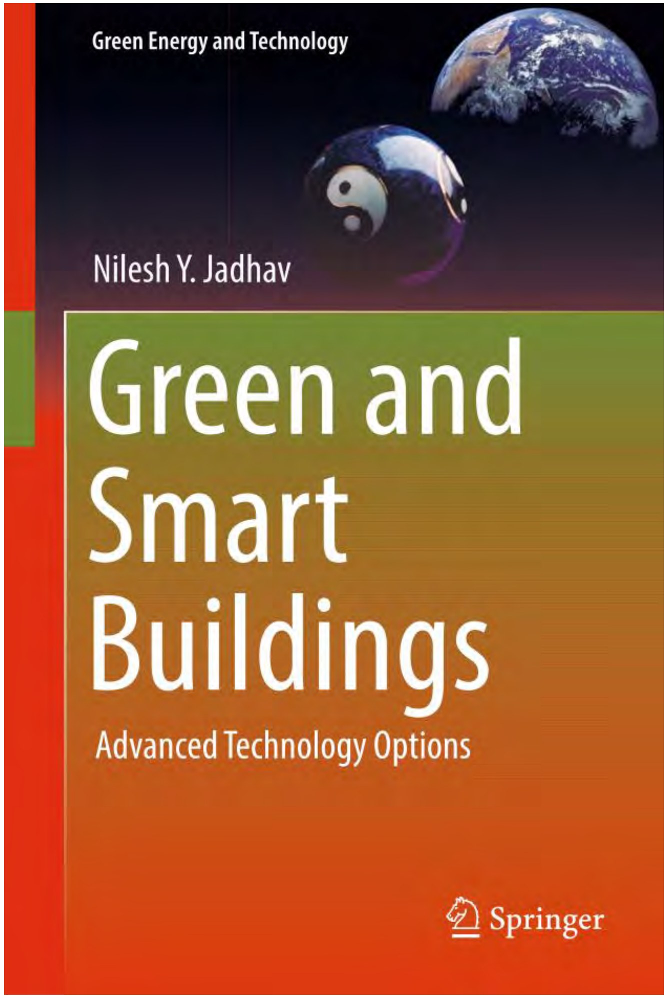
"**archetypes** is the level of basic architectural design where issues of siting, orientation, location, shape, proportions and surface to volume ratio are considered, along with neighborhood or urban fabric context of building groups that set the pattern for access to sun, wind and lights" -SW&L pg.6



Hierarchy of Strategies for Net-Zero Building Design

ENVIRONMENTAL DESIGN
USING MASS COMPUTATIONAL MODELING


Kjell Anderson
DESIGN ENERGY SIMULATION FOR ARCHITECTS
GUIDE TO 3D GRAPHICS
ROUTLEDGE


Green Energy and Technology
Nilesh Y. Jadhav
Green and Smart Buildings
Advanced Technology Options
Springer

USING MASS COMPUTATIONAL MODELING FOR PRELIMINARY ENERGY ASSESSMENT

WHY? :

Initial mass modeling addresses 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 maintenance 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

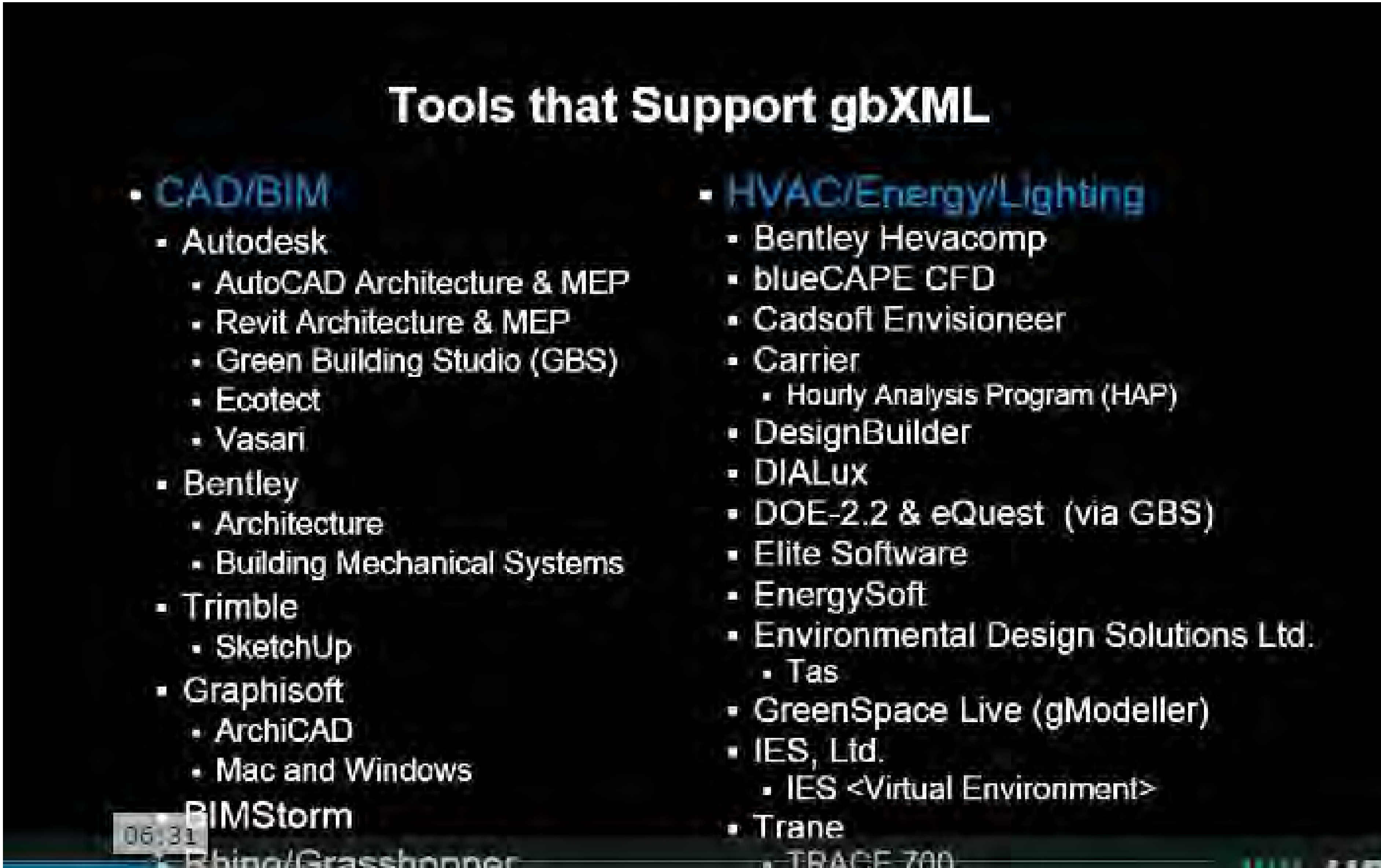
1. EnergyPlus by the U.S. Department of energy (free tool), available at: https:// energyplus.net/.
2. IES Virtual Environment (VE): http://www.iesve.com/.
3. eQUEST, quick energy simulation tool: http://www.doe2.com/equest/.
   AutodeskGreenBuildingStudio:https://gbs.autodesk.com/GBS/(cloudbased).

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
06:31

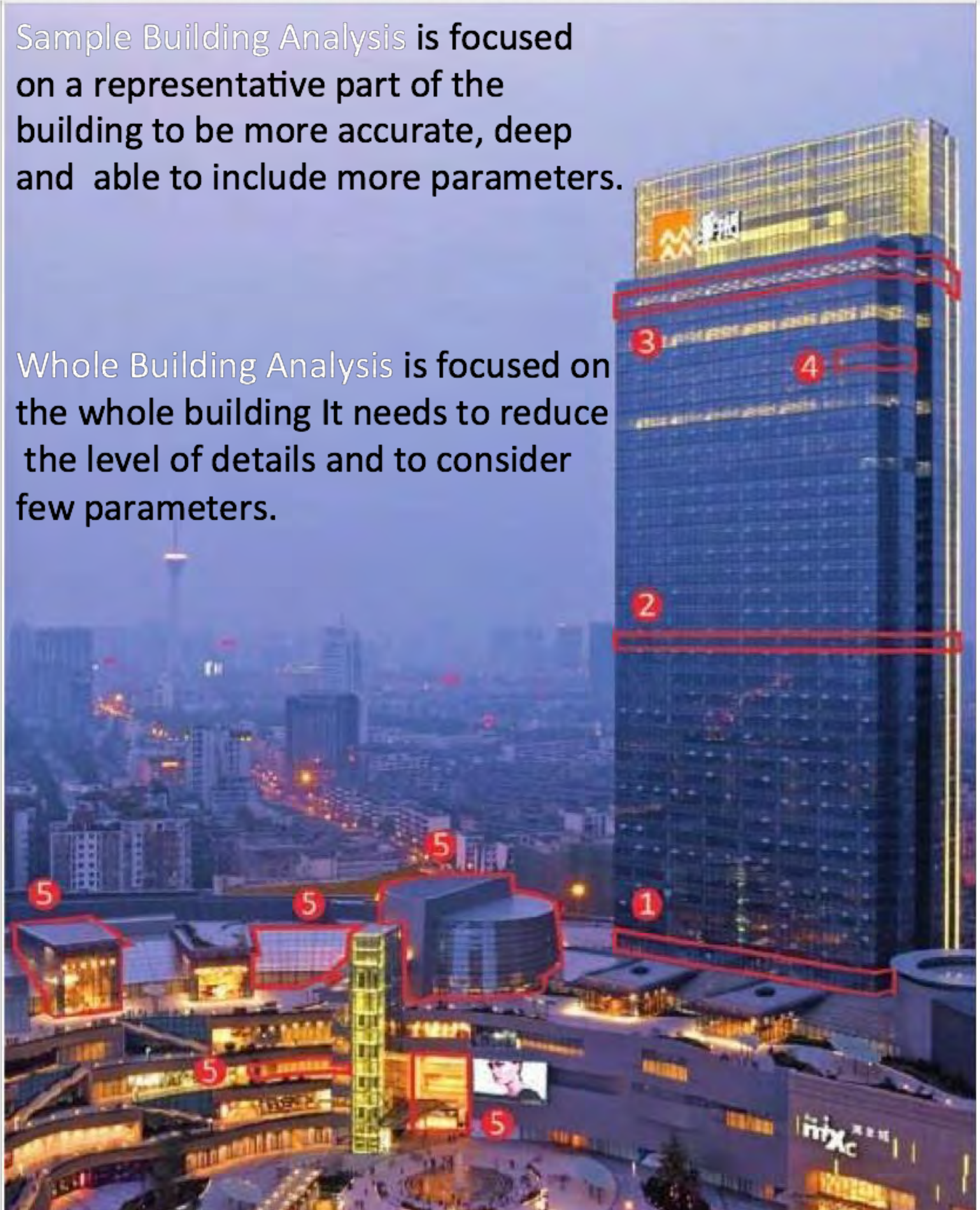
Massing contribution to a passive design

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’.

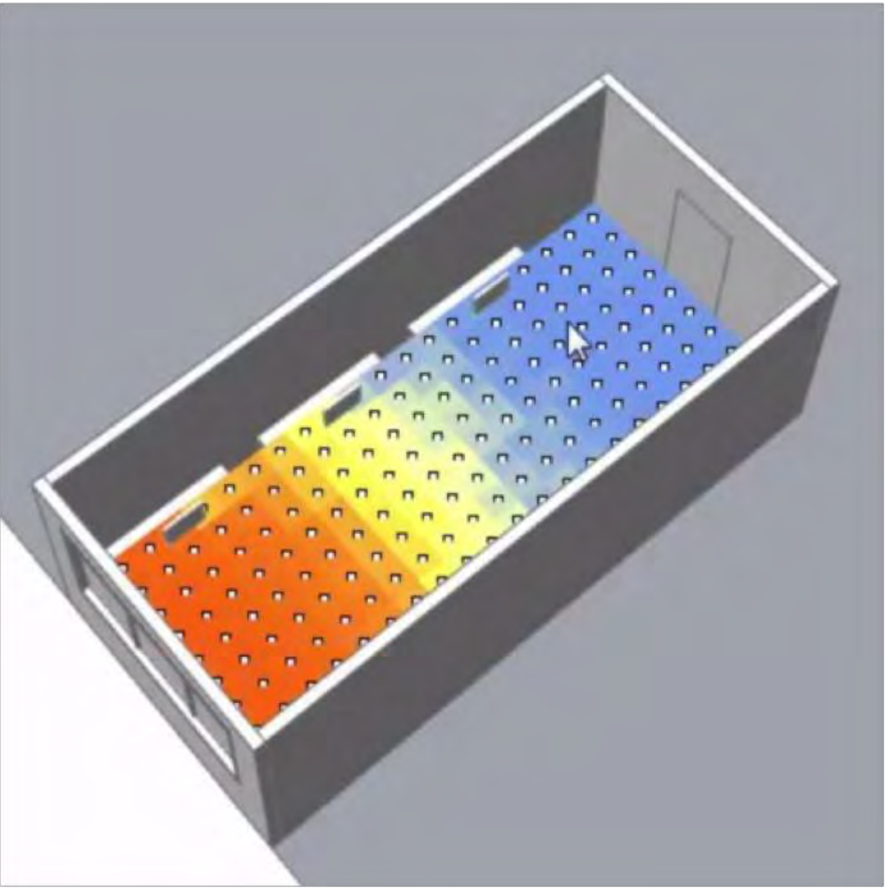
Sample Building Analysis is focused on a representative part of the building to be more accurate, deep and able to include more parameters.

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

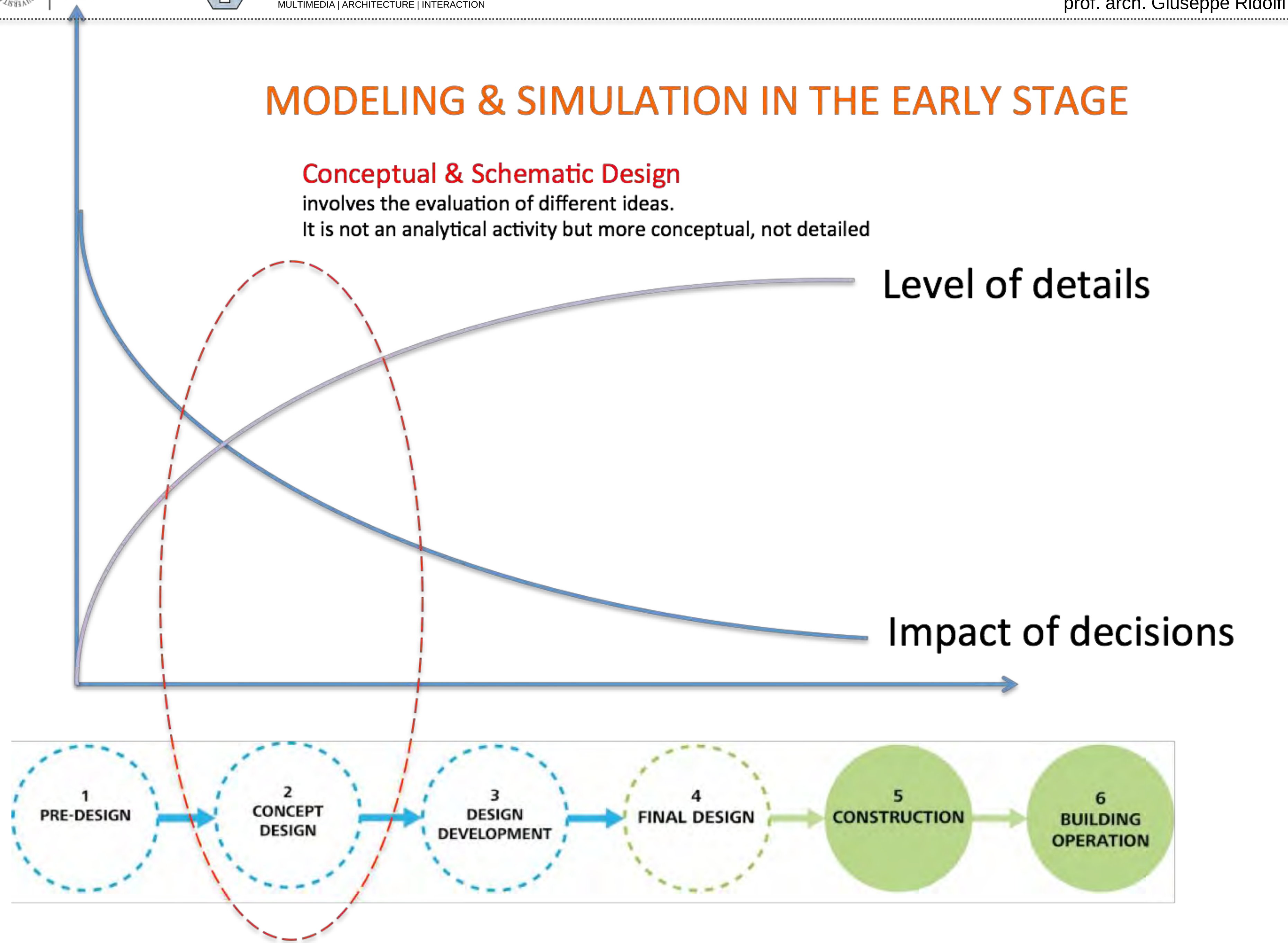
STATIC

DINAMIC

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

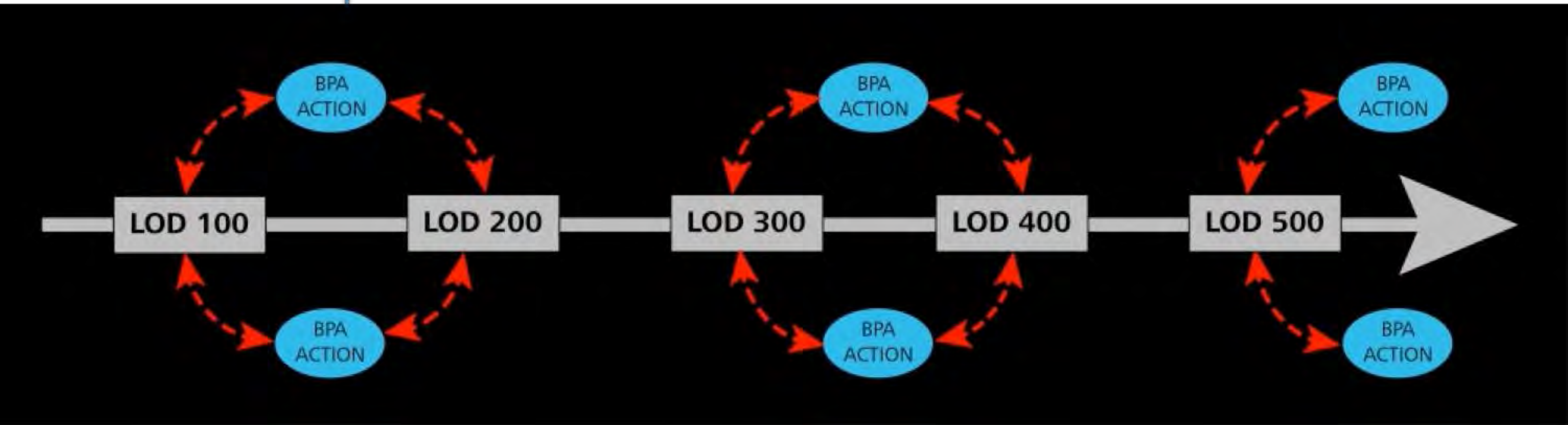
POINT-IN-TIME (PIT) analysis= in a precise single moment segment like hottest hours

MODELING & SIMULATION IN THE EARLY STAGE

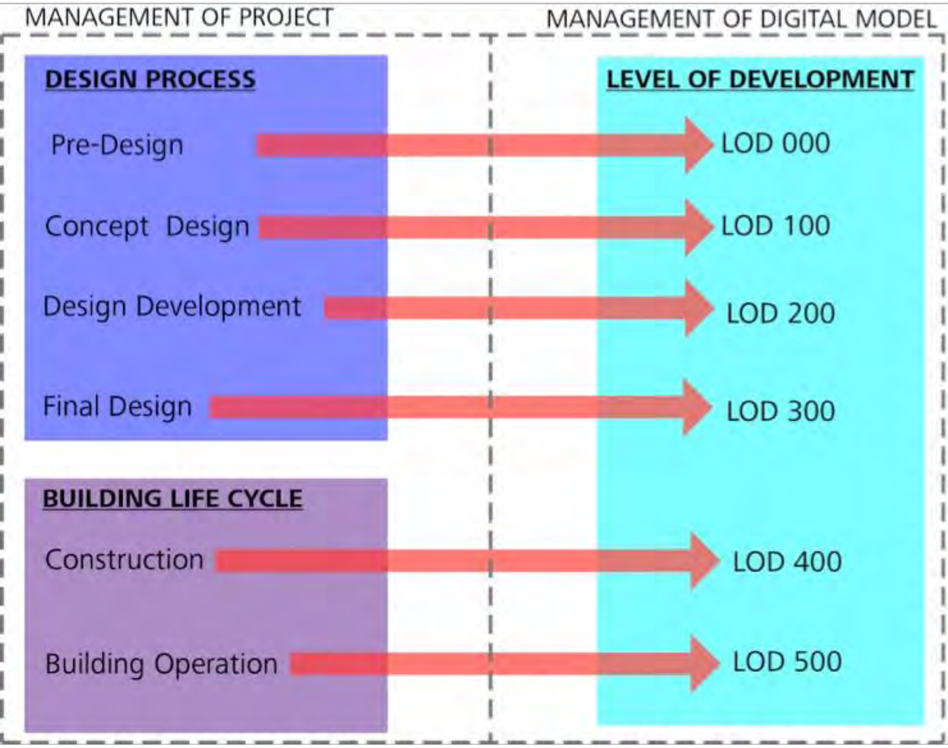


WHICH LEVEL OF DETAIL IS REQUIRED IN THE EARLY STAGE THE BIM PROCESS

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
Lighting Efficiency

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

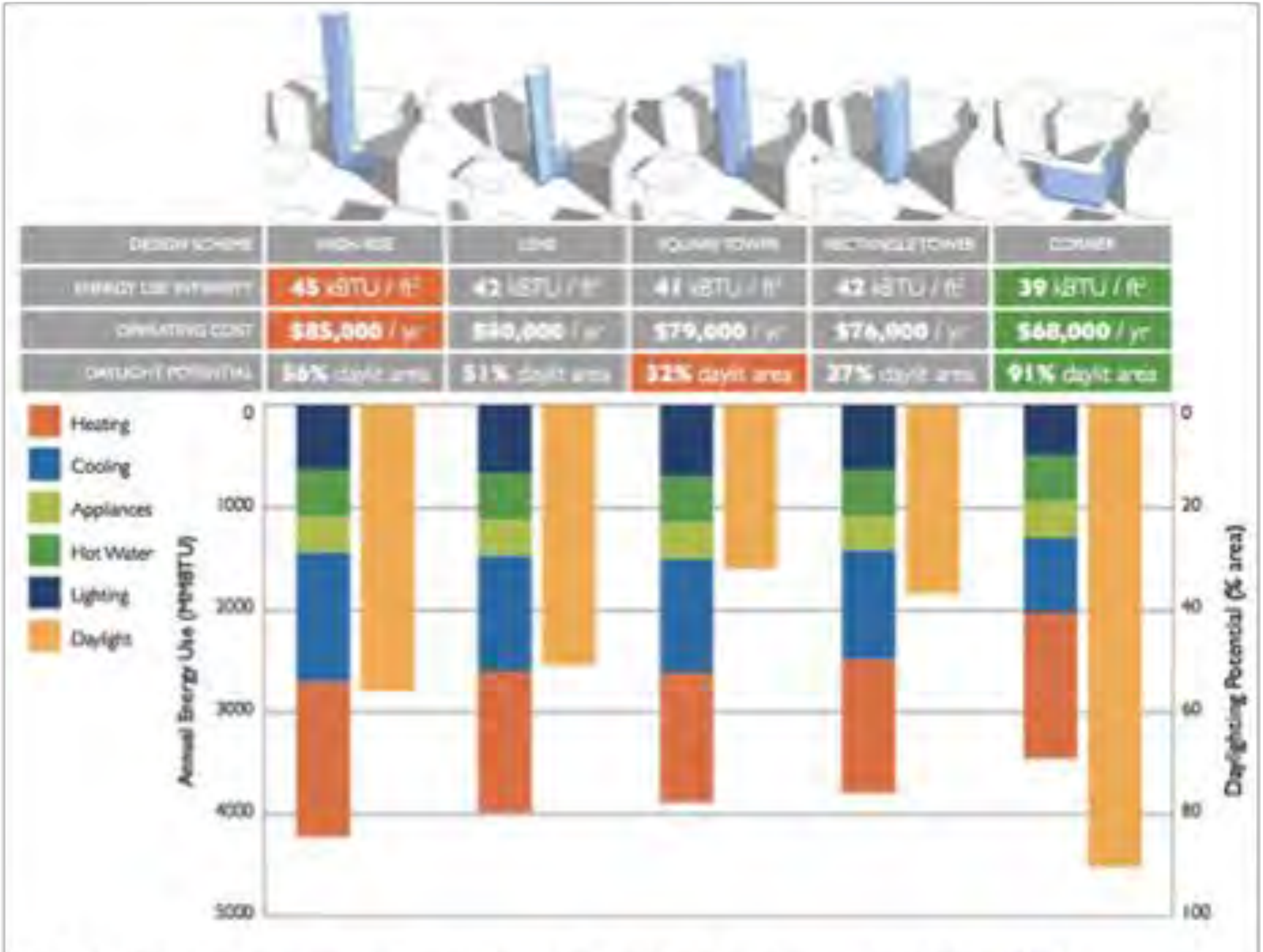
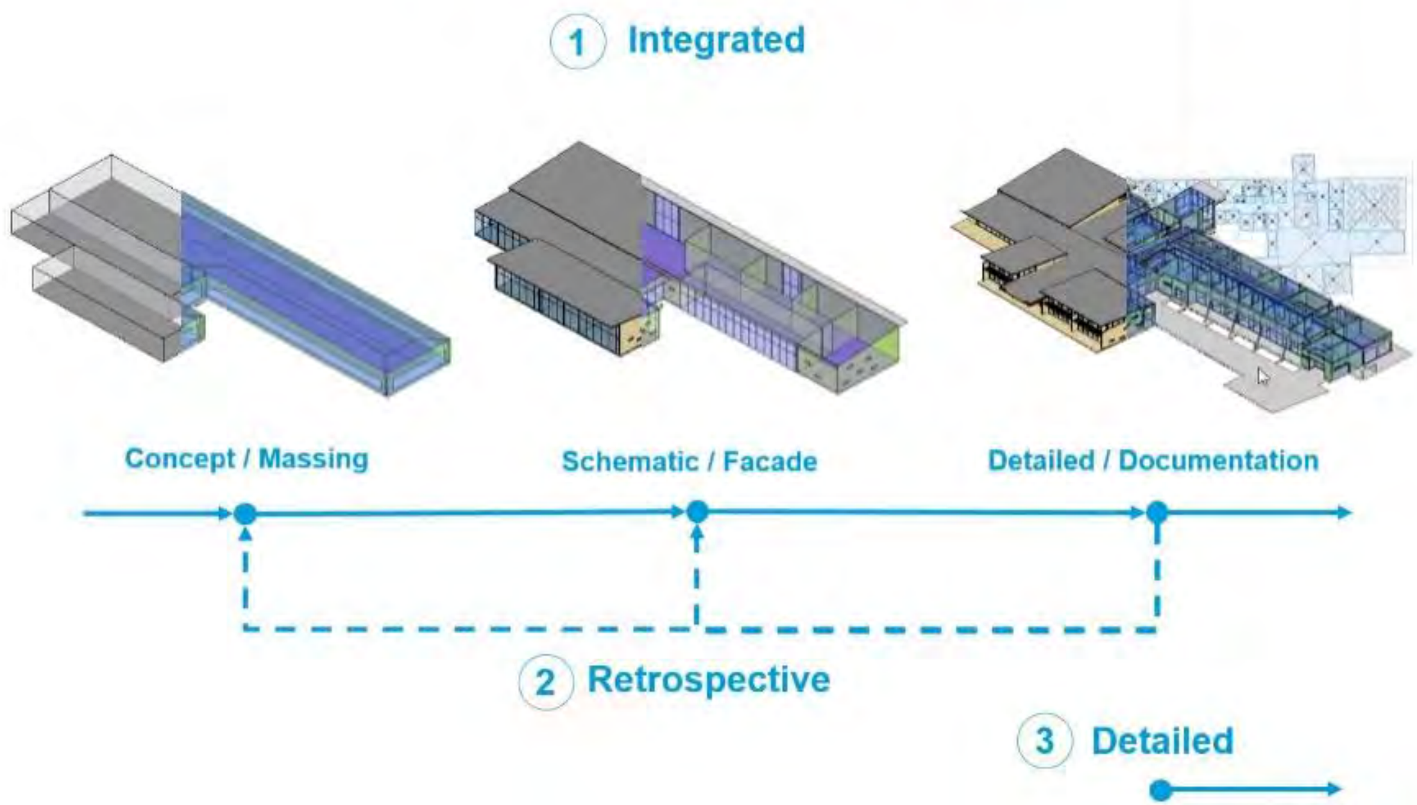


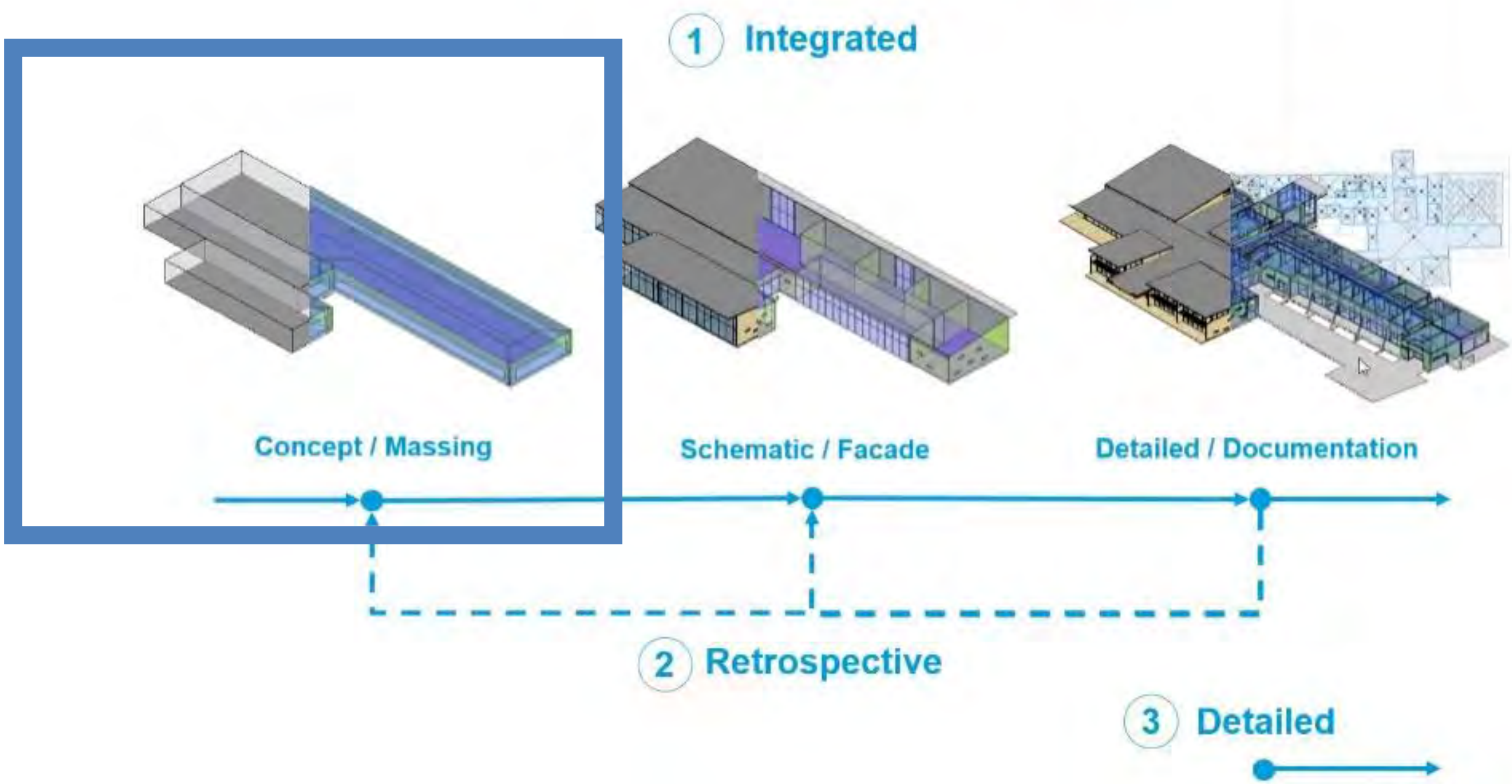
Fig. 4.4 Massing options and implication on building performance (Sefaira 2013)

Level 3 Overview – Scales from Concept to Detail

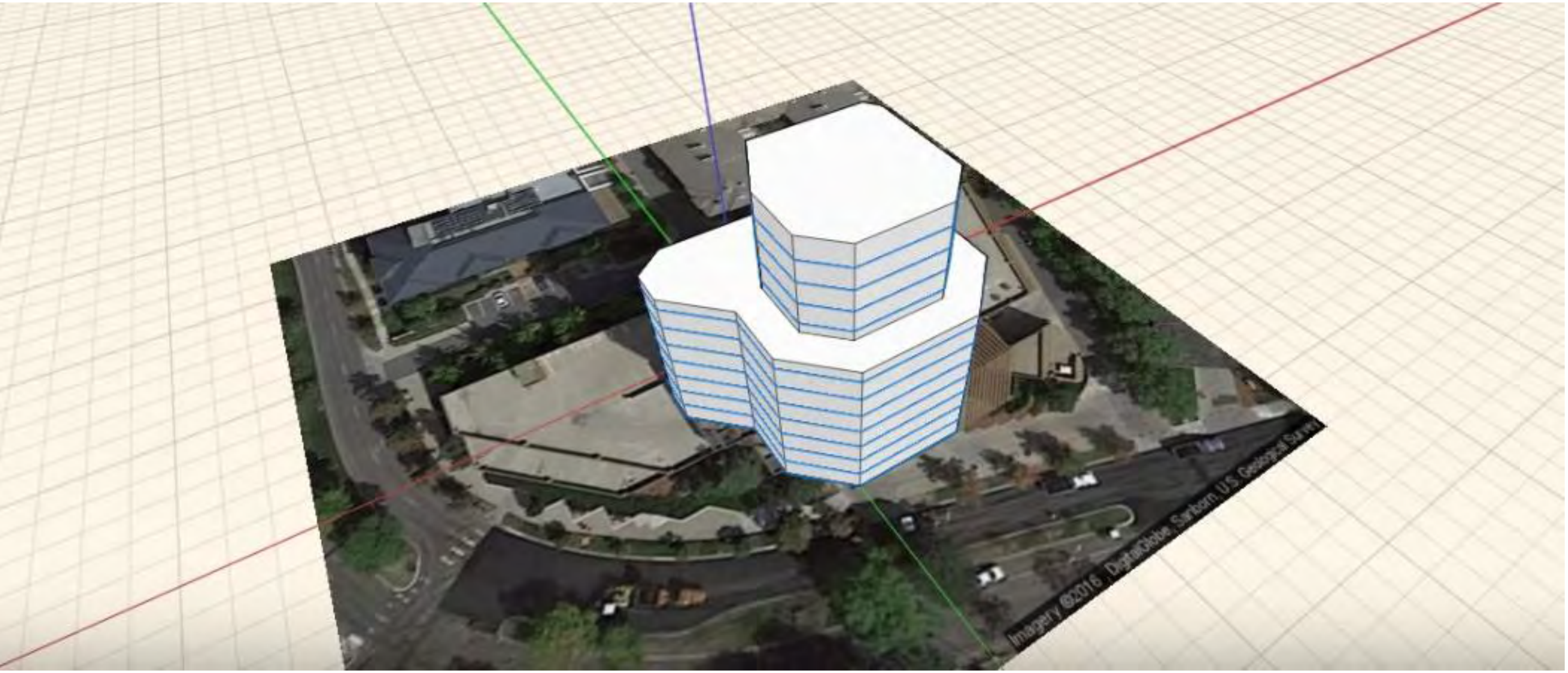


DO THE RIGHT CHOICE FROM THE BEGINNING

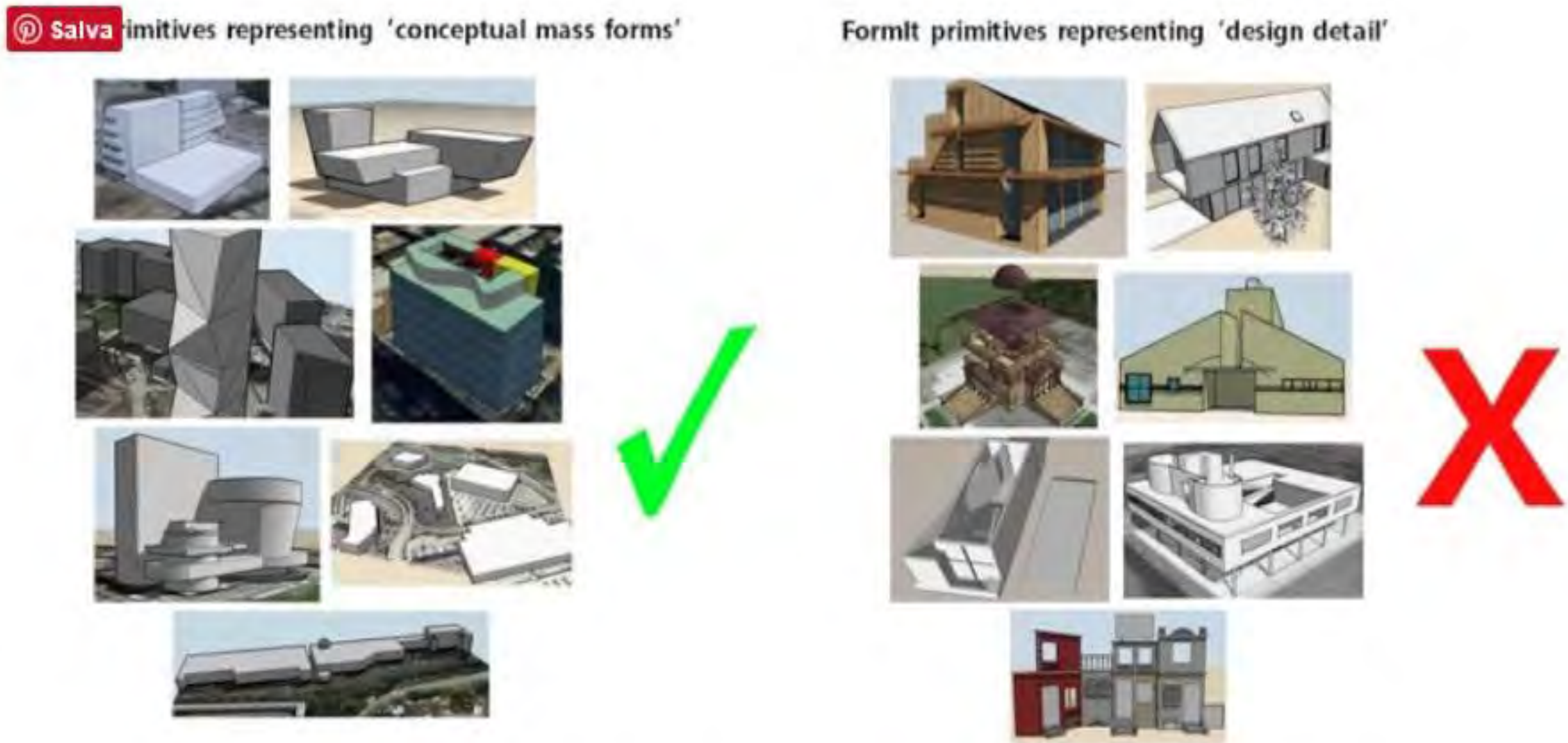
Level 3 Overview – Scales from Concept to Detail



CONCEPTUAL MASS MODELING IN THE EARLY STAGE DESIGN



CONCEPTUAL MASS MODELING IN THE EARLY STAGE DESIGN

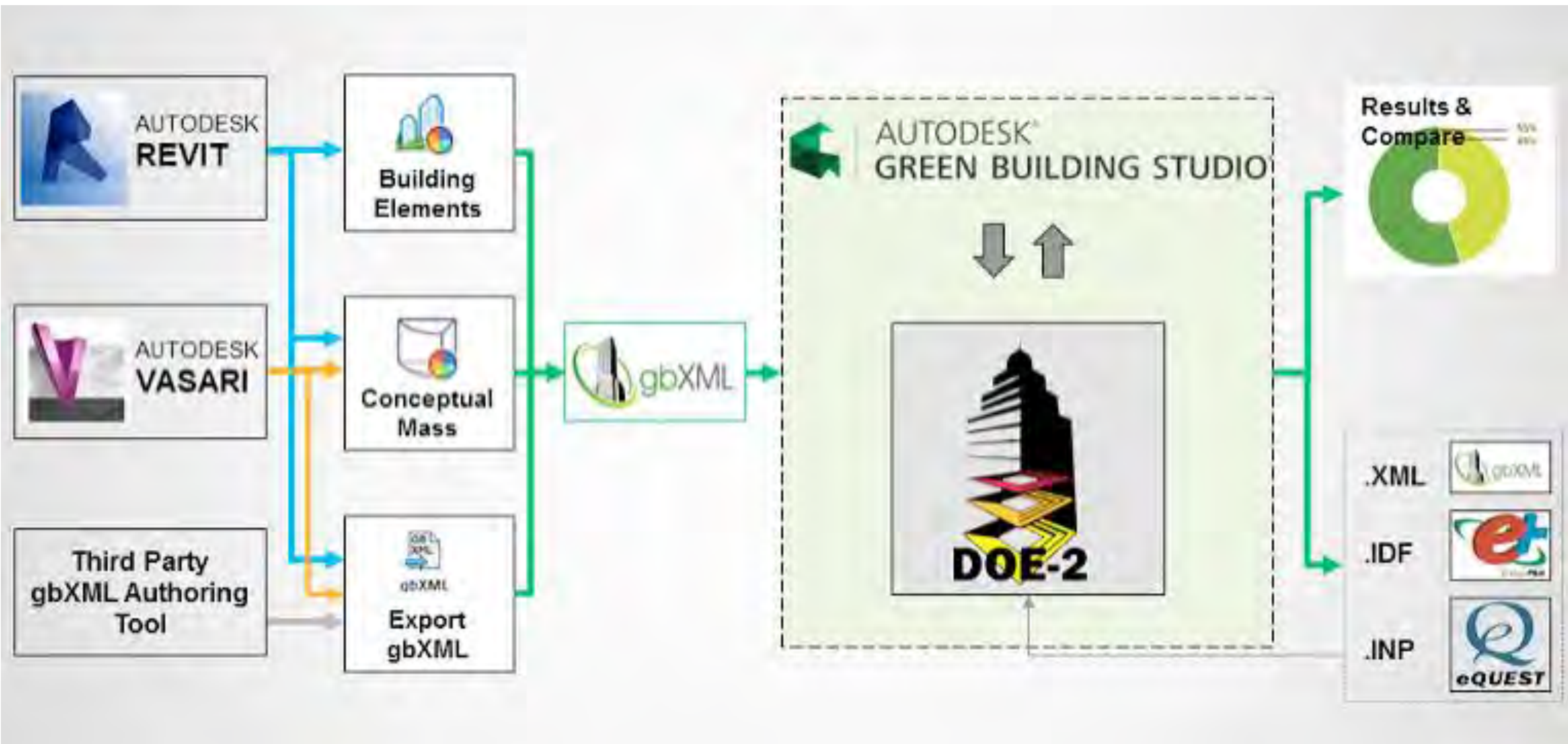


An illustration of FormIt conceptual mass models suited (and not) for Energy Analysis

CONCEPTUAL MASS MODELING IN THE EARLY STAGE DESIGN

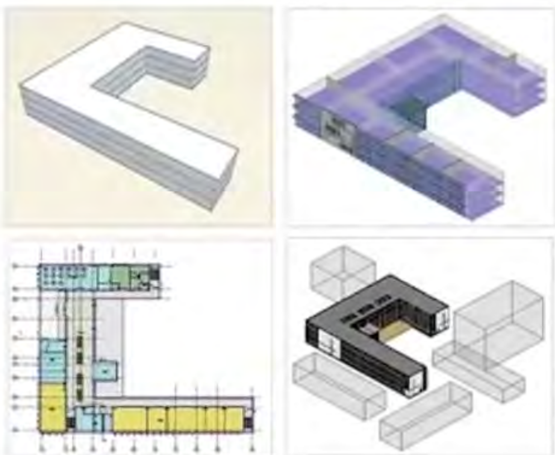
MASS MODELING FOR ENERGY EVALUATION
USING REVIT + GREEN BUILDING STUDIO

WHAT IS REVIT?



MASS ENERGY EVALUATION WORKFLOW IN AUTODESK

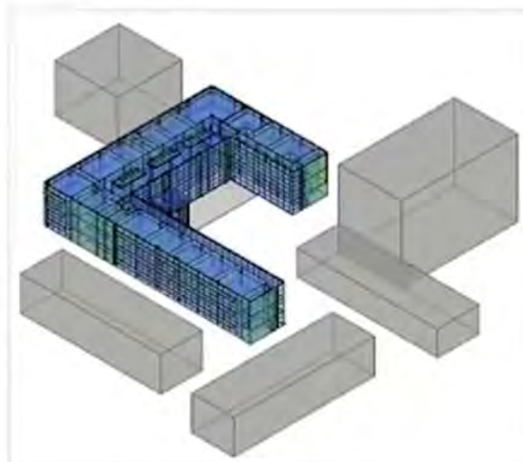
Architectural Modeling



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

Typically includes many small modeling inaccuracies & omissions.

Energy Analytical Model Creation



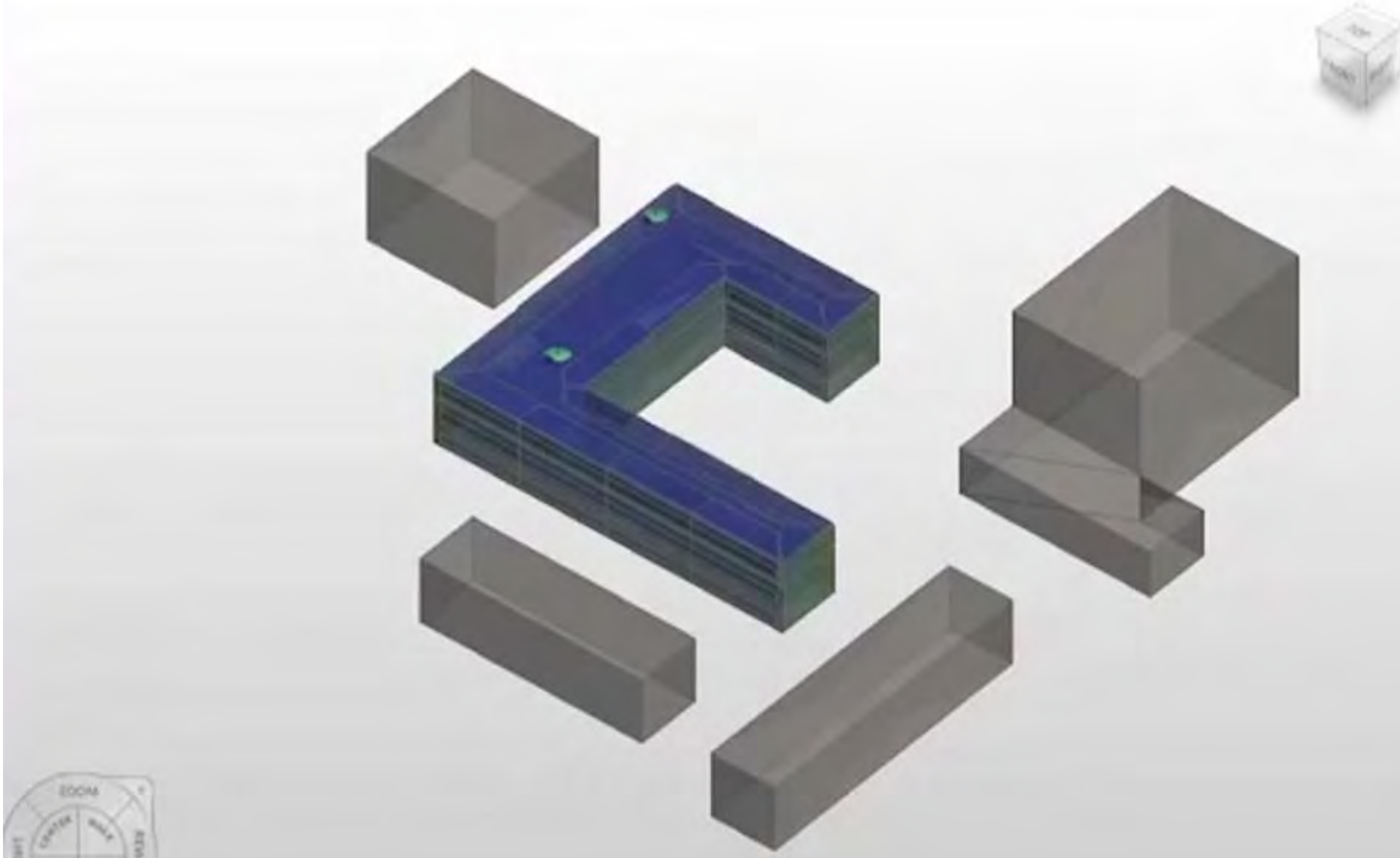
Fully automated using Architectural Model elements with little to no 'cleaning or special modifications'.

Whole Building Energy Simulation

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

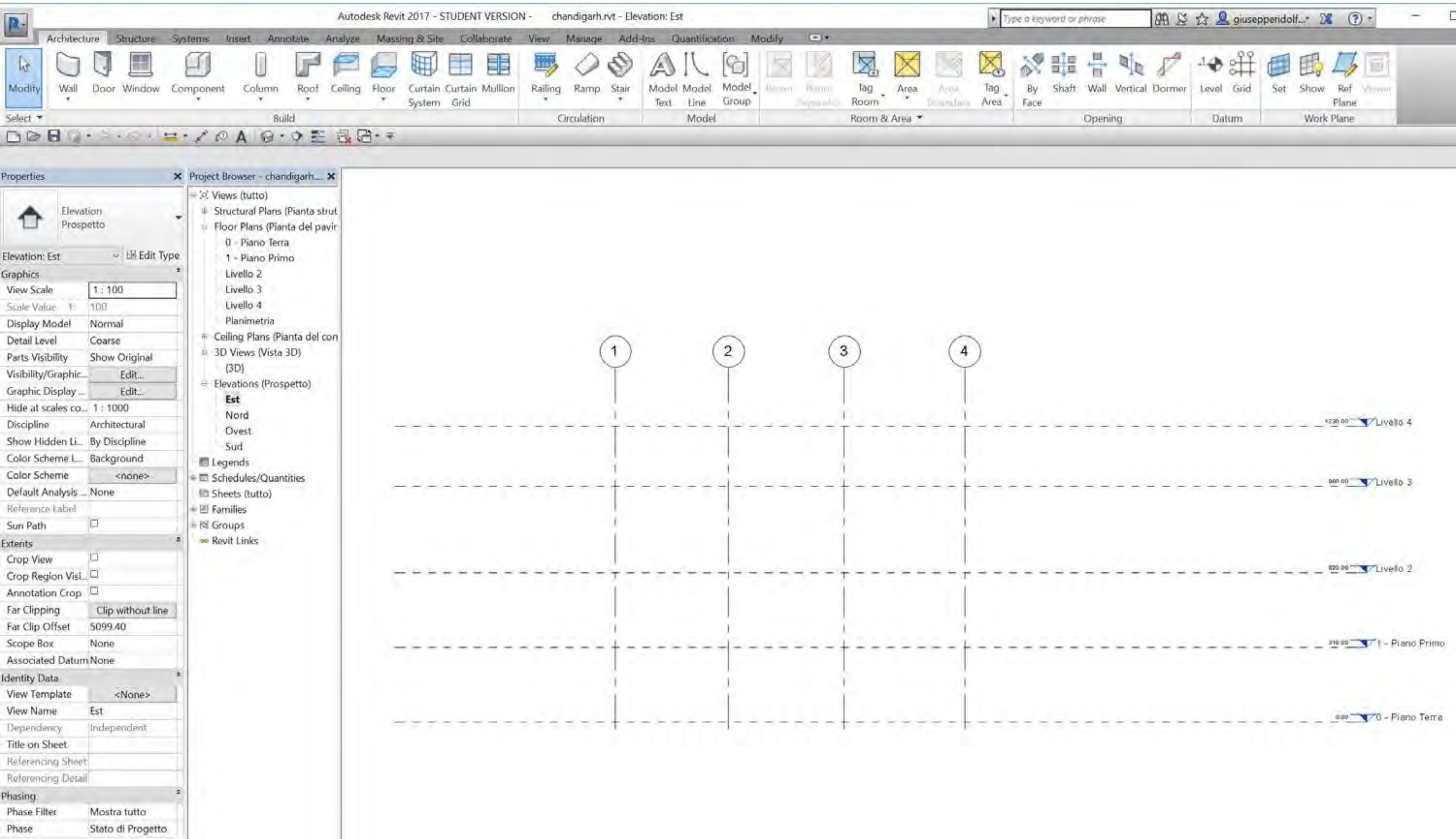
Custom detailed dashboards and parametric run configuration.

1st STEP: MODEL ARCHITECTURAL MASSES



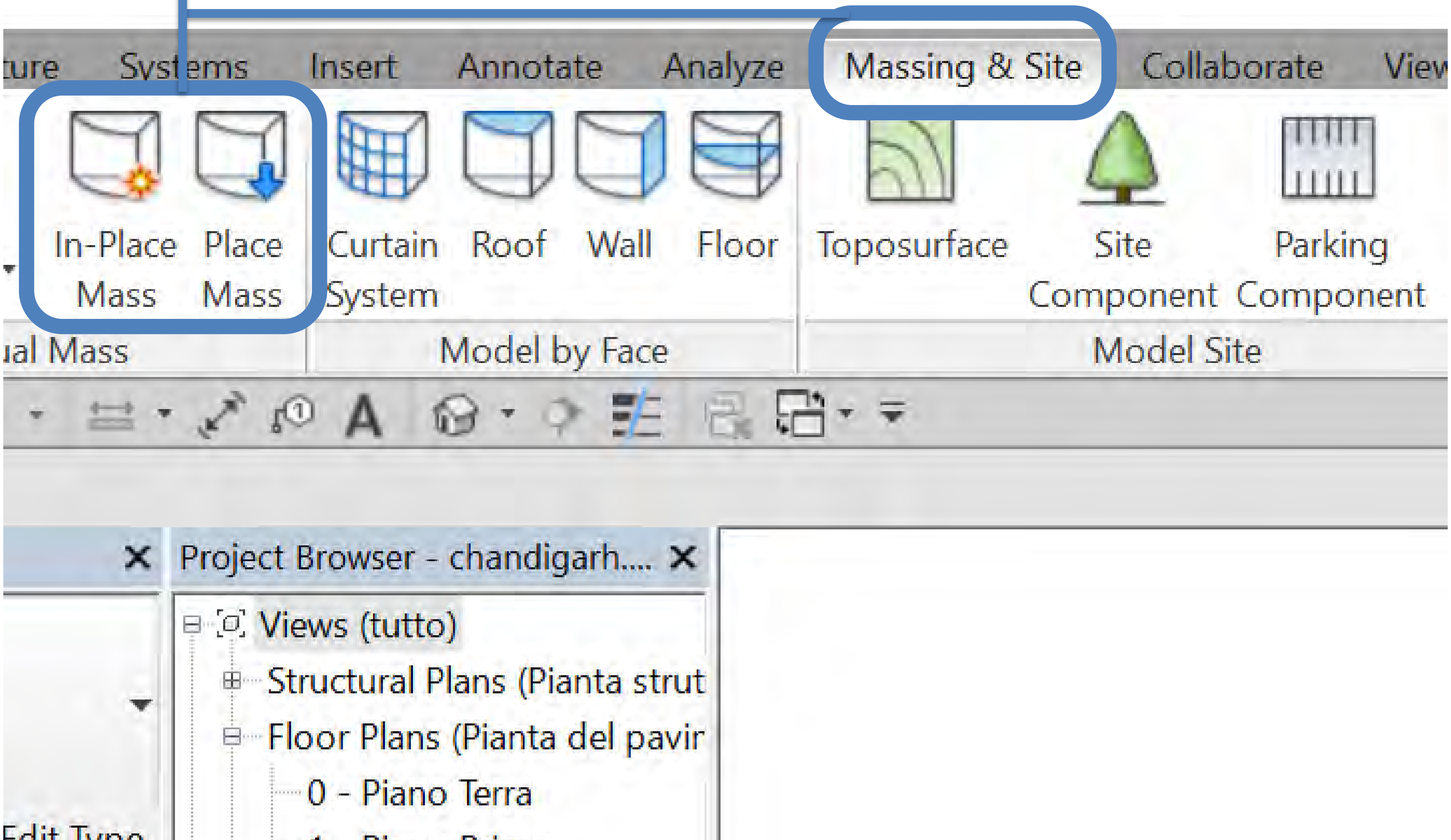
1st STEP: MODEL ARCHITECTURAL MASSES

- create grid levels



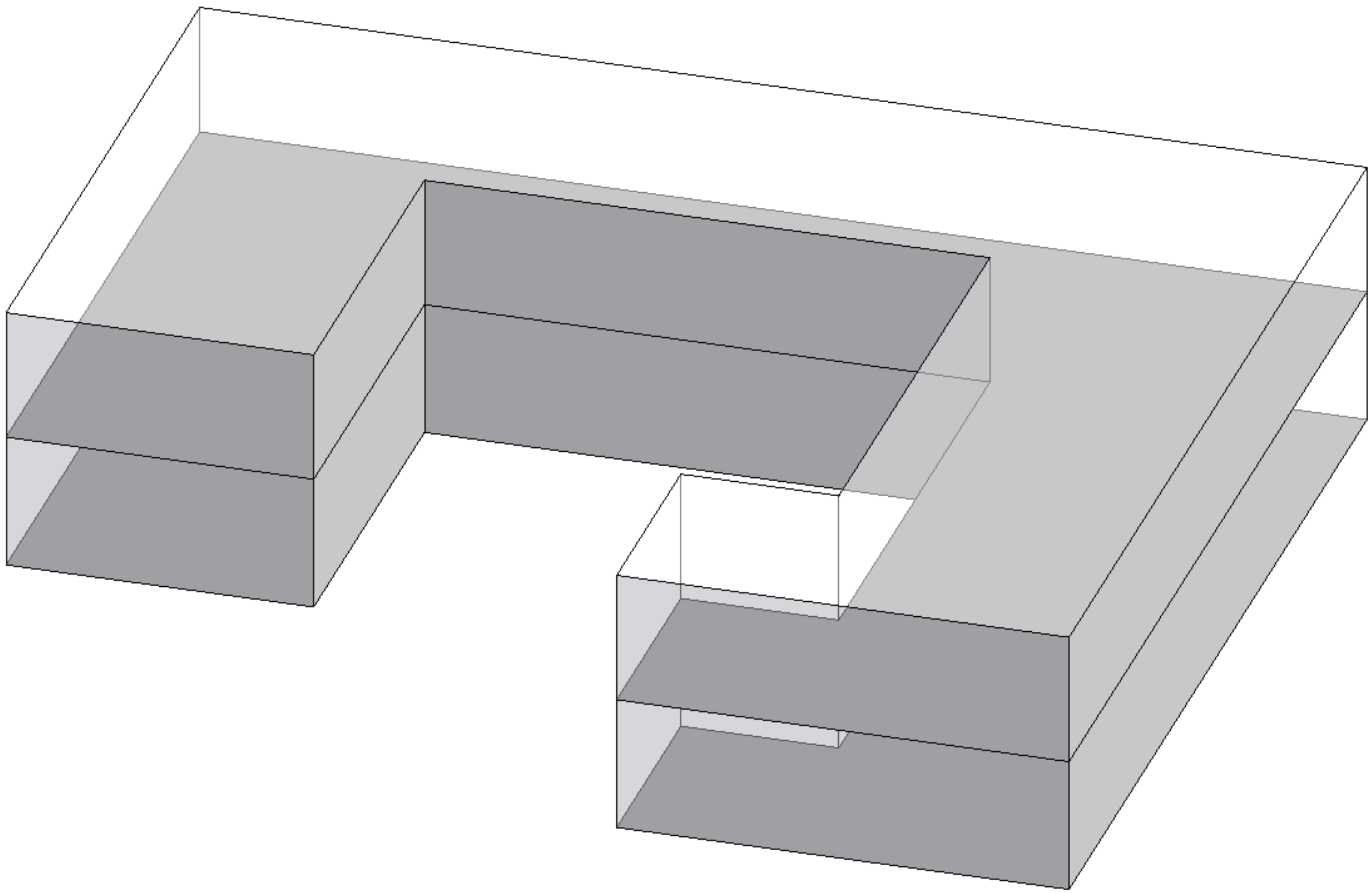
1st STEP: MODEL ARCHITECTURAL MASSES

- start mass modeling

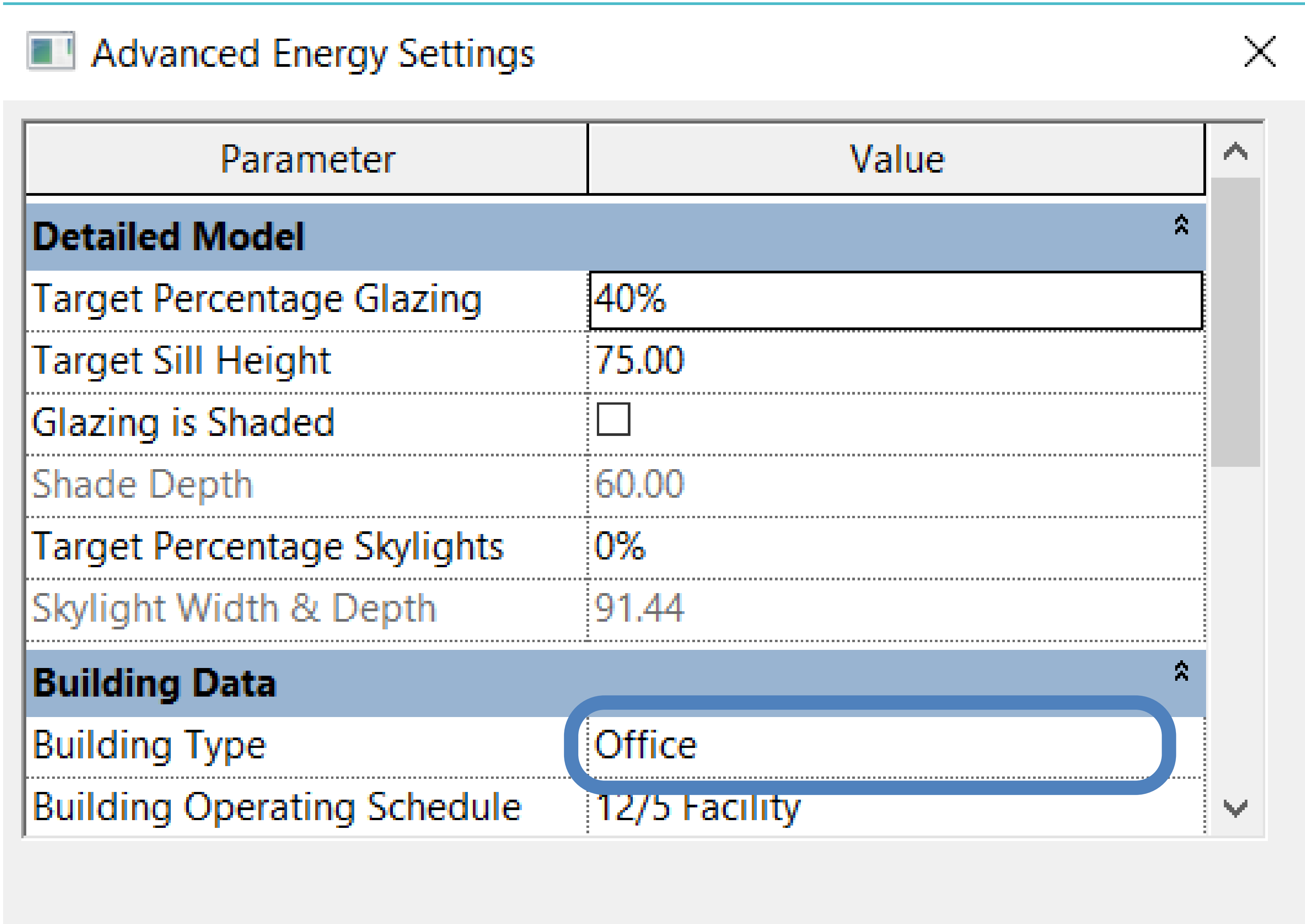


1st STEP: MODEL ARCHITECTURAL MASSES

- create floors from the generic mass using grid level



2st STEP: SET FUNCTIONAL DESTINATION



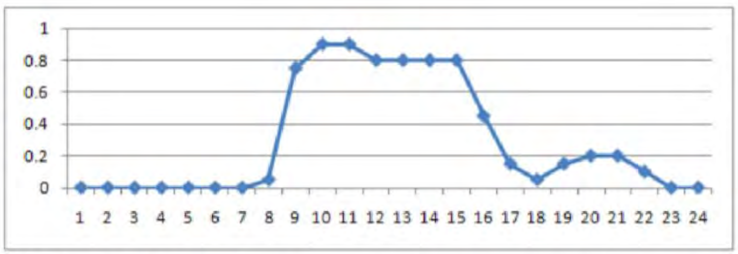
TYPICAL INPUT PARAMETERS FOR BUILDING ENERGY MODELING

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

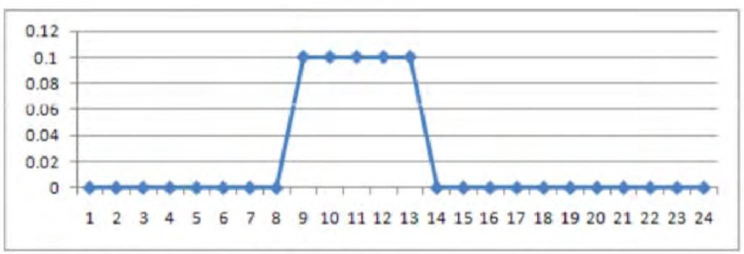
Commercial software have built-in industry standard default related to physical and technological properties, and benchmarks.

2st STEP: SET FUNCTIONAL DESTINATION

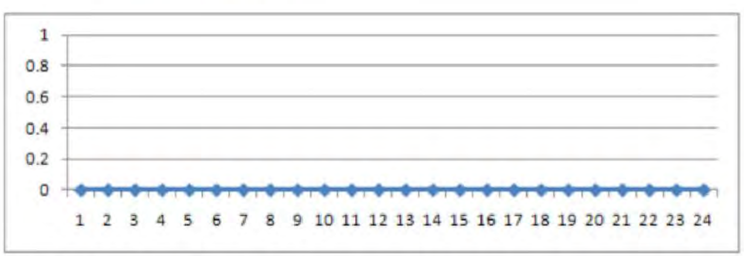
* eventually: specify Scheduling and Hourly Operational Profile



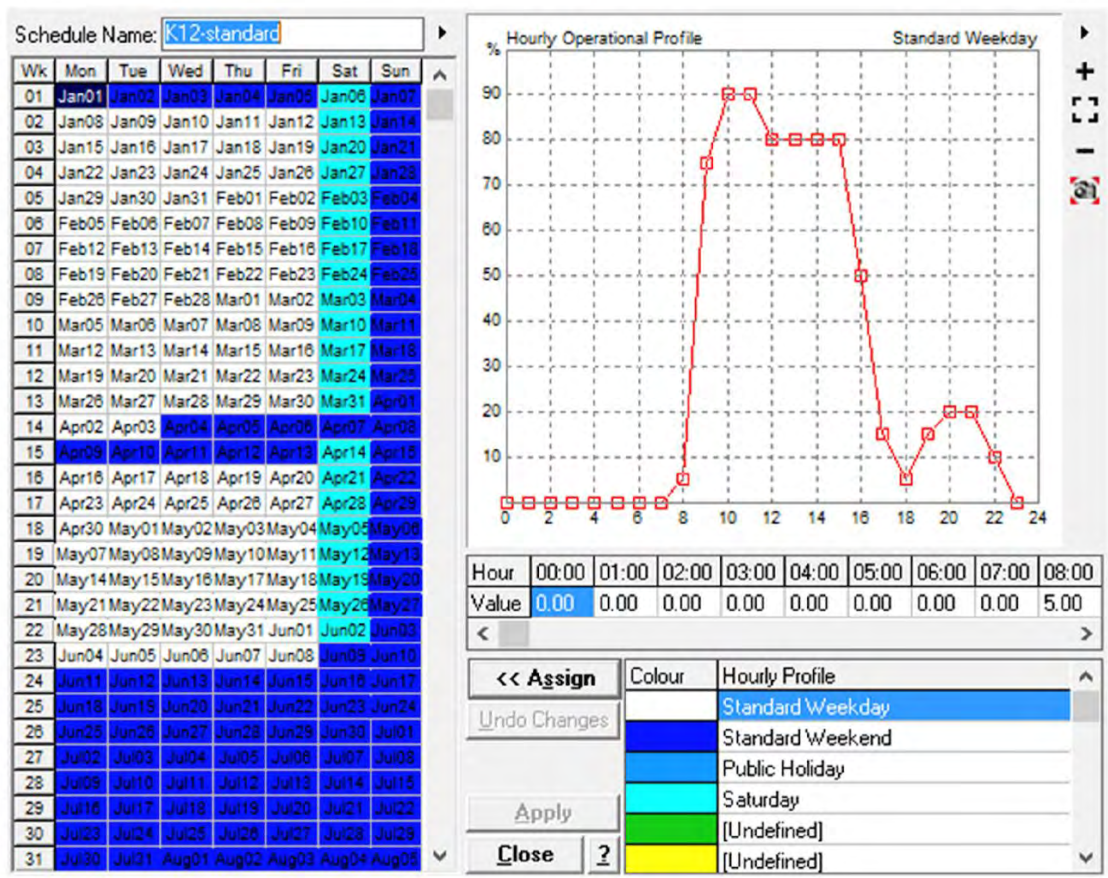
School schedule on weekdays



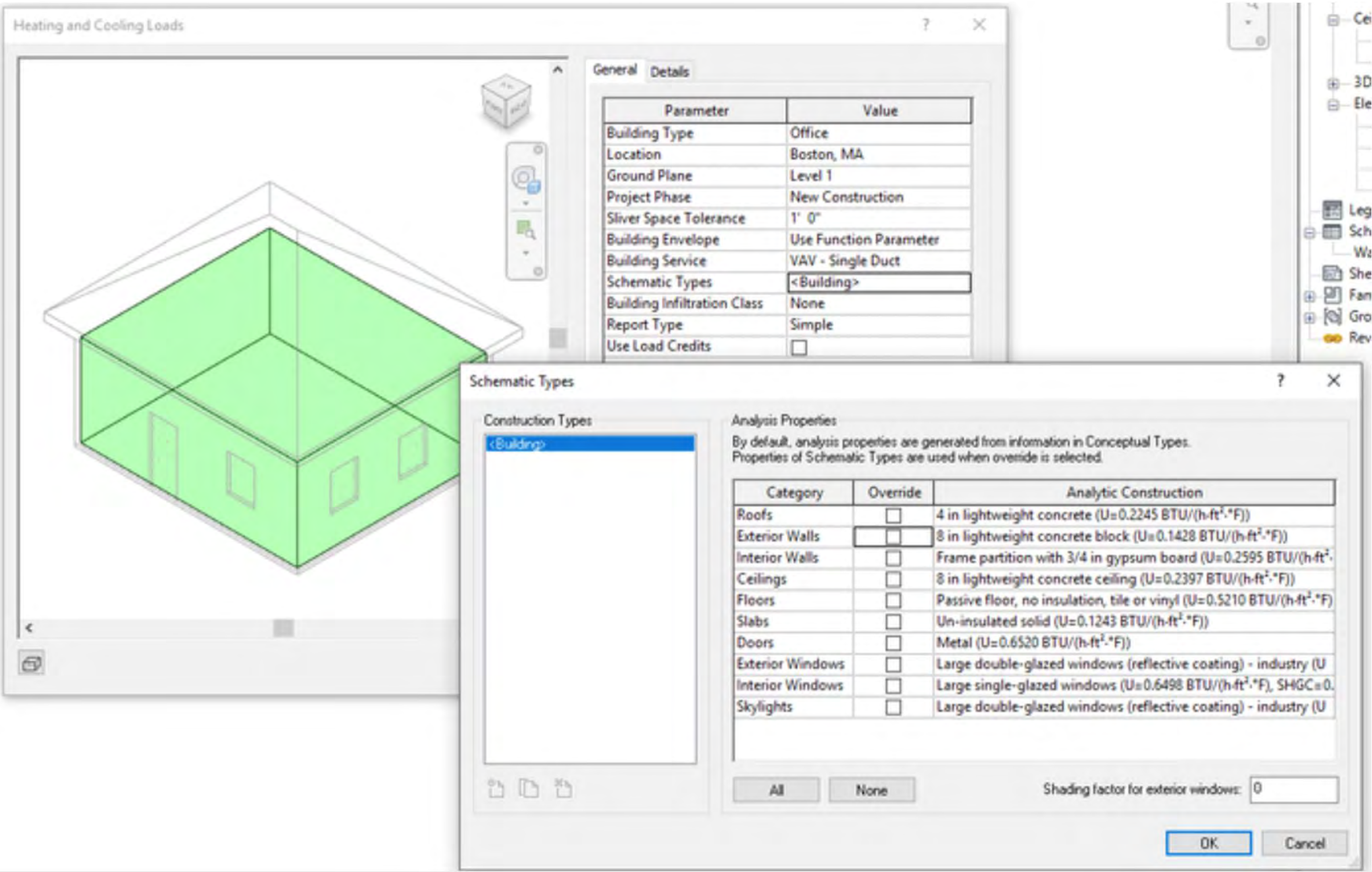
School schedule on Saturday



School schedule on Sunday



3st STEP: CHECK & SET DEFAULT CONSTRUCTION TYPES



3st STEP: CHECK & SET DEFAULT CONSTRUCTION TYPES

Schematic Types

? ×

Construction Types

<Building>

Analysis Properties

By default, analysis properties are generated from information in Conceptual Types.
Properties of Schematic Types are used when override is selected.

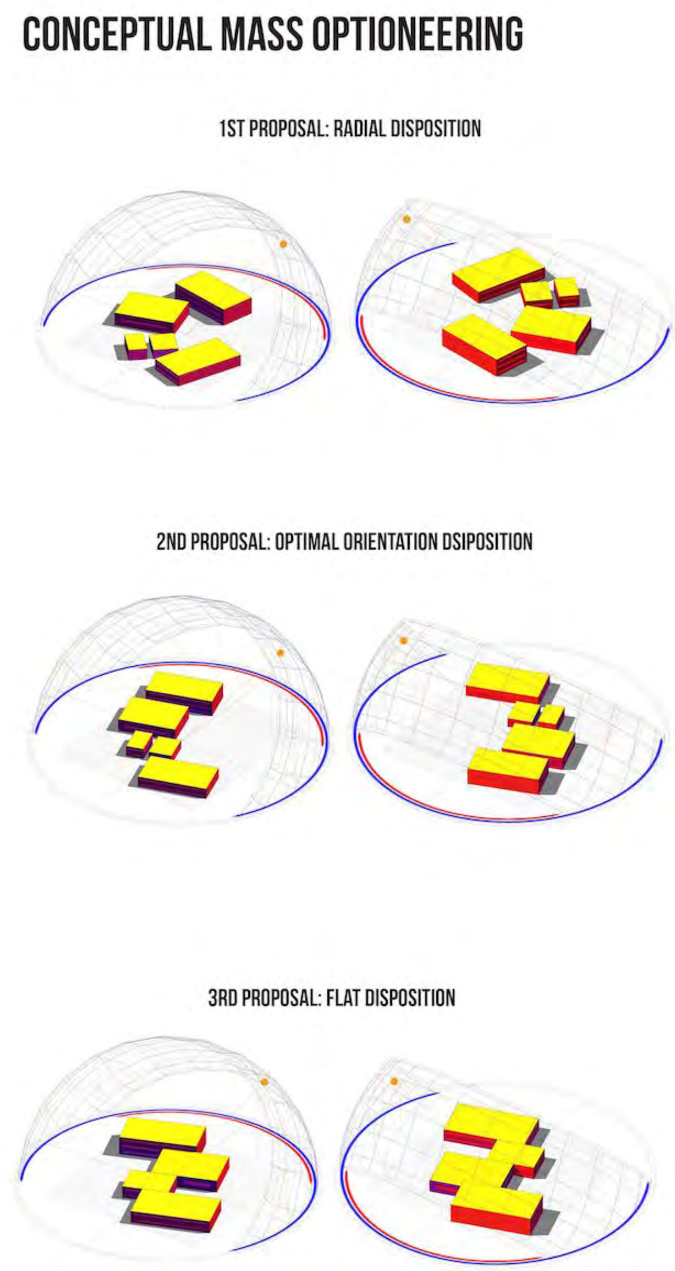
Category	Override	Analytic Construction
Roofs	☑	4 in lightweight concrete (U=1.2750 W/(m²·K))
Exterior Walls	☑	8 in lightweight concrete block (U=0.8108 W/(m²·K))
Interior Walls	☑	Frame partition with 3/4 in gypsum board (U=1.4733 W/(m²·K))
Ceilings	☑	8 in lightweight concrete ceiling (U=1.3610 W/(m²·K))
Floors	☑	Passive floor, no insulation, tile or vinyl (U=2.9582 W/(m²·K))
Slabs	☑	Un-insulated solid (U=0.7059 W/(m²·K))
Doors	☑	Metal (U=3.7021 W/(m²·K))
Exterior Windows	☑	Large double-glazed windows (reflective coating) - industry (U
Interior Windows	☑	Large single-glazed windows (U=3.6898 W/(m²·K), SHGC=0.86)
Skylights	☑	Large double-glazed windows (reflective coating) - industry (U

All | None

Shading factor for exterior windows: 0

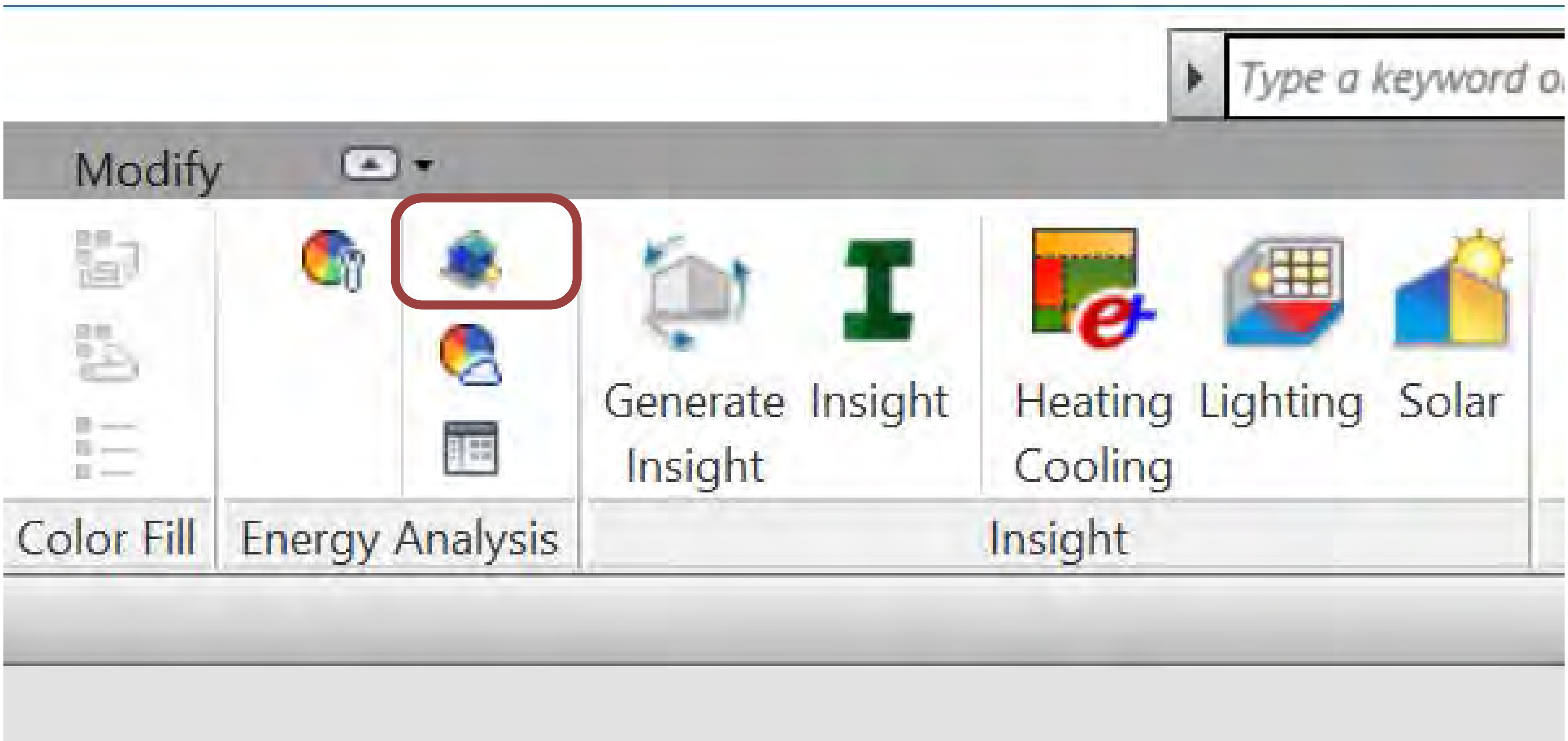
OK | Cancel

4st STEP: DEFINE DIFFERENT ALTERNATIVES

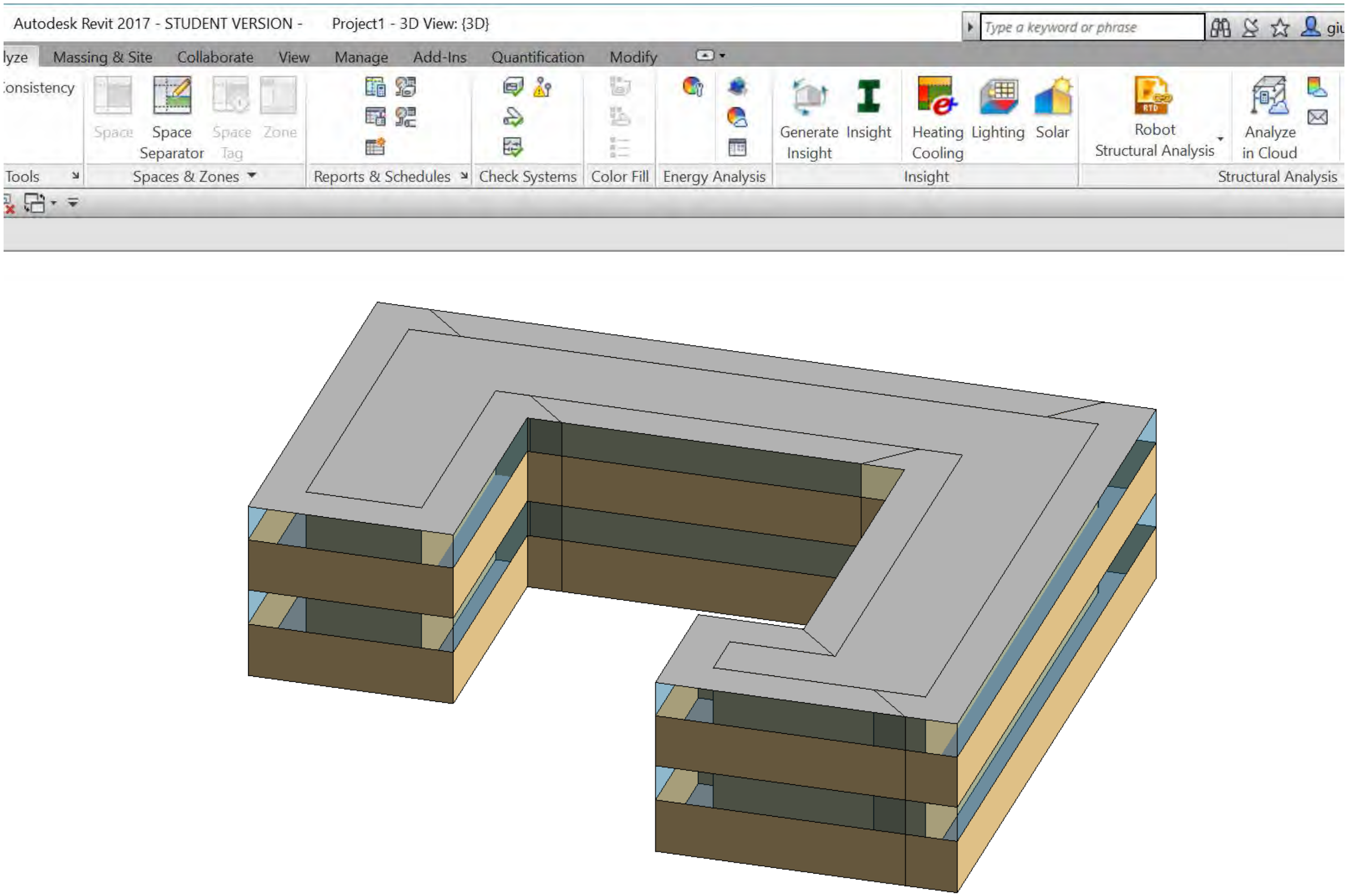


considering and evaluating:
-building orientation
-compactness (footprint/volume)
-glazing ratio
-...

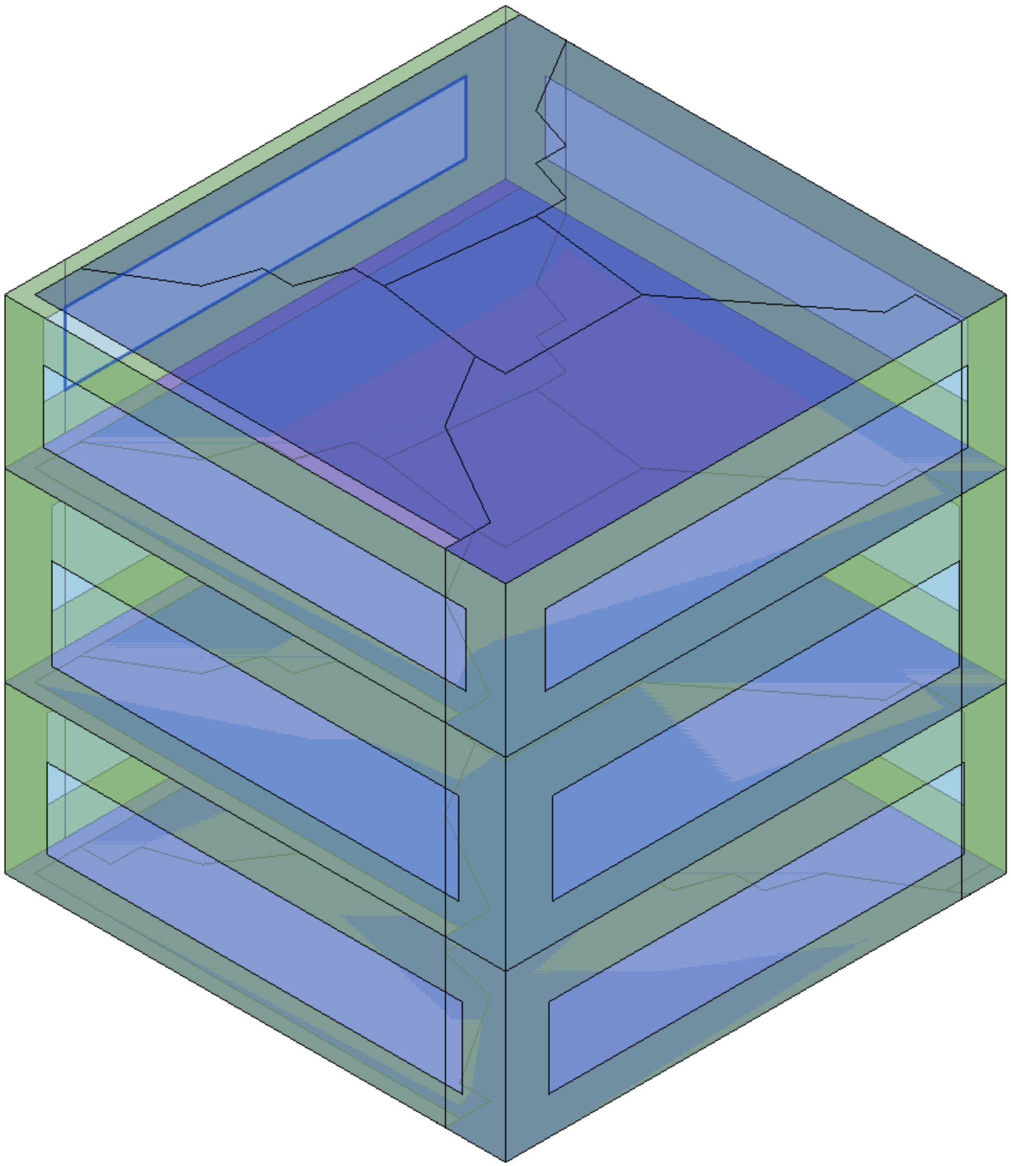
4st STEP: GENERATE THERMAL BLOCK



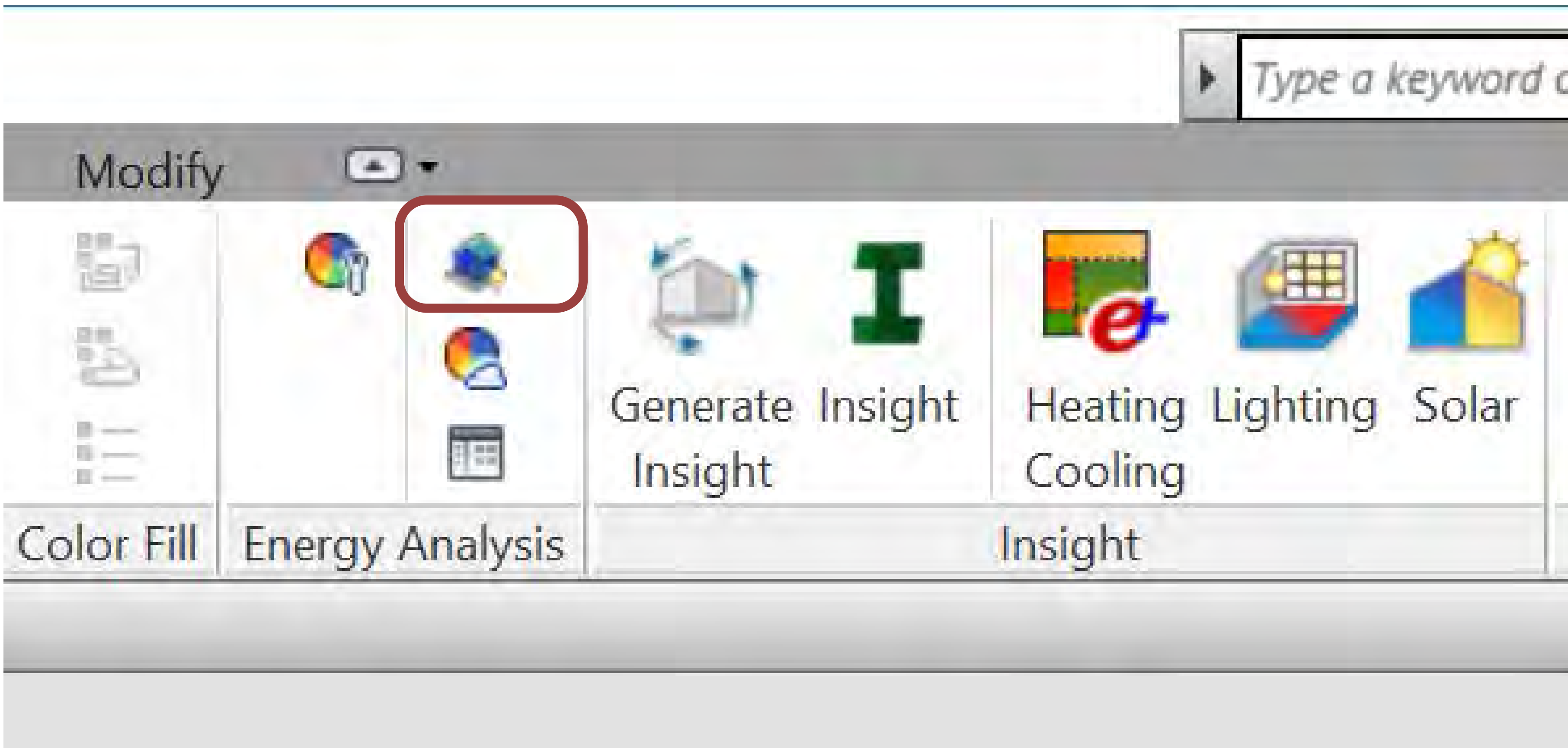
4st STEP: GENERATE THERMAL BLOCK



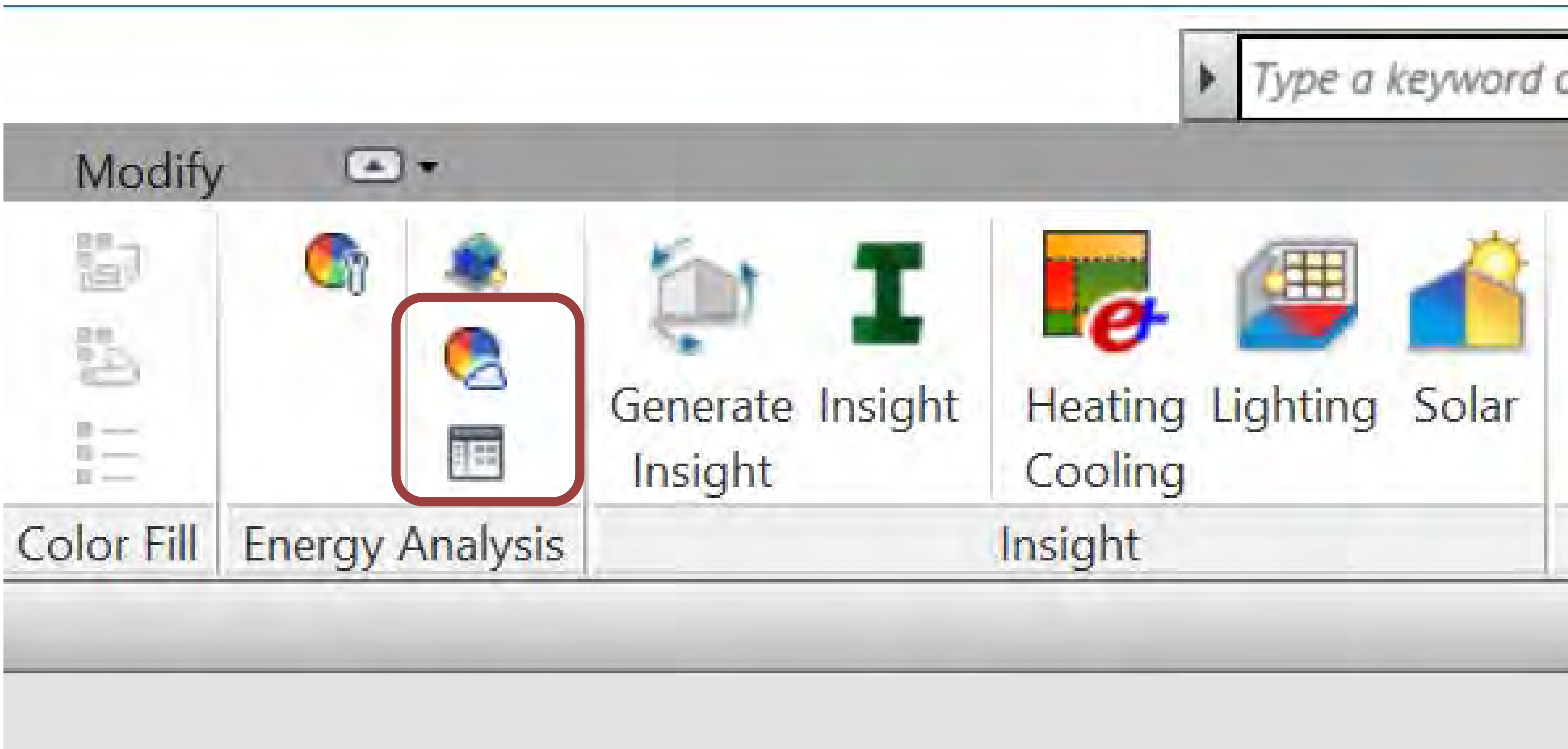
4st STEP: GENERATE THERMAL BLOCK



5st STEP: RUN ENERGY COMPUTATION

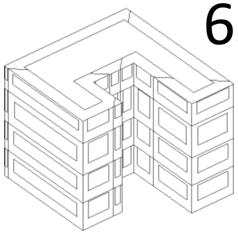


6st STEP: PRODUCE & PRINT AND READ ENERGY REPORT



6st STEP: PRODUCE & PRINT AND READ ENERGY REPORT

Energy Analysis Result



Building Performance Factors

Location:	Chandigarh, India
Weather Station:	429042
Outdoor Temperature:	Max: 46°C/Min: 3°C
Floor Area:	665 m²
Exterior Wall Area:	844 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:	$136,069

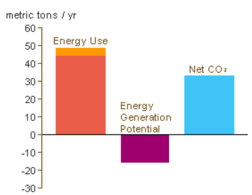
*30-year life and 6.1% discount rate for costs

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

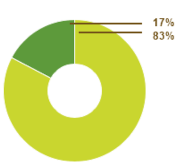
*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems

Annual Carbon Emissions



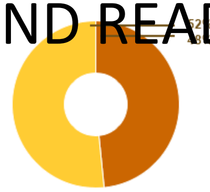
	(metric tons / yr)
Electricity Consumption	44
Fuel Consumption	4
Roof PV Potential (High Efficiency)	-15
Single 15' Wind Turbine Potential	0
Net CO_2	33

Annual Energy Use/Cost



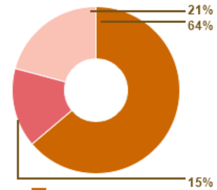
Electricity	83%	$9,337	116,713	kWh
Fuel	17%	$653	87,951	MJ
		$9,990		

Energy Use: Fuel



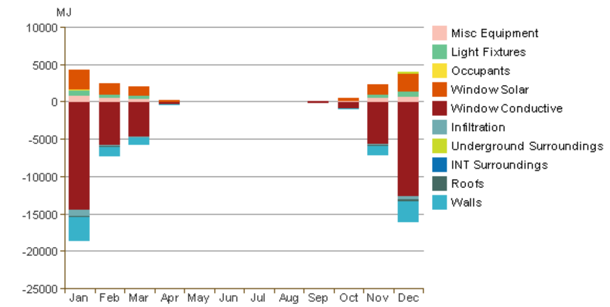
			(MJ)
HVAC	48%	$316	42,574
Domestic Hot Water	52%	$337	45,376
		$653	87,950

Energy Use: Electricity

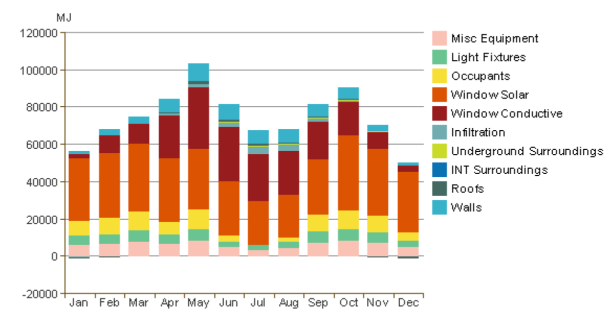


			(kWh)
HVAC	64%	$5,731	71,641
Lighting	15%	$1,379	17,239
Misc Equipment	21%	$1,870	23,380
		$8,980	112,260

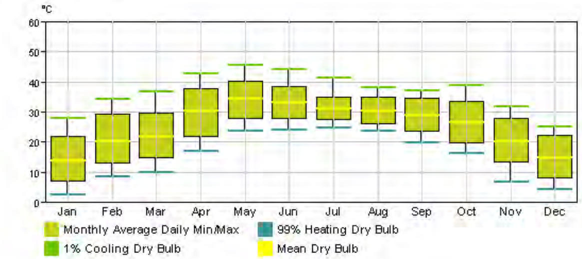
Monthly Heating Load



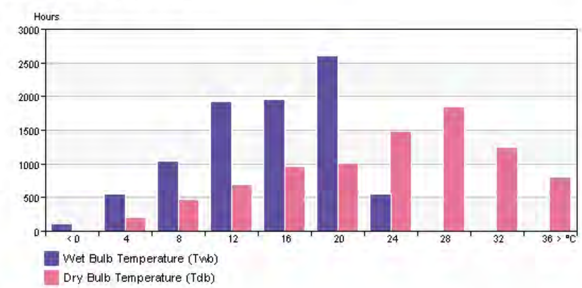
Monthly Cooling Load



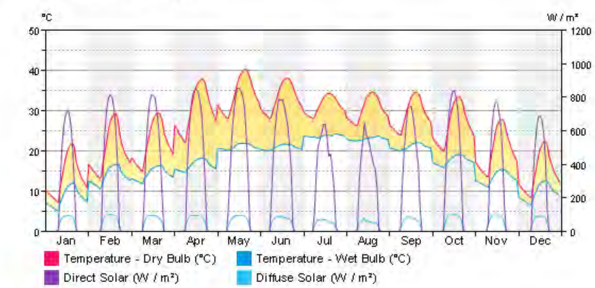
Monthly Design Data



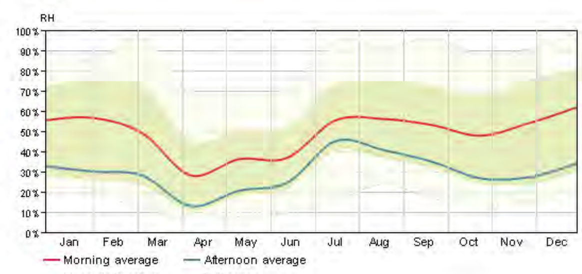
Annual Temperature Bins



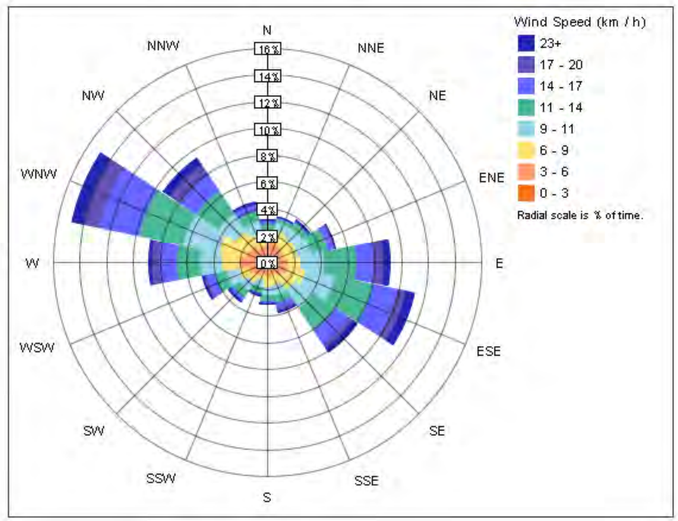
Diurnal Weather Averages



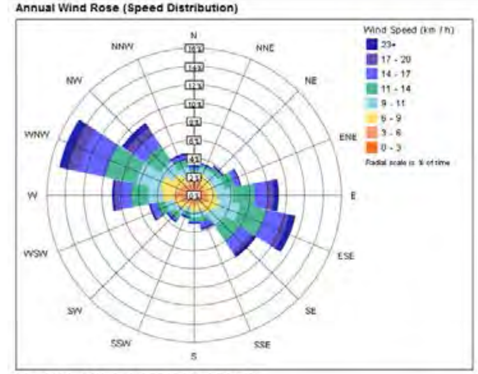
Humidity



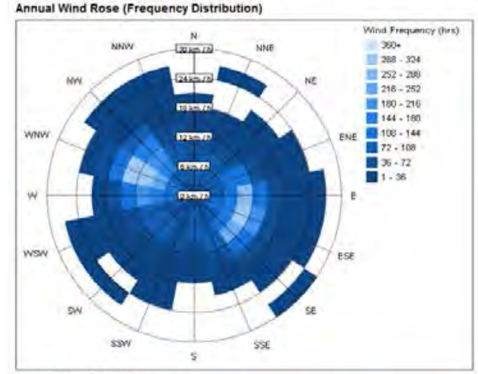
Annual Wind Rose (Speed Distribution)



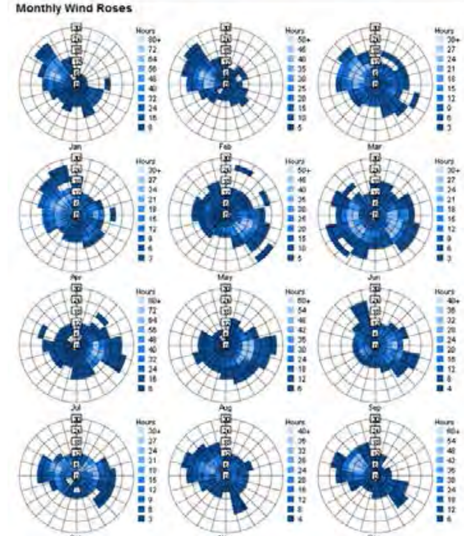
Annual Wind Rose (Speed Distribution)



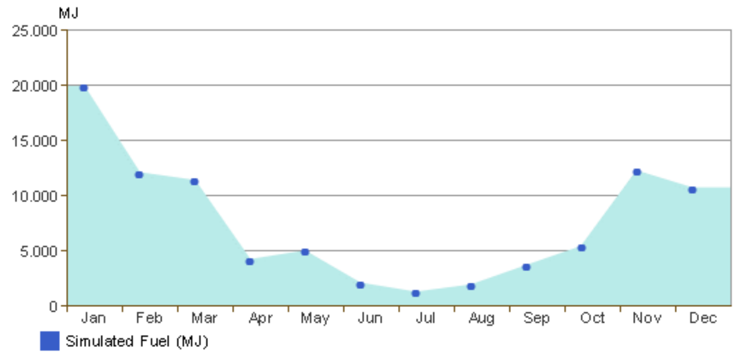
Annual Wind Rose (Frequency Distribution)



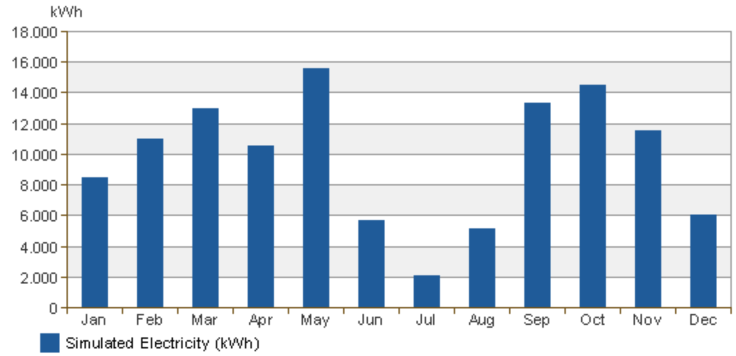
Monthly Wind Roses



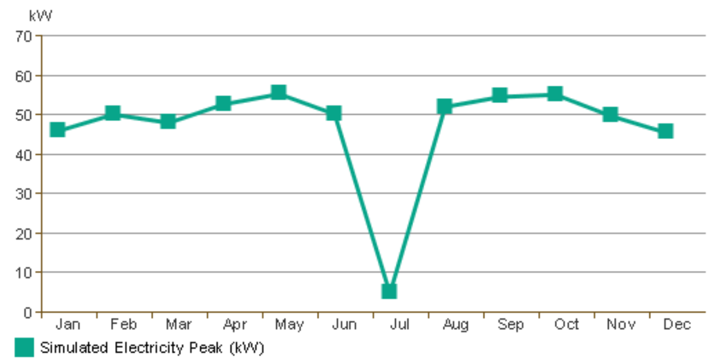
Monthly Fuel Consumption



Monthly Electricity Consumption



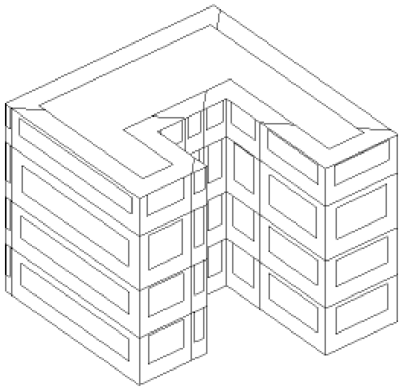
Monthly Peak Demand



6st STEP: PRODUCE & PRINT AND READ ENERGY REPORT

* subtract renewable energy contribution in order to have comparable alternatives

Energy Analysis Result



Building Performance Factors

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Weather Station:	429042
Outdoor Temperature:	Max: 46°C/Min: 3°C
Floor Area:	665 m²
Exterior Wall Area:	844 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
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Total EUI:	764 MJ / sm / yr

Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	3,501,393 kWh
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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

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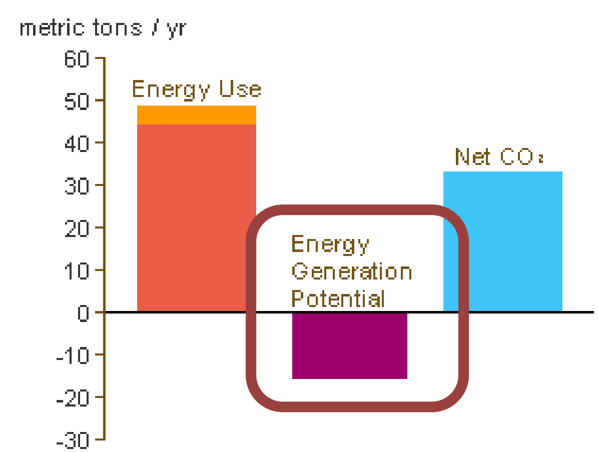

	(metric tons / yr)
Electricity Consumption	44
Fuel Consumption	4
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Net CO_2	33

6st STEP: PRODUCE & PRINT AND READ ENERGY REPORT

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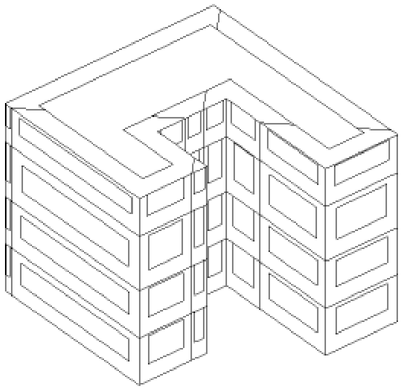
Energy Analysis Result



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Average Lighting Power:	10.66 W / m²
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Fuel Cost:	\$0.78 / Therm

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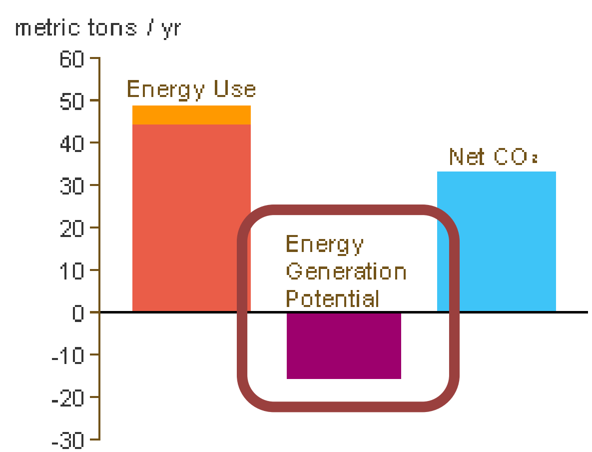
Annual Carbon Emissions



	(metric tons / yr)
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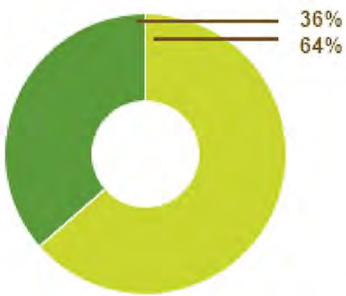
Fuel Consumption	4
Roof PV Potential (High Efficiency)	-15
Single 15' Wind Turbine Potential	0
Net CO_2	33

6st STEP: PRODUCE & PRINT AND READ ENERGY REPORT

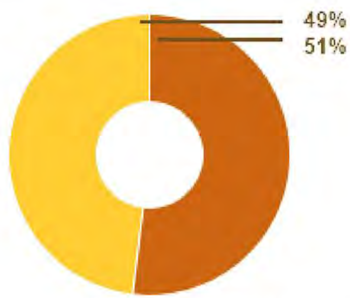
* compare Fuel vs Electricity (HVAC/Lighting) in order to understand if the building is mainly that or to cool

Annual Energy Use/Cost



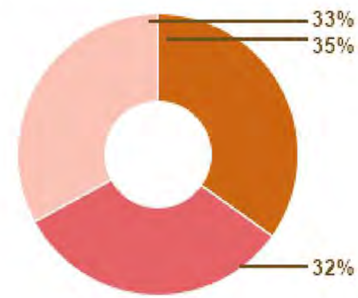
Electricity	64%	$223,701	810,215	kWh
Fuel	36%	$22,296	1,673,880	MJ
		$245,997		

Energy Use: Fuel



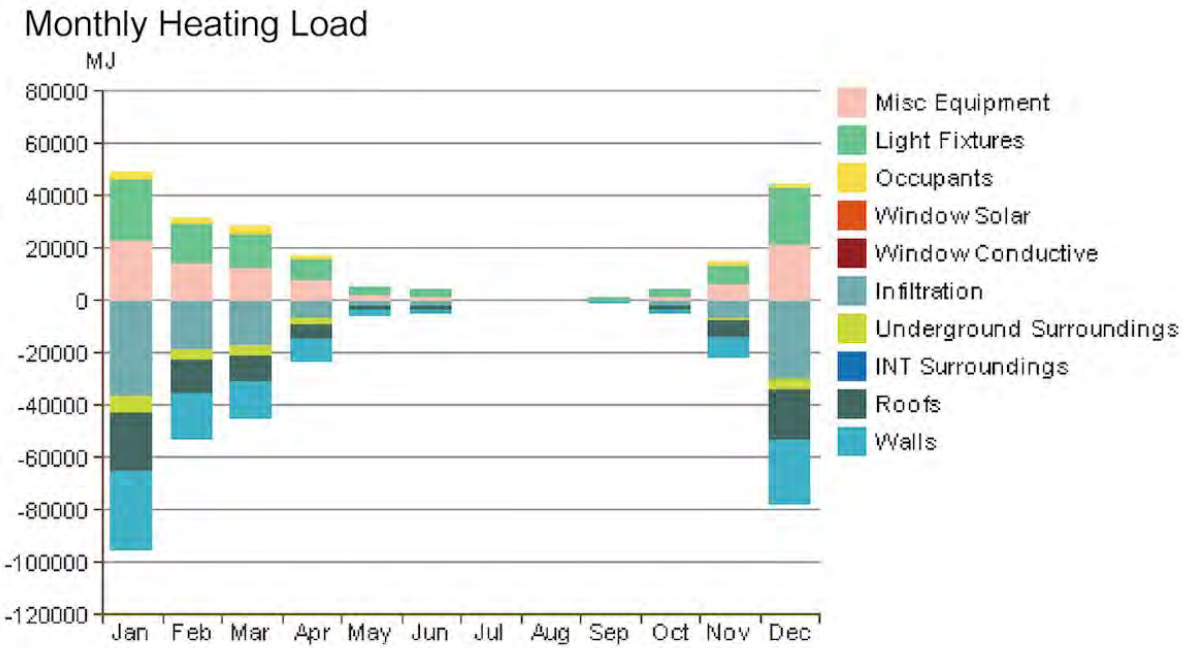
			(MJ)
HVAC	51%	$11,572	868,810
Domestic Hot Water	49%	$10,723	805,069
		$22,295	1,673,879

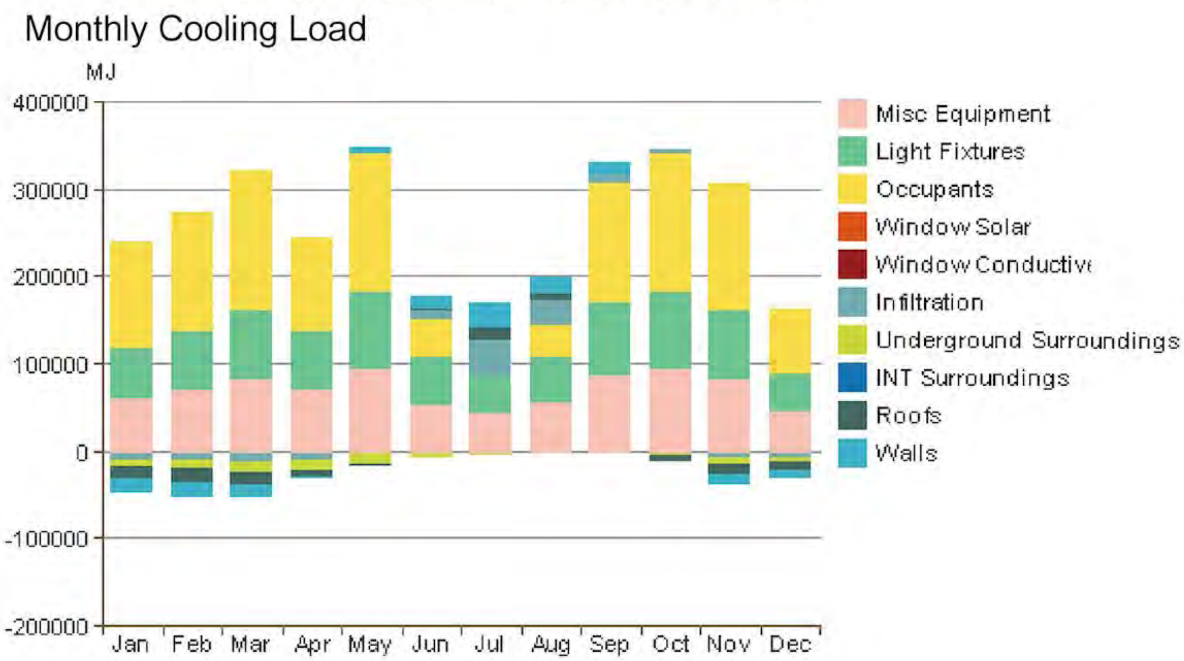
Energy Use: Electricity



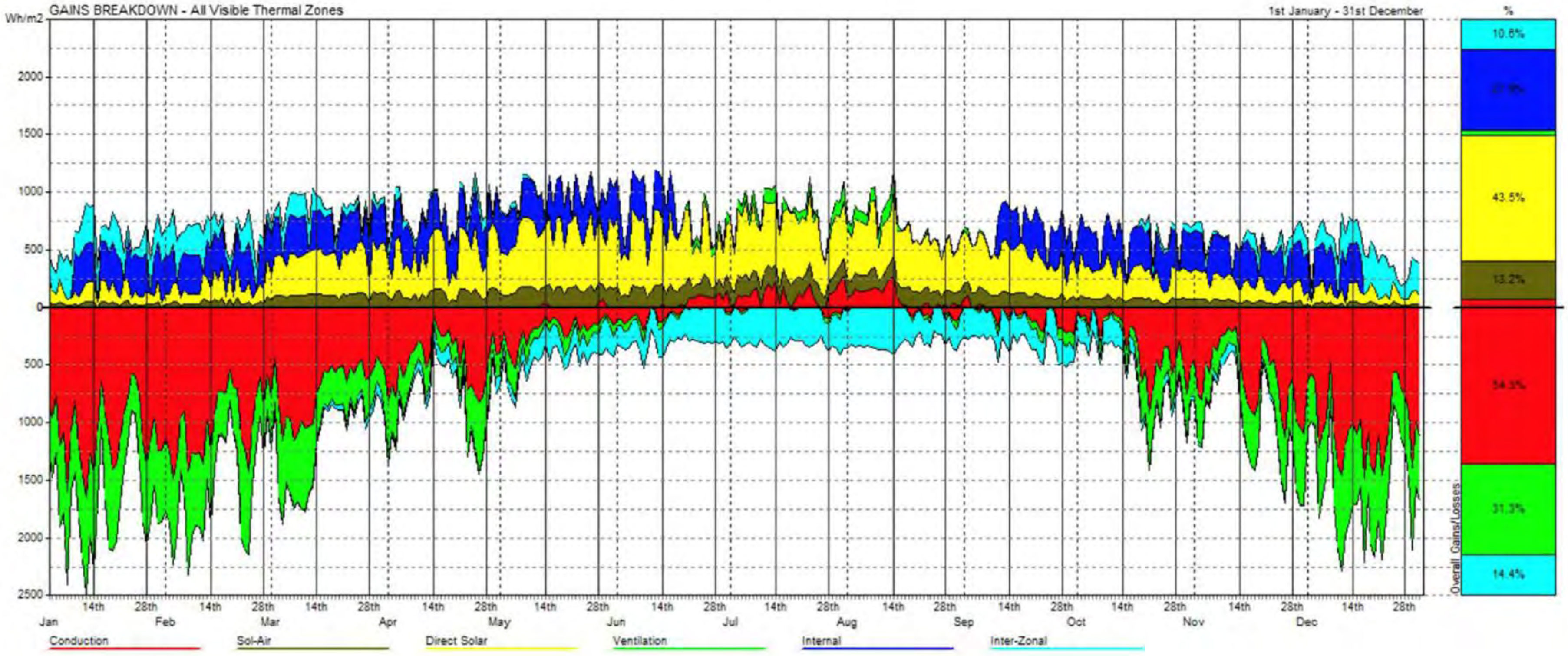
			(kWh)
HVAC	35%	$77,553	280,888
Lighting	32%	$71,650	259,508
Misc Equipment	33%	$73,318	265,550
		$222,521	805,946

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





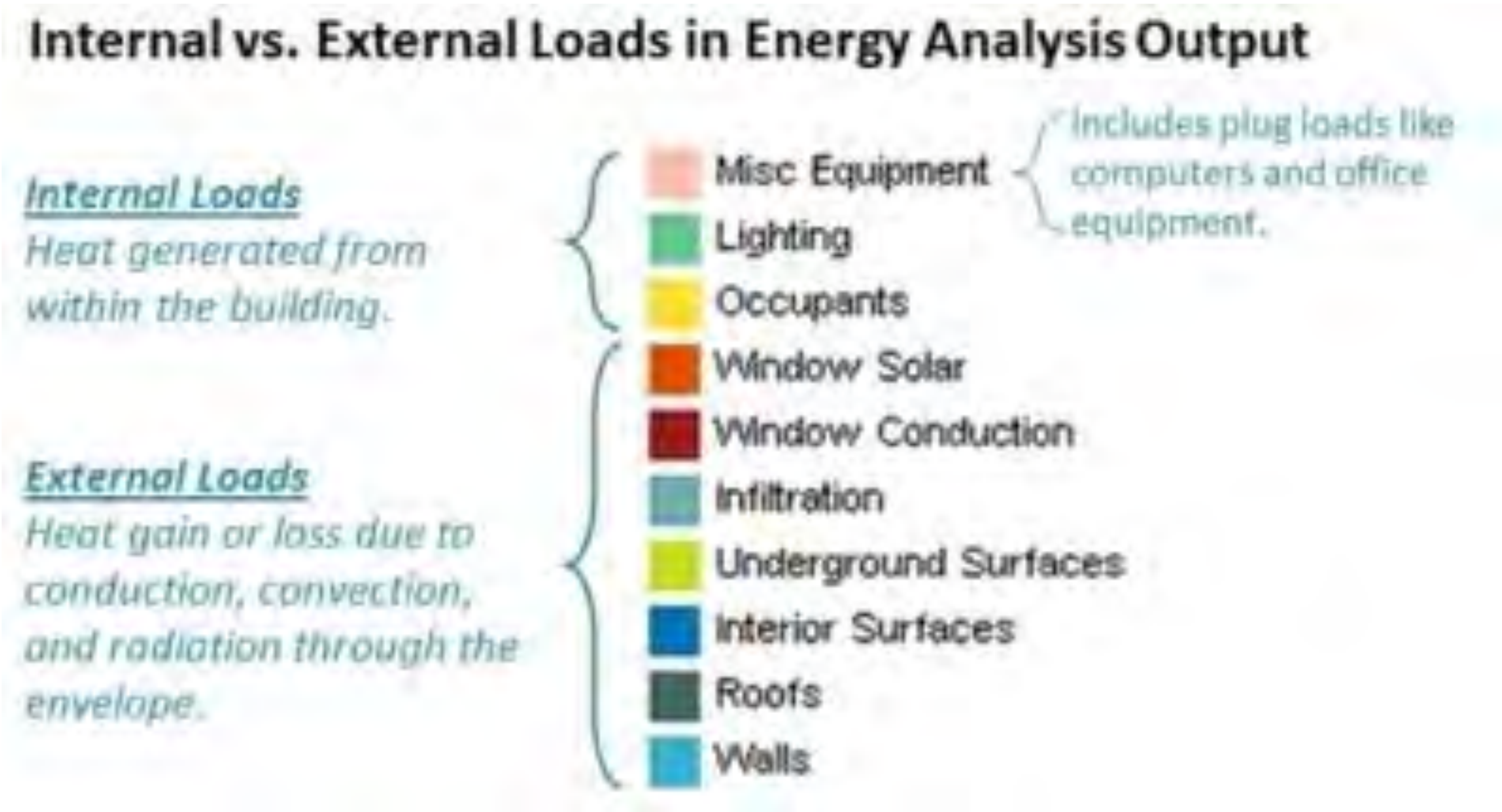
* pay attention to Energy Loads in order to understand the biggest concern for gains/losses



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.
External Loads
Heat gain or loss due to conduction, convection, and radiation through the envelope.
Misc Equipment
Includes plug loads like computers and office equipment.
Lighting
Occupants
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.

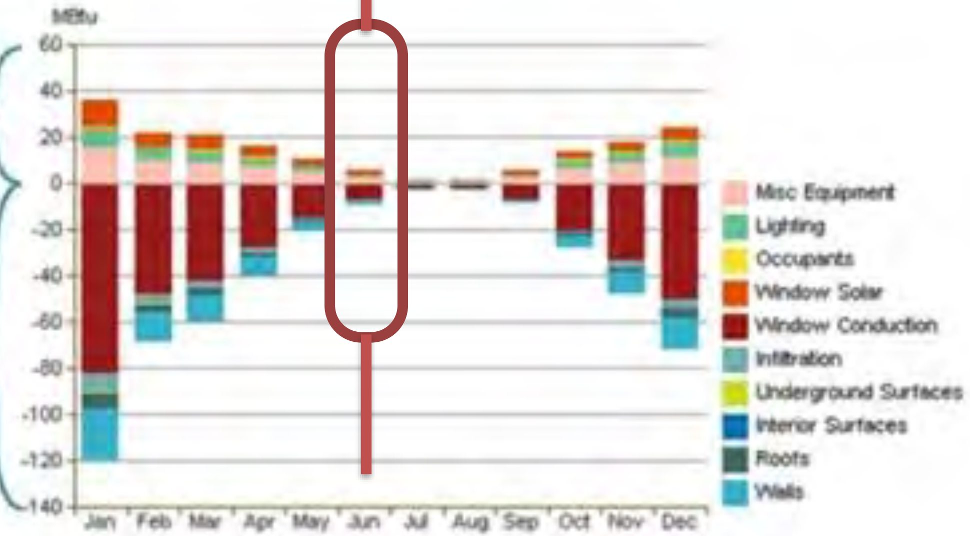
Heat losses that offset cooling loads.

Monthly Heating Loads

Hottest hours >> Day Hours

Heat gains that offset the heating loads.

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

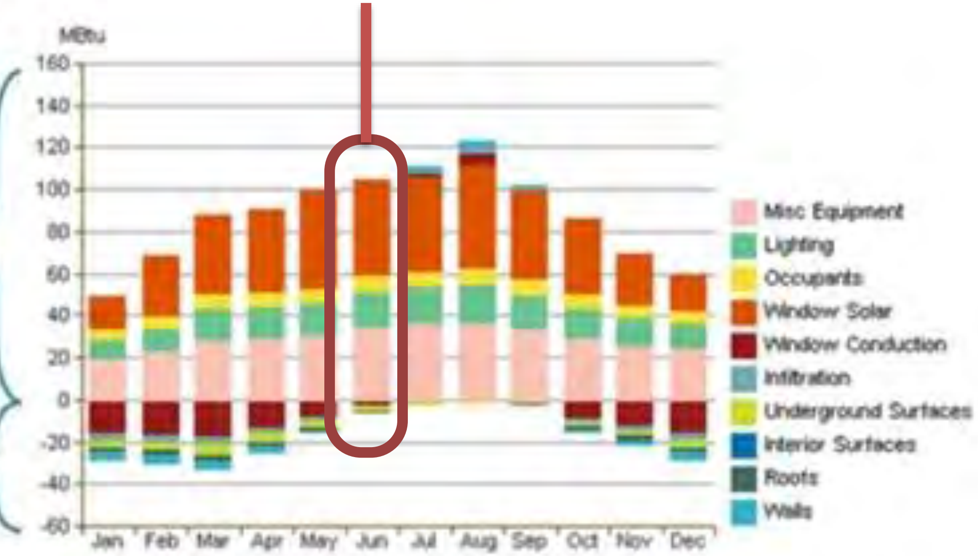


Coldest hours >> Night Hours

Monthly Cooling Loads

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

Heat losses that offset cooling loads.



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.

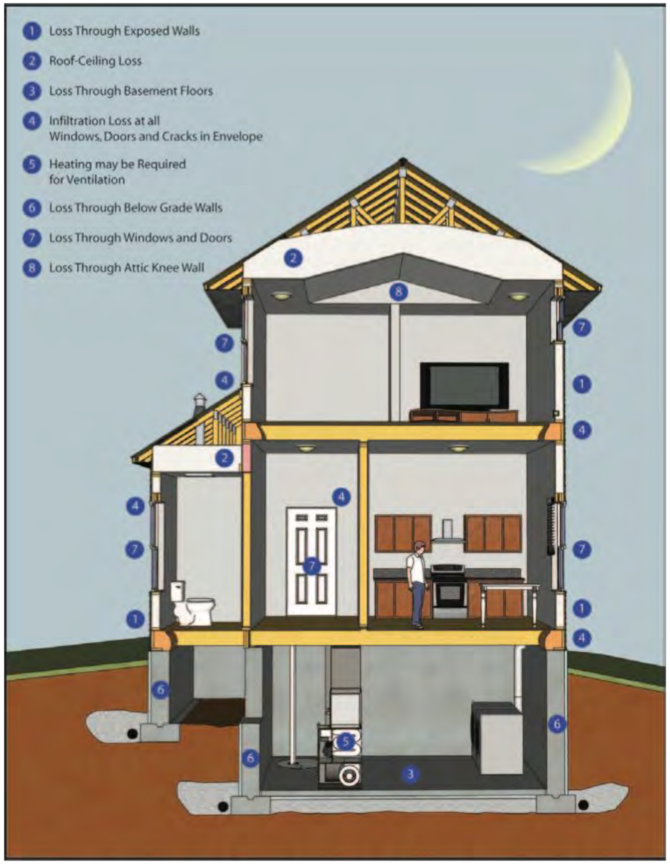


Figure 5. Heat Loss Locations

<no sun / no occupants contribution>

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.

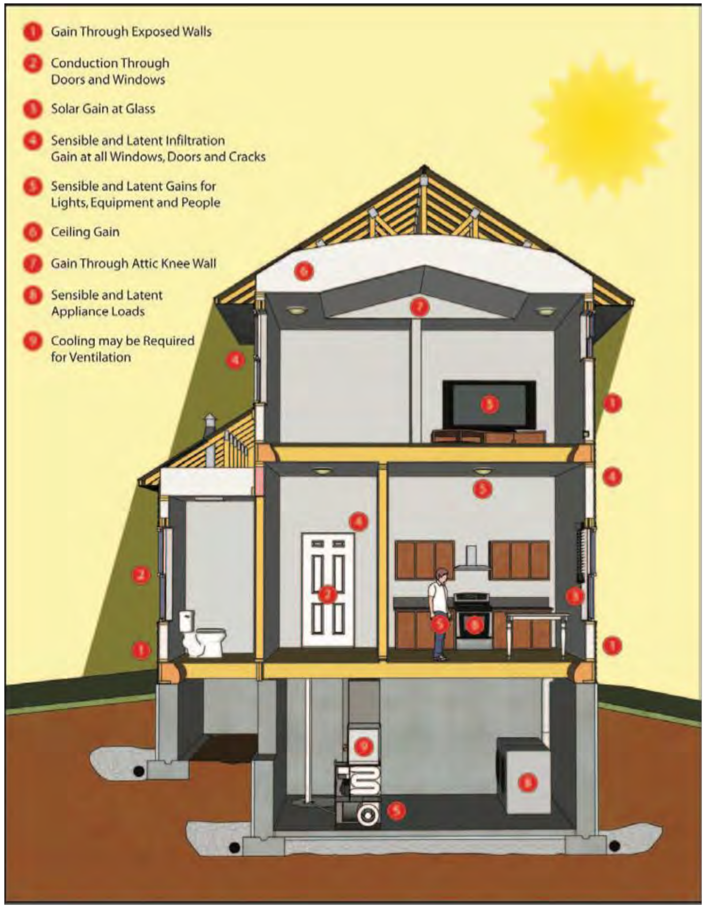
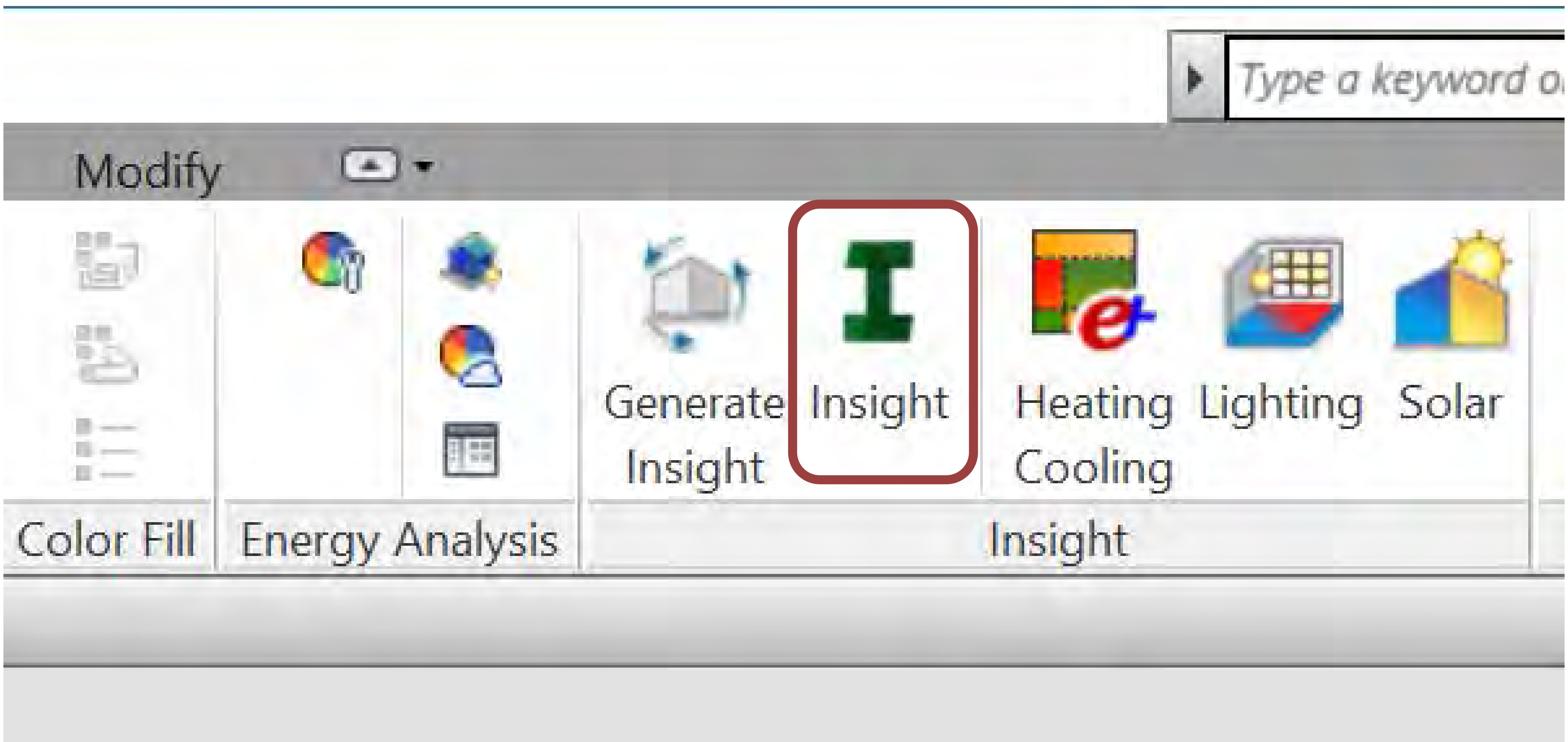
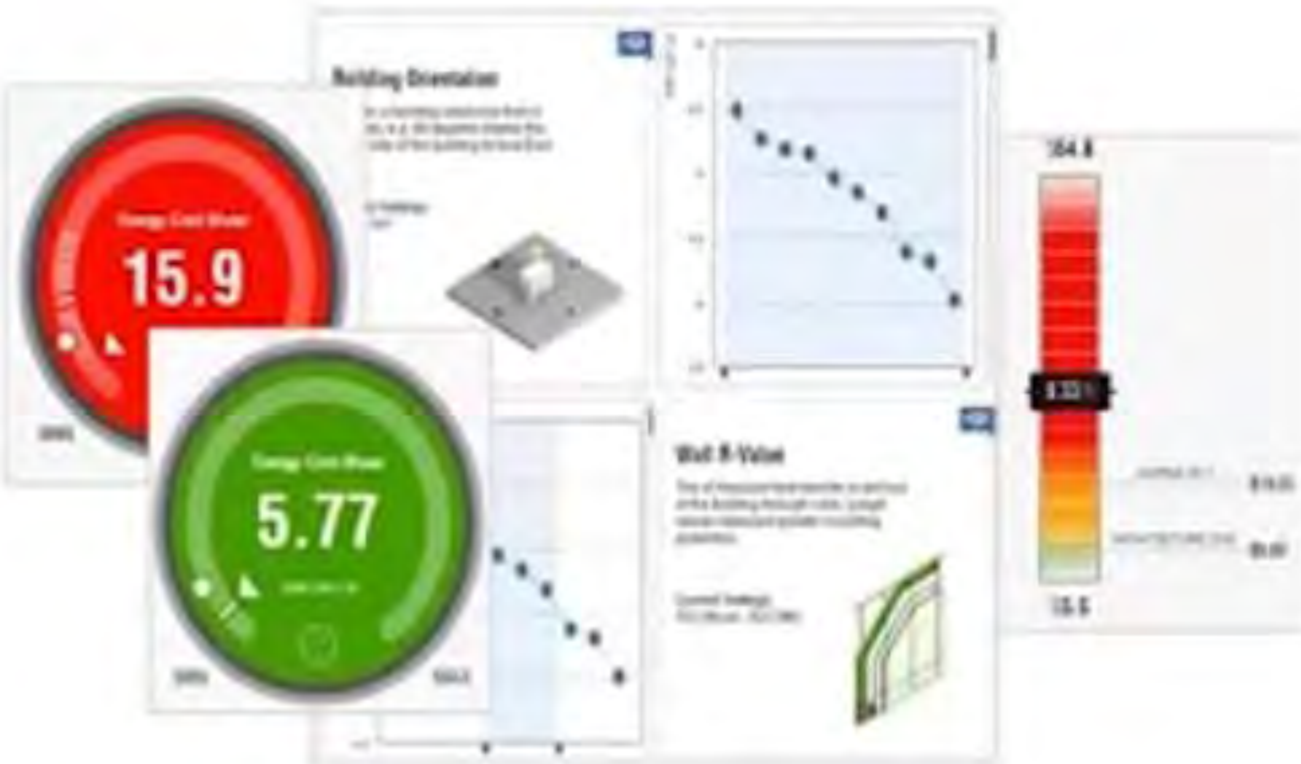


Figure 6. Heat Gain Locations

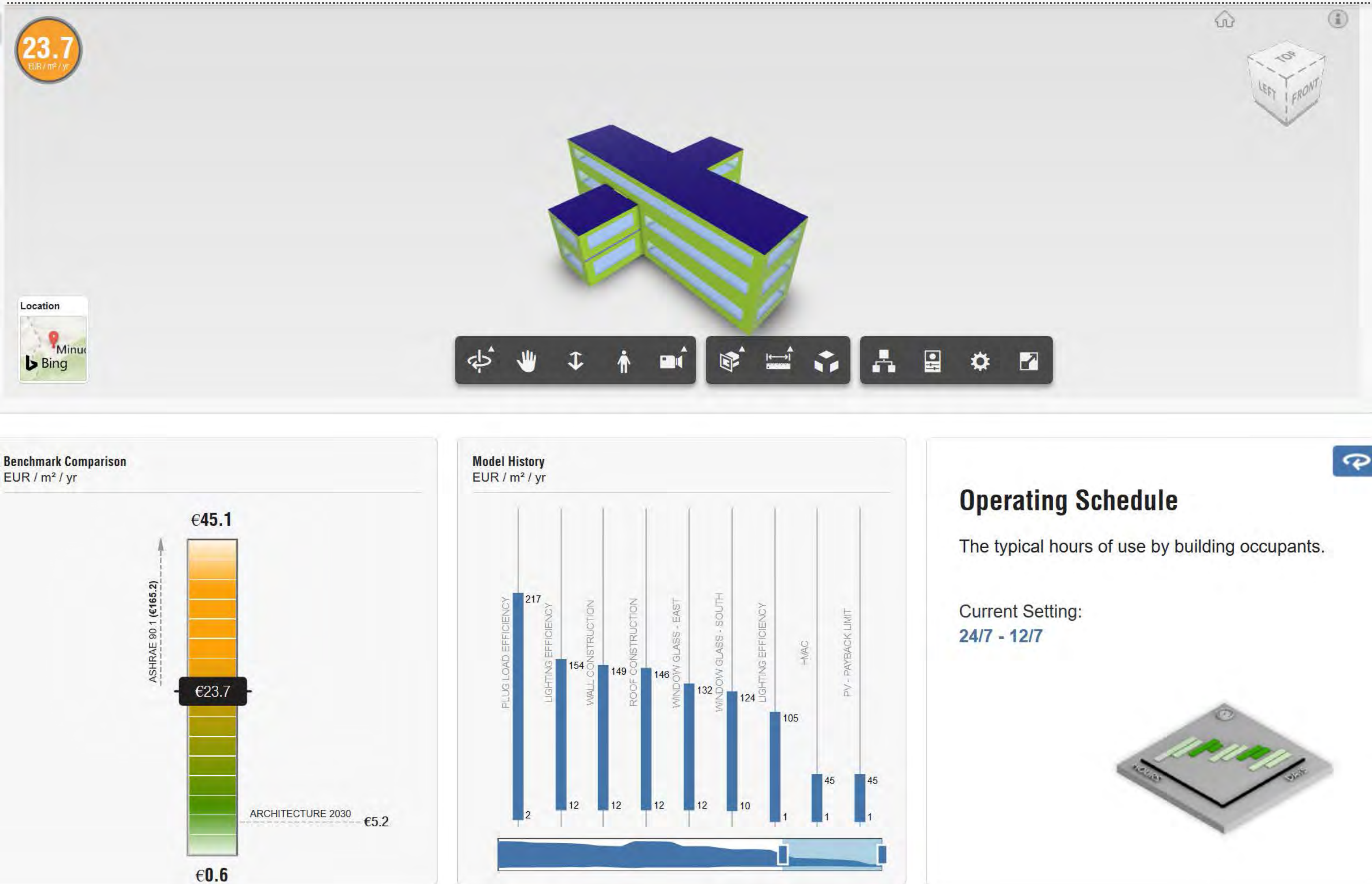
7st STEP: BENCHMARKING OPTIONS AND TUNING SOLUTIONS WITH AUTODESK INSIGHT

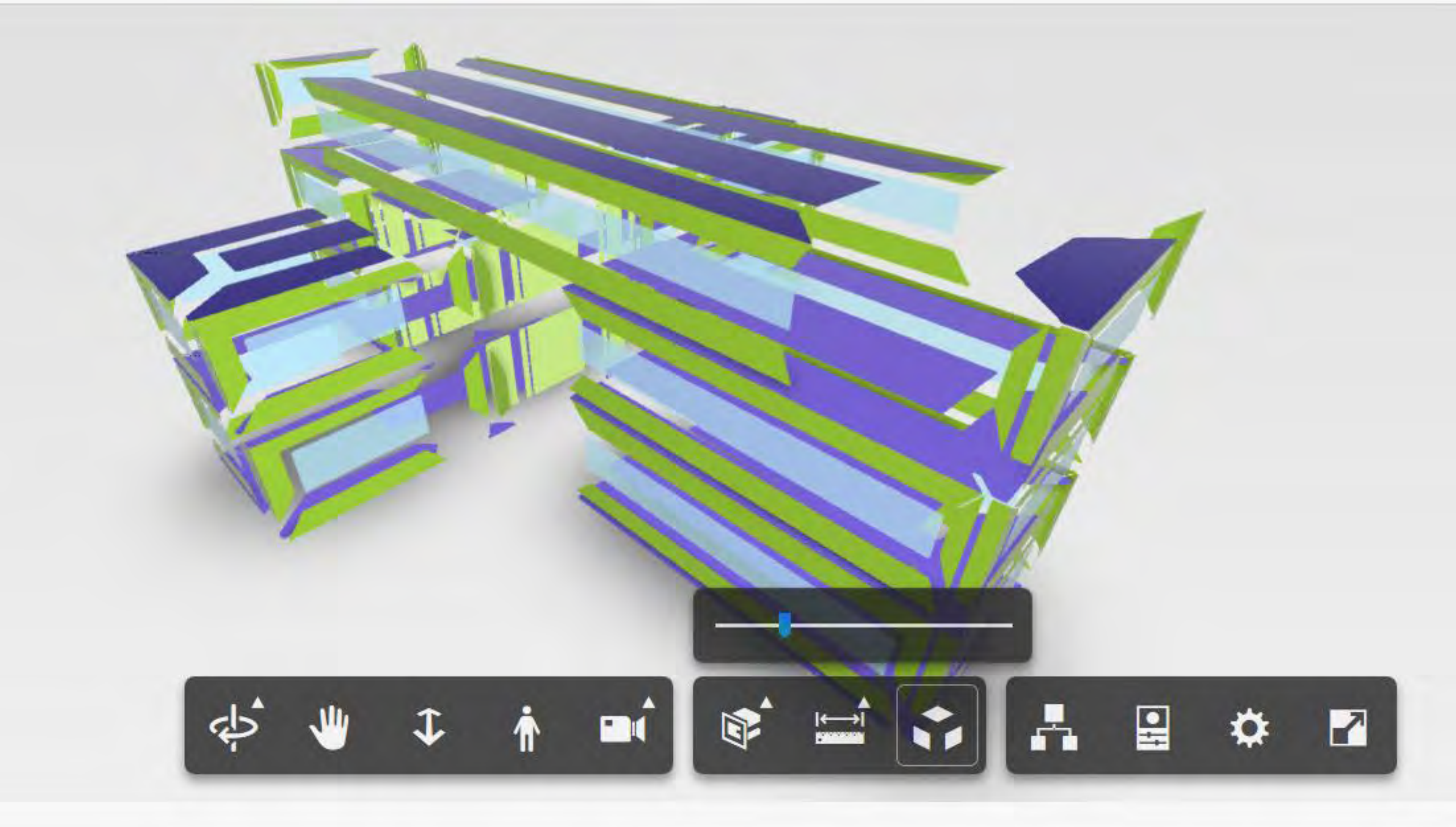


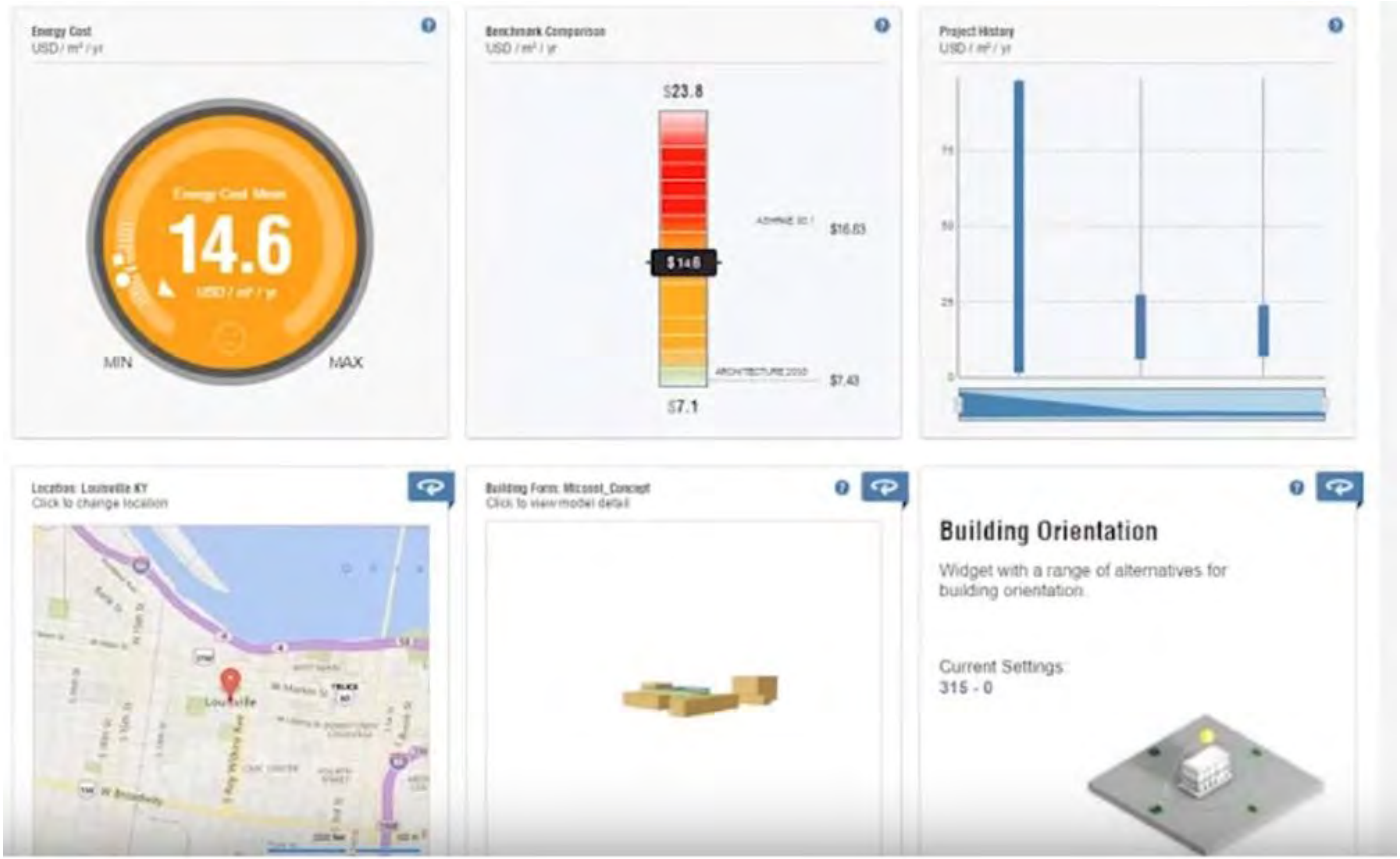
Early Targeting & Feasibility

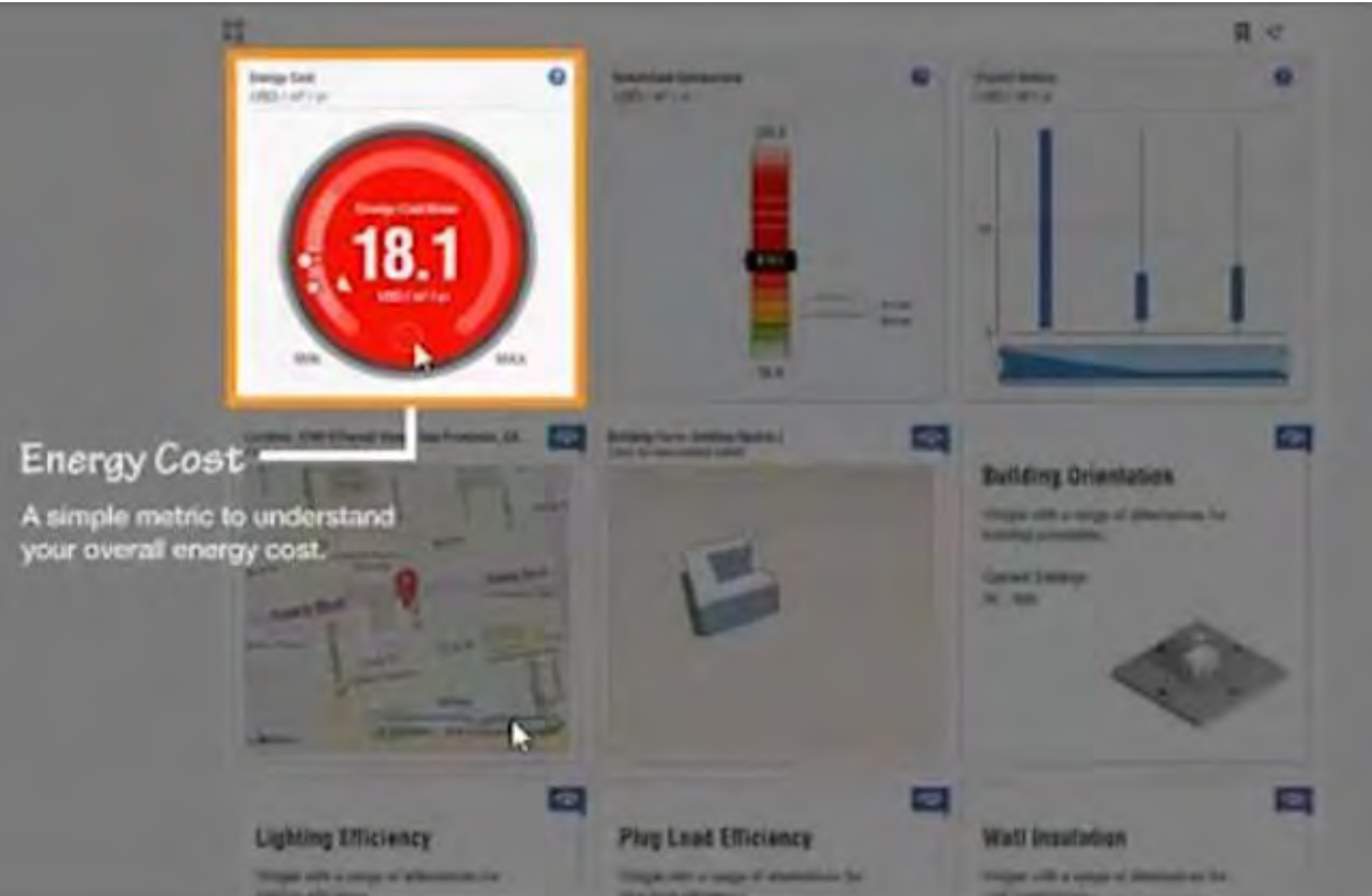


Energy Cost Range, Benchmarks, Factors & History

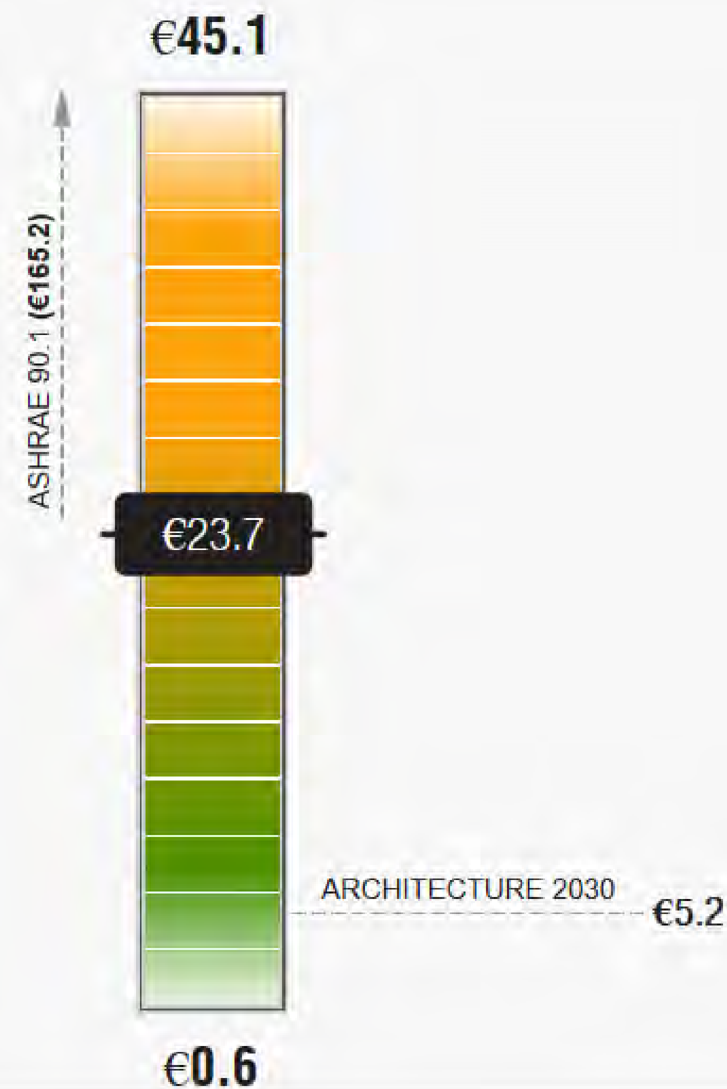

23.7
EUR / m² / yr
TOP
LEFT
FRONT
Location
Bing
Benchmark Comparison
EUR / m² / yr
€45.1
ASHRAE 90.1 (€165.2)
€23.7
ARCHITECTURE 2030
€5.2
€0.6
Model History
EUR / m² / yr
PLUG LOAD EFFICIENCY
LIGHTING EFFICIENCY
WALL CONSTRUCTION
ROOF CONSTRUCTION
WINDOW GLASS - EAST
WINDOW GLASS - SOUTH
LIGHTING EFFICIENCY
HVAC
PV - PAYBACK LIMIT
217
154
149
146
132
124
105
45
45
2
12
12
12
12
10
1
1
1
Operating Schedule
The typical hours of use by building occupants.
Current Setting:
24/7 - 12/7
HOURS
DAYS




Energy Cost
USD / m² / yr
Energy Cost Mean
14.6
USD / m² / yr
MIN
MAX
Benchmark Comparison
USD / m² / yr
$23.8
$16.63
$14.6
ARCHITECTURE 2030
$7.43
$7.1
Project History
USD / m² / yr
Location: Louisville KY
Click to change location
Click to view model detail
Building Orientation
Widget with a range of alternatives for building orientation.
Current Settings:
315 - 0


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

Benchmark Comparison
EUR / m² / yr

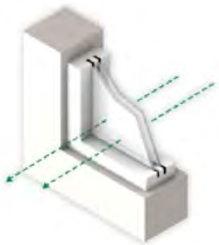



13.2
Project History
Track your project performance over the lifecycle of the design.

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.

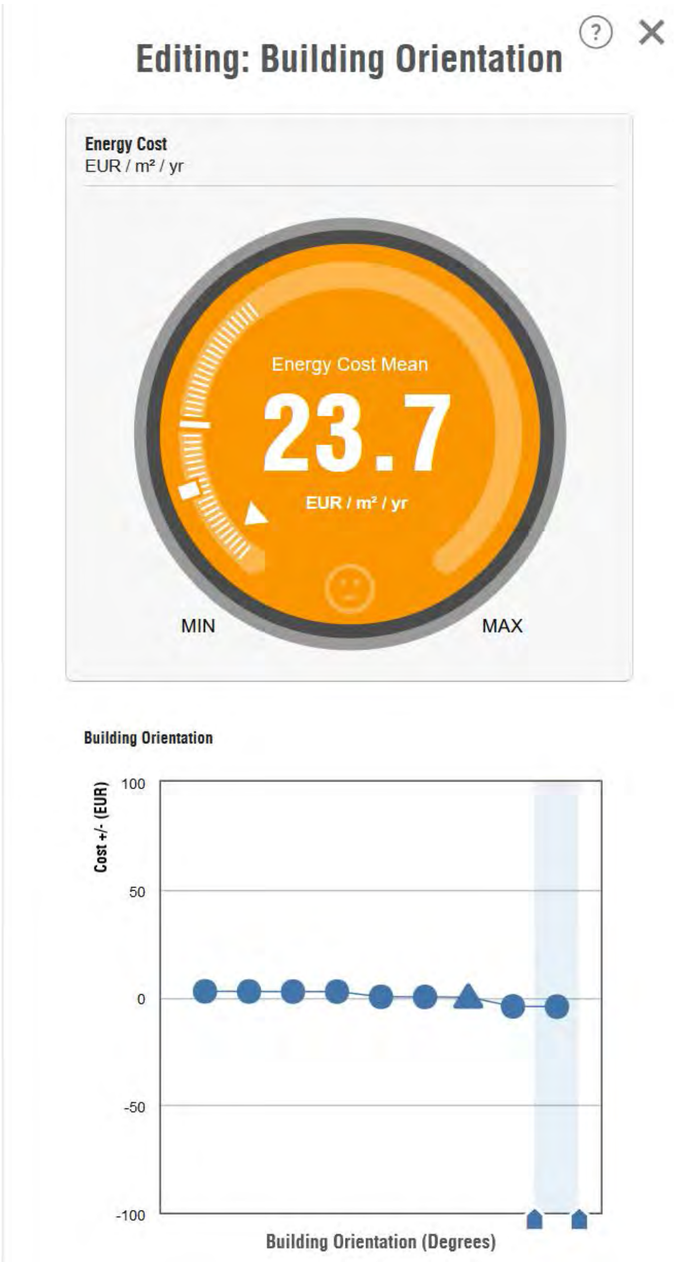
Current Setting:
None - Daylighting & Occupancy Controls

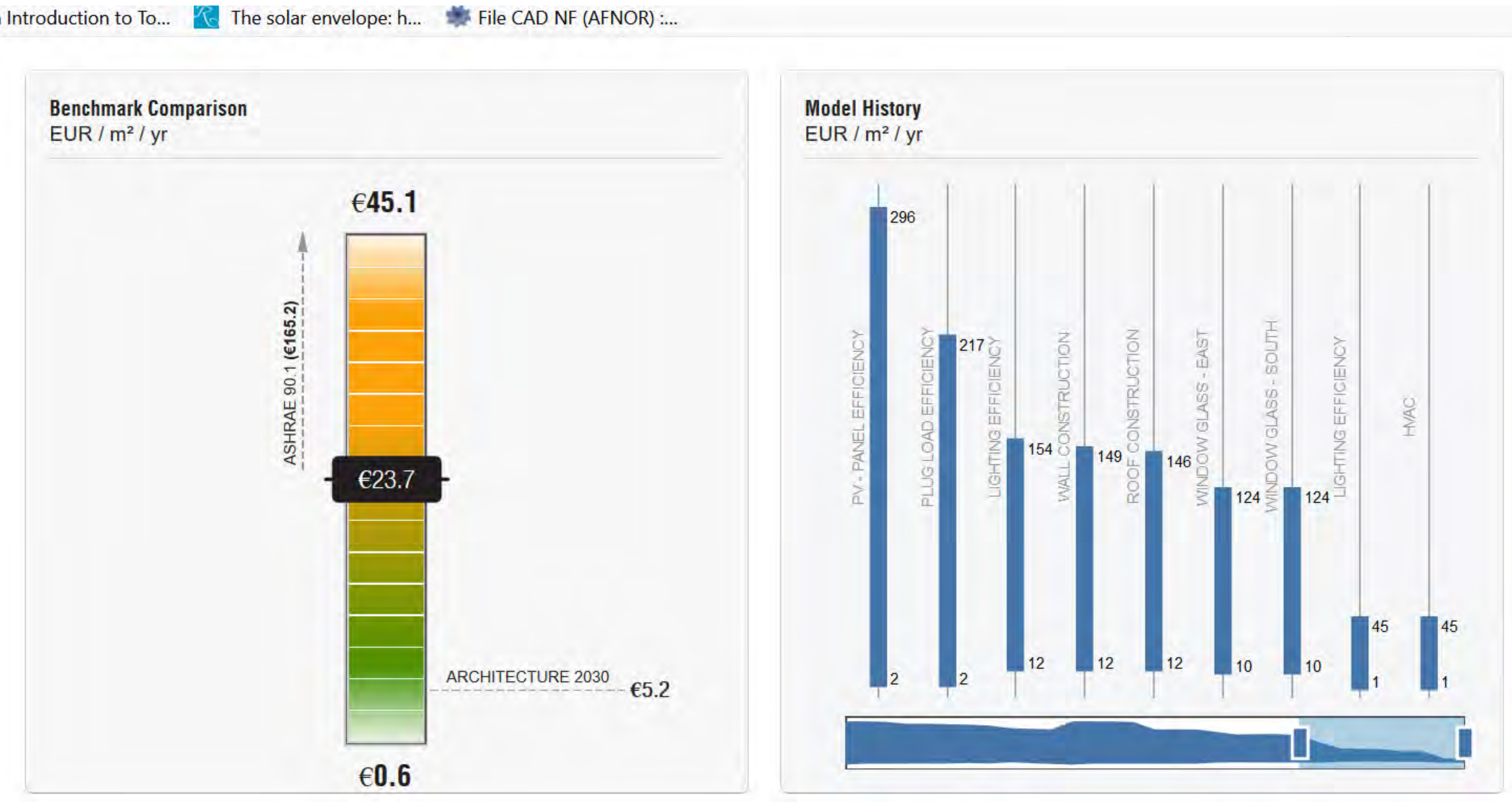
Window Shades - South

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

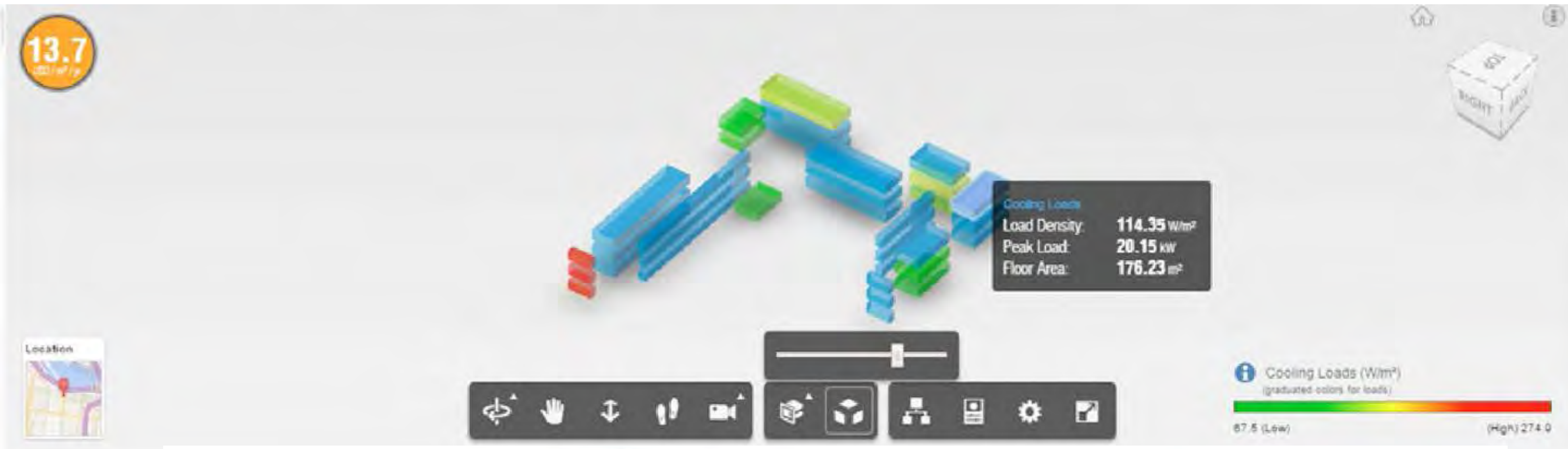

6.40
Factors
Tune parts of the building design or operation to improve building performance and achieve project goals.
6.38
Factors
Tune parts of the building design or operation to improve building performance and achieve project goals.

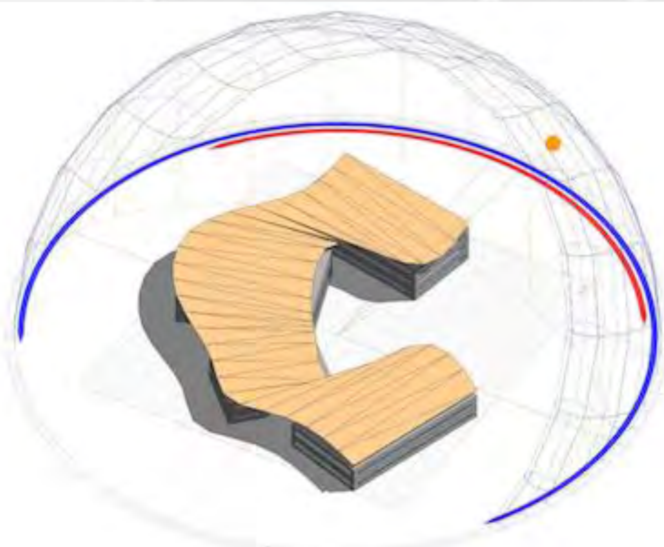

Editing: Building Orientation
Energy Cost
EUR / m² / yr
Energy Cost Mean
23.7
EUR / m² / yr
MIN
MAX
Building Orientation
Cost +/- (EUR)
100
50
0
-50
-100
Building Orientation (Degrees)

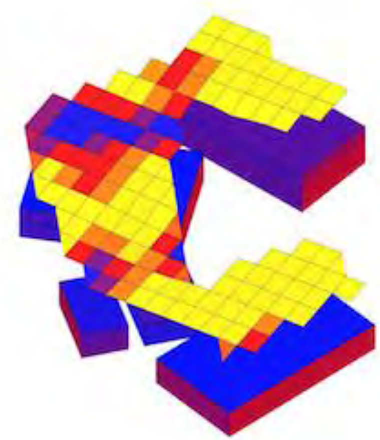

Introduction to To...
The solar envelope: h...
File CAD NF (AFNOR) :...
Benchmark Comparison
EUR / m² / yr
€45.1
ASHRAE 90.1 (€165.2)
€23.7
ARCHITECTURE 2030
€5.2
€0.6
Model History
EUR / m² / yr
PV - PANEL EFFICIENCY
296
2
PLUG LOAD EFFICIENCY
217
2
LIGHTING EFFICIENCY
154
12
WALL CONSTRUCTION
149
12
ROOF CONSTRUCTION
146
12
WINDOW GLASS - EAST
124
10
WINDOW GLASS - SOUTH
124
10
LIGHTING EFFICIENCY
45
1
HVAC
45
1

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







END