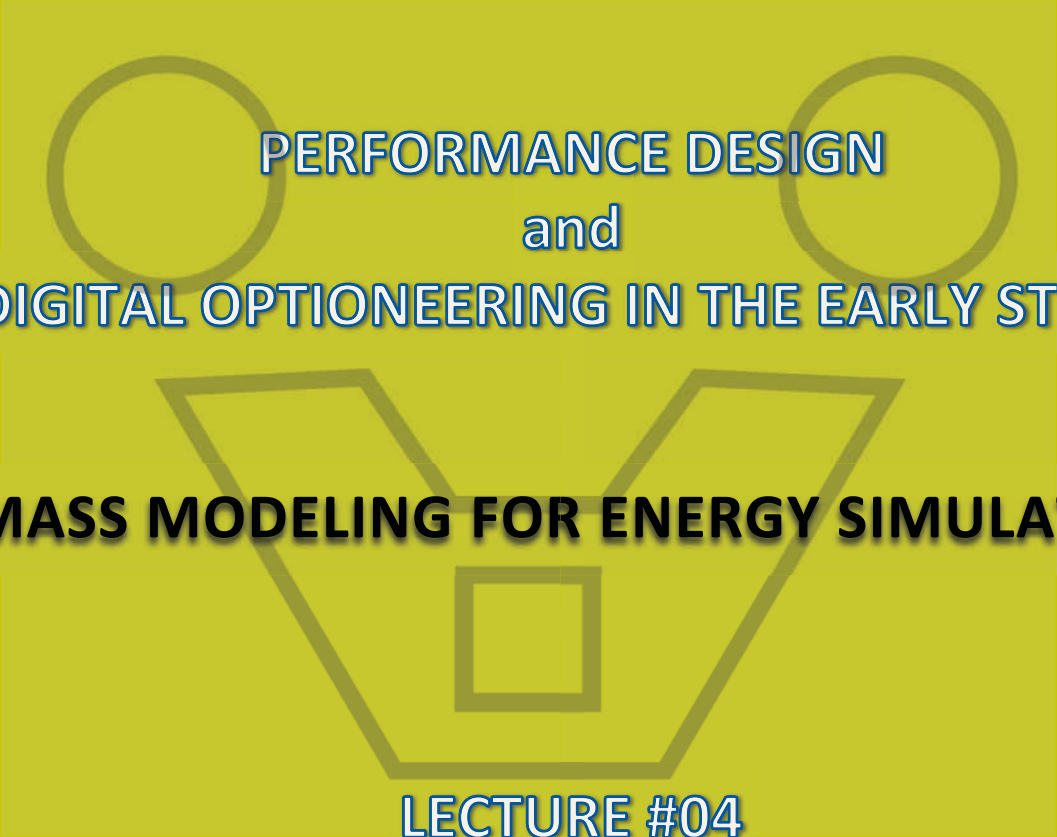




PERFORMANCE DESIGN and DIGITAL OPTIONEERING IN THE EARLY STAGE

MASS MODELING FOR ENERGY SIMULATION

LECTURE #04



SKETCHING • DRAWING • DRAFTING • MODELING • DESIGNING •



PORTA NORMALE
LT = 80"

PORTA SERVIZIO
LT = 62"

CASA D.B.
TERNI 70-73

MANUT.

155

113

98.8

PAN TO CIVILE
1000

FACCIA UCCIA

PIASTRELLA
70x20

VINAVIL

RUSTICO

135
F. 100
102.76
13

*NB: LA PORTA DI
80 NON COMBINA
CON UN MULTIPLO
DELLE PIASTRELLE
COME LA PORTA DI SERVIZIO

CASA D.B. TR - 1971
INFISSI MANUT.

VOLATA

TELAIO

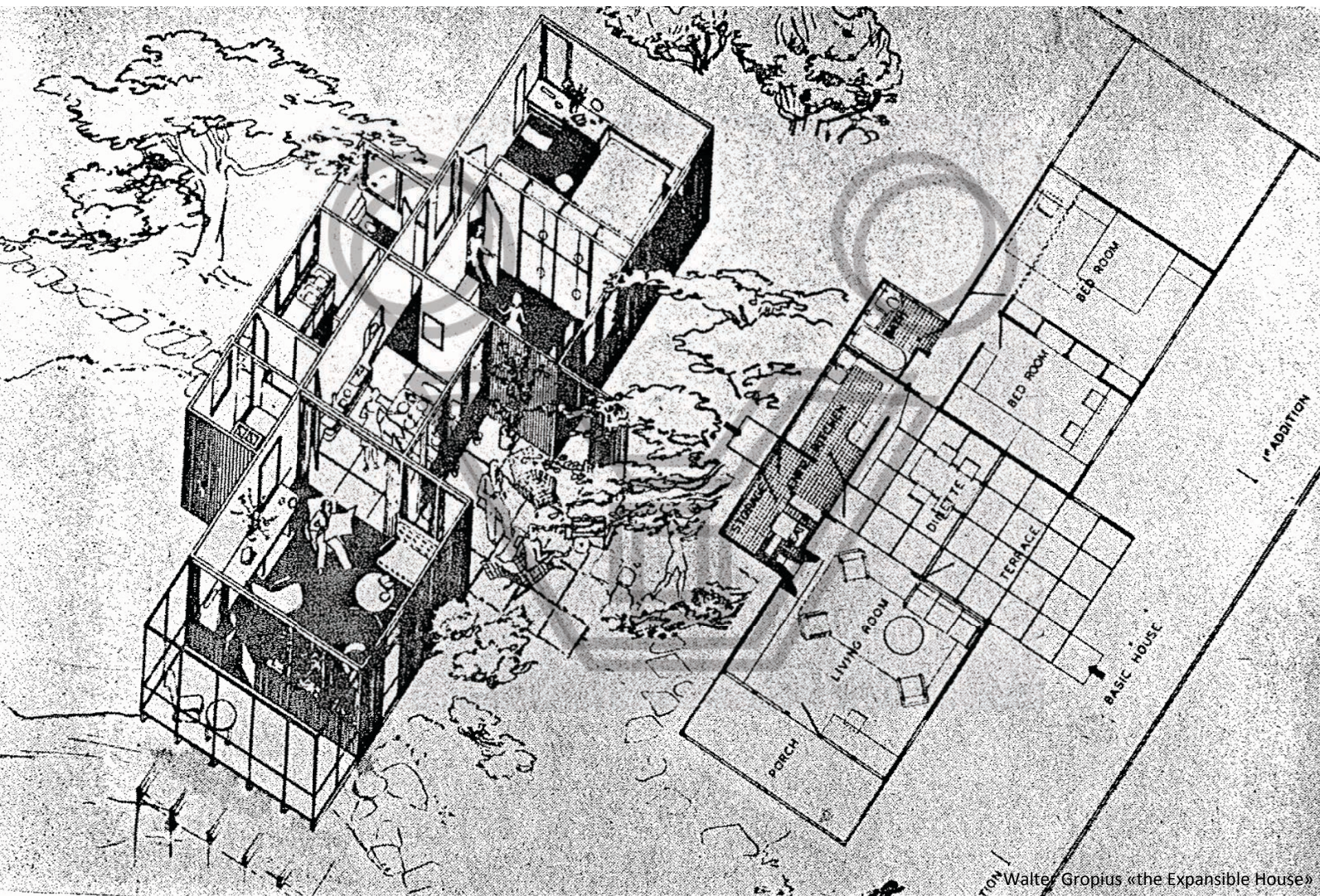
TUTTO AVOZ

F. 100

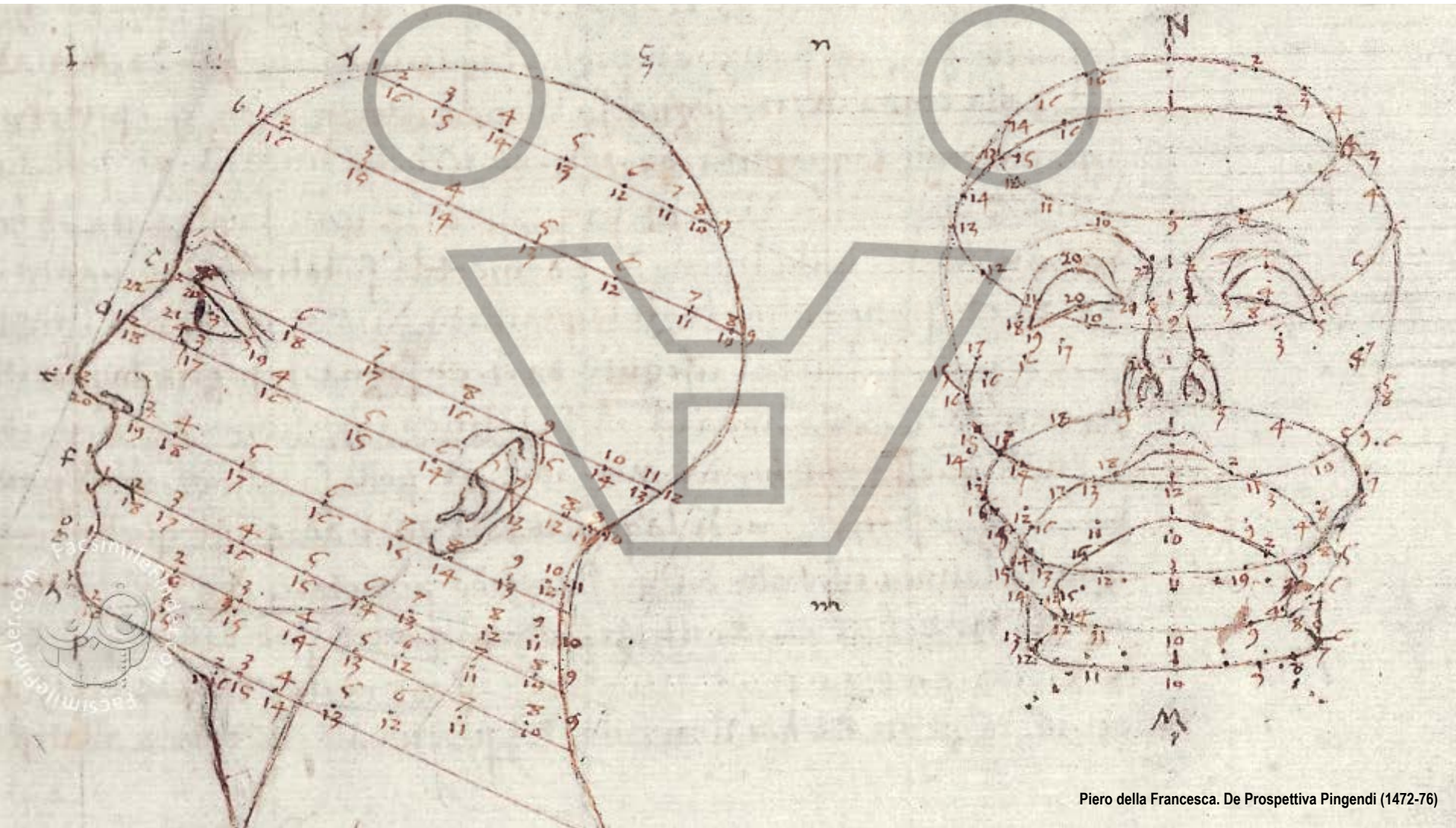
138

F. 82

3 PIASTRELLA: 8432



INVESTIGATION • RESEARCH LEARNING • KNOWING

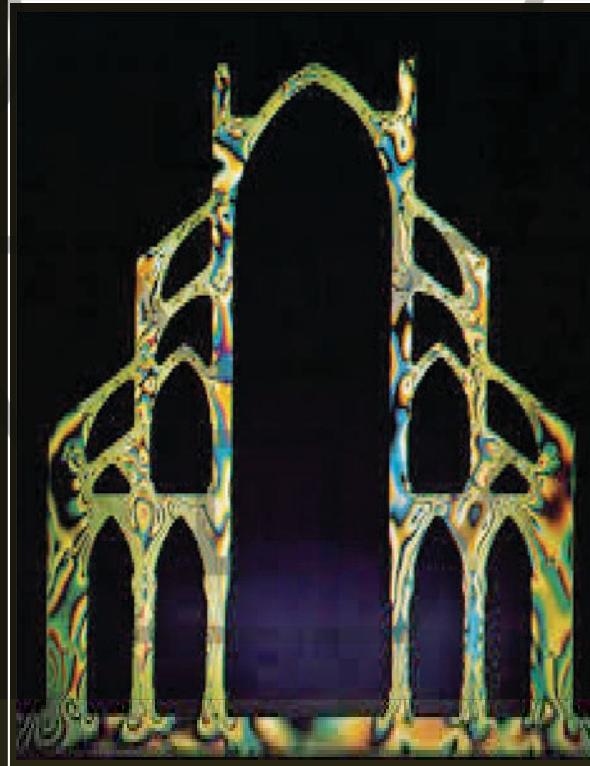




MODELING: the Language of Design



Leonardo da Vinci. Anatomical drawings (around 1510)

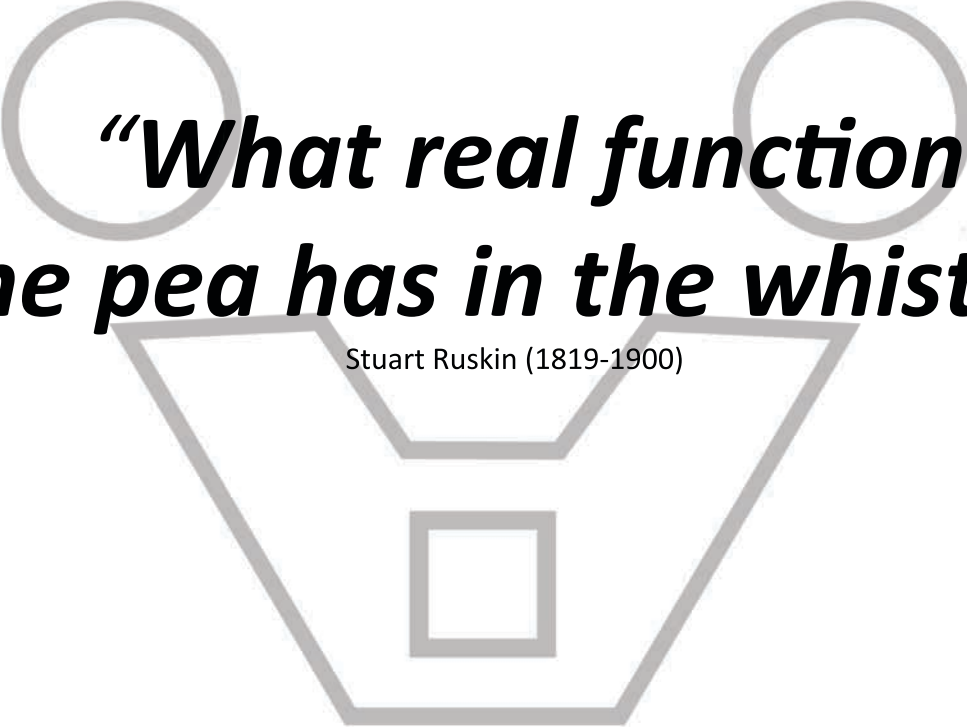


R. Mark. Force visualization on Gothic Cathedral



Riccardo Morandi. Bridge studies (1987/89)

Simulation of materiality in order to understand how it works



***“What real function
the pea has in the whistle”***

Stuart Ruskin (1819-1900)



***“Design is not just what it
looks like and feels like.
Design is how it works.”***

S. Jobs (1955-2011)



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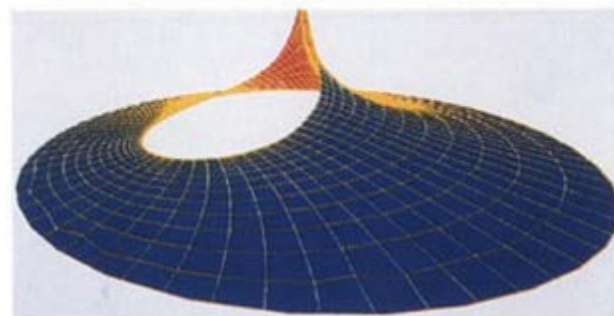
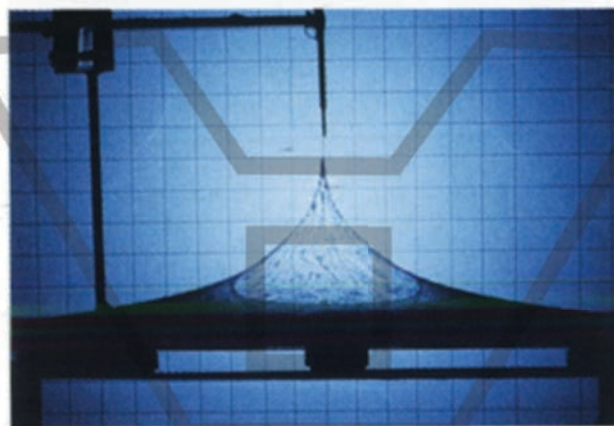
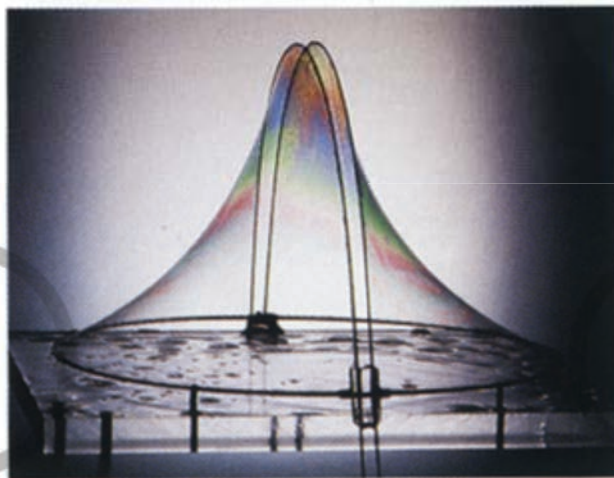
LABORATORIO DI PROGETTAZIONE AMBIENTALE

PROGETTAZIONE DEI SISTEMI COSTRUTTIVI | prof. arch. G.Ridolfi, PhD

PERFORMANCE DESIGN

VISUALIZING MATTER

Functionality and Performance Design

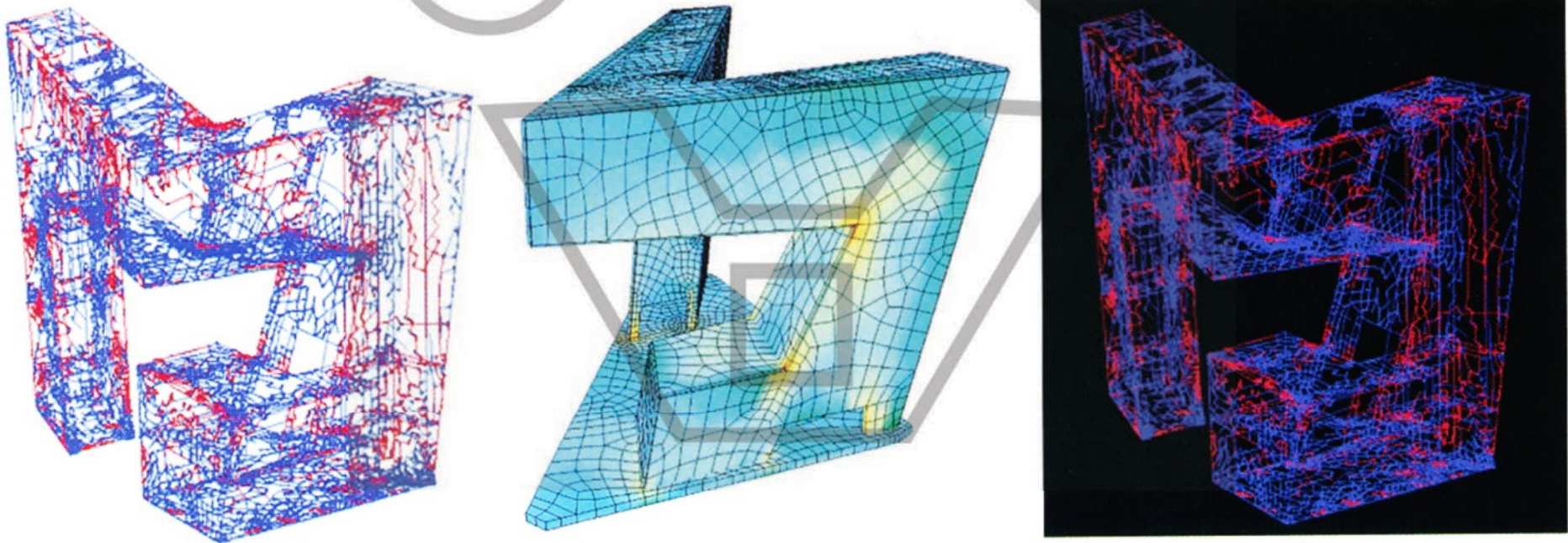


Frey Otto's studies & researches

- 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)



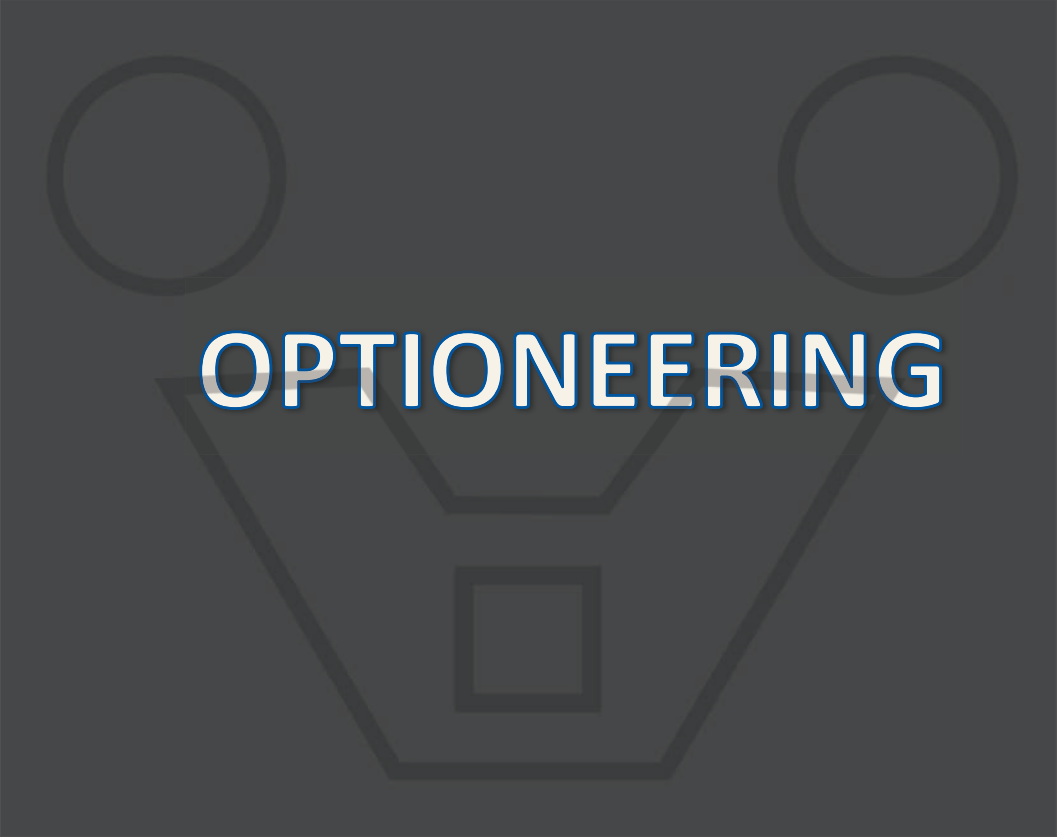
AKT, South Bank Pavilion (Zaha Hadid). Load paths. © Adams Kara Taylor (AKT).



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OPTIONEERING



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The race for the sky

N-40V-74



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)

**Empire State Building
procedurals innovations**

Fast tracking

Project Management (P/M)

Design and Manage (D&M)

Just in Time

Lean Production

Integrated Delivery Project (IPD)

What if ?

Optioneering

defining the final solution through the evaluation of alternatives

From September the 16th to October the 3^d, 1929

16 alternatives (2 by day) were delivered and compared:

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

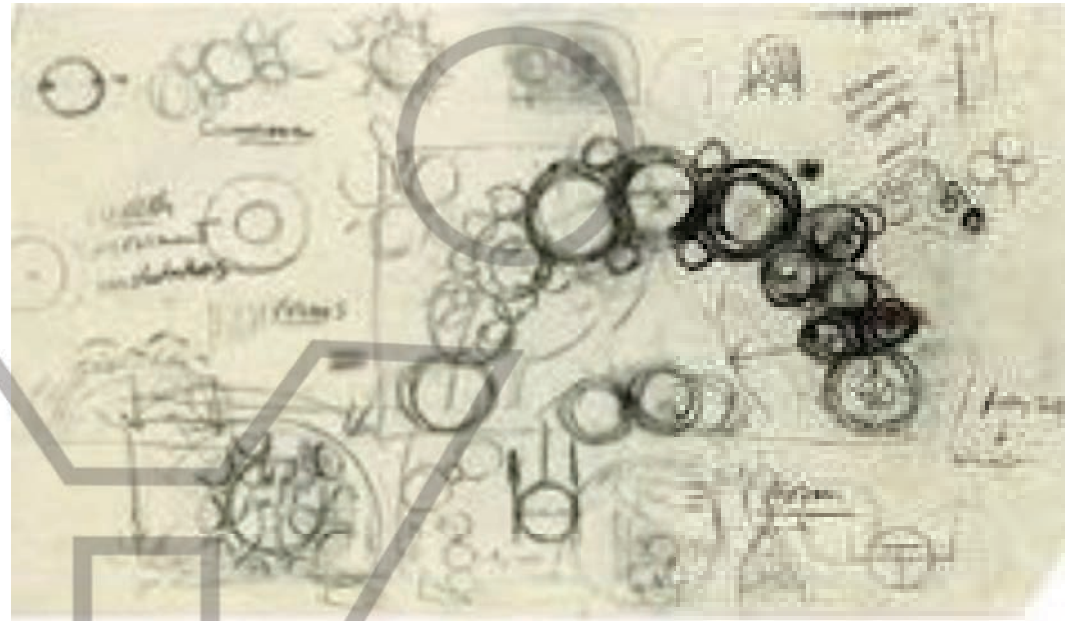
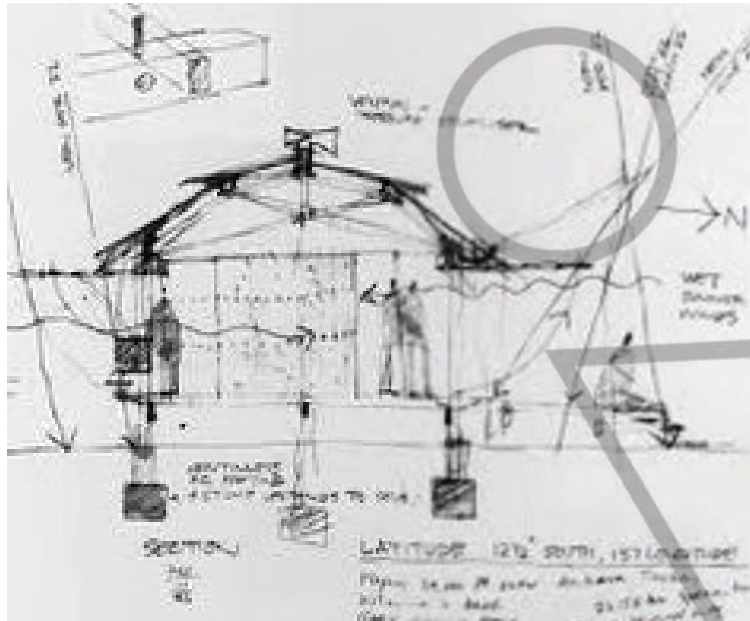


Computational Design as a scientific research

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 interpreting the results”

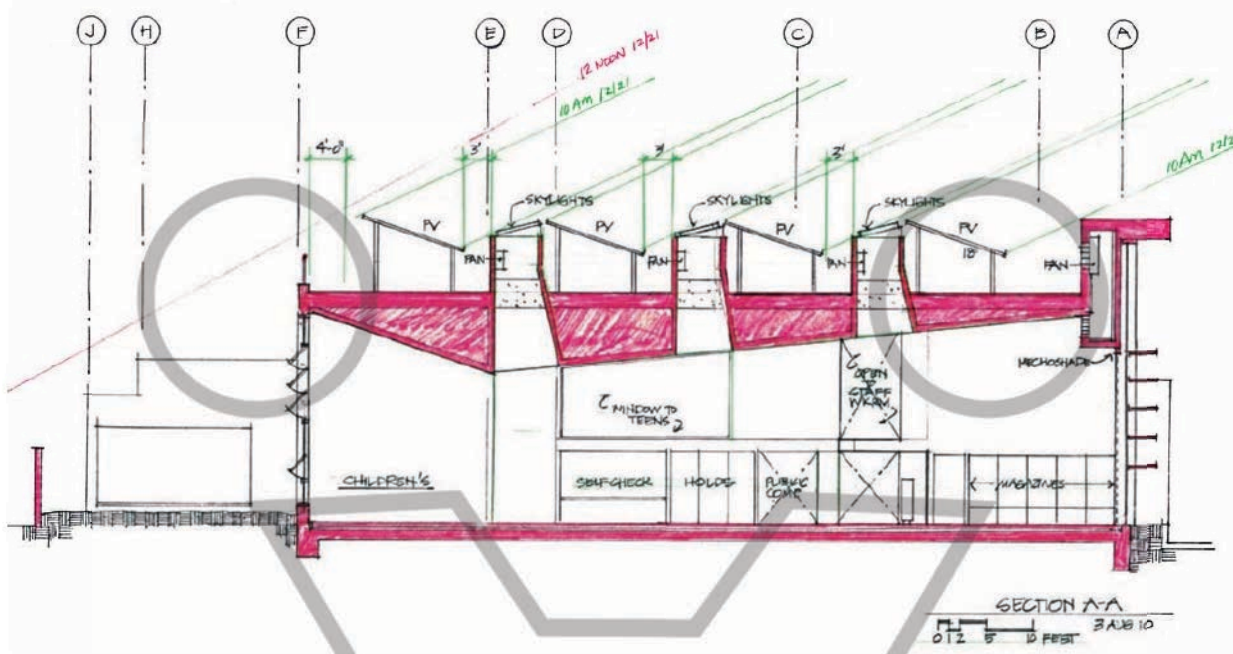
K. Andersonn



louis kahn sketches

Decision-Making through:

- rules of thumb
- individual intuition
- experience & tacit knowledge



1.6

Early design section through the reading room of the Net Zero Energy-designed West Berkeley Library. The design team used a combination of intuition and design simulation to create a roof form that correctly balanced the space for renewable energy, deep light wells, and natural ventilation. See case studies 8.2 and 9.1.

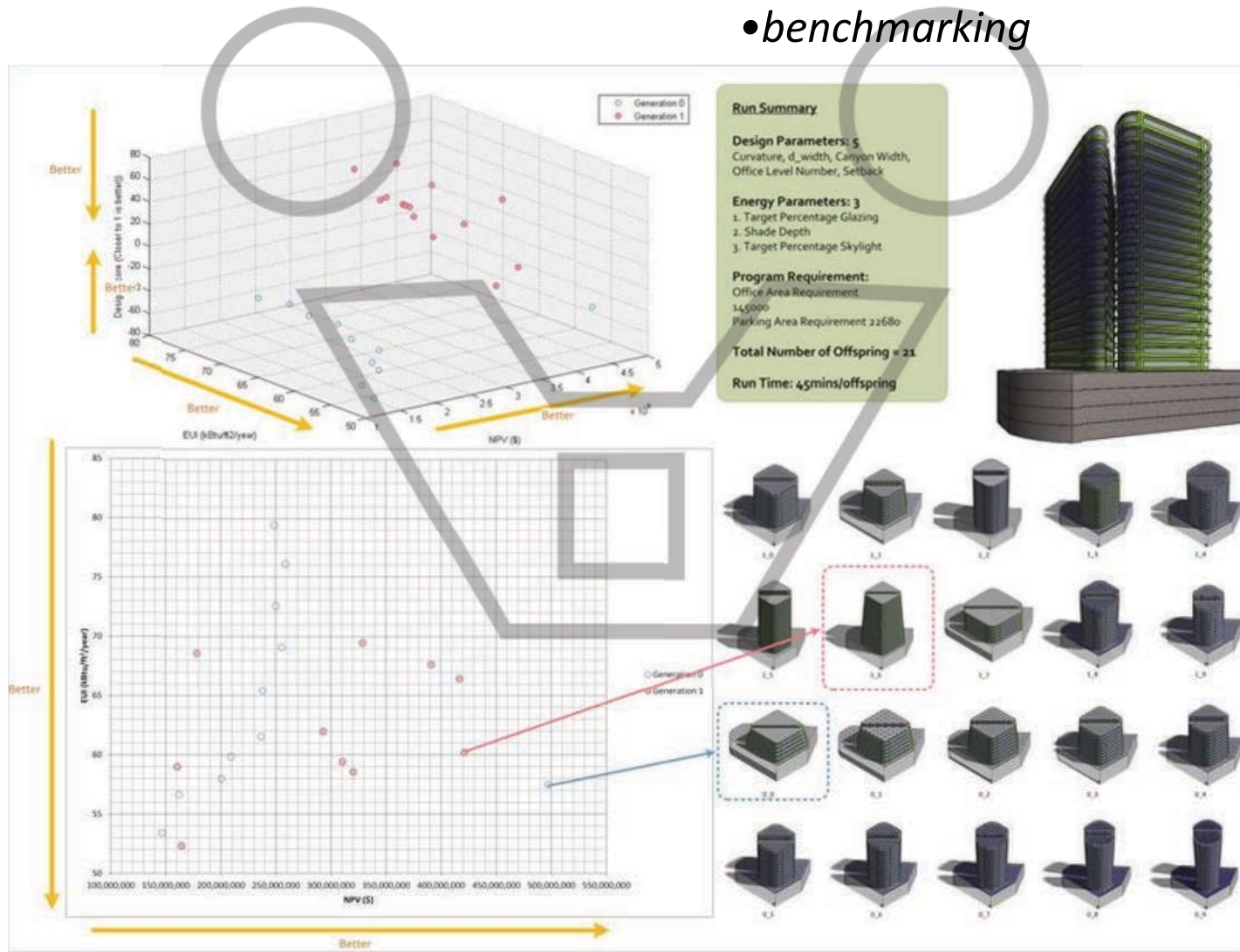
Source: Concept sketch by Edward Dean, courtesy of Harley Ellis Devereaux Architects.

The traditional architectural approach is a limited iterative process based on qualitative analogies

Computational Design as a scientific research

Decision-Making through:

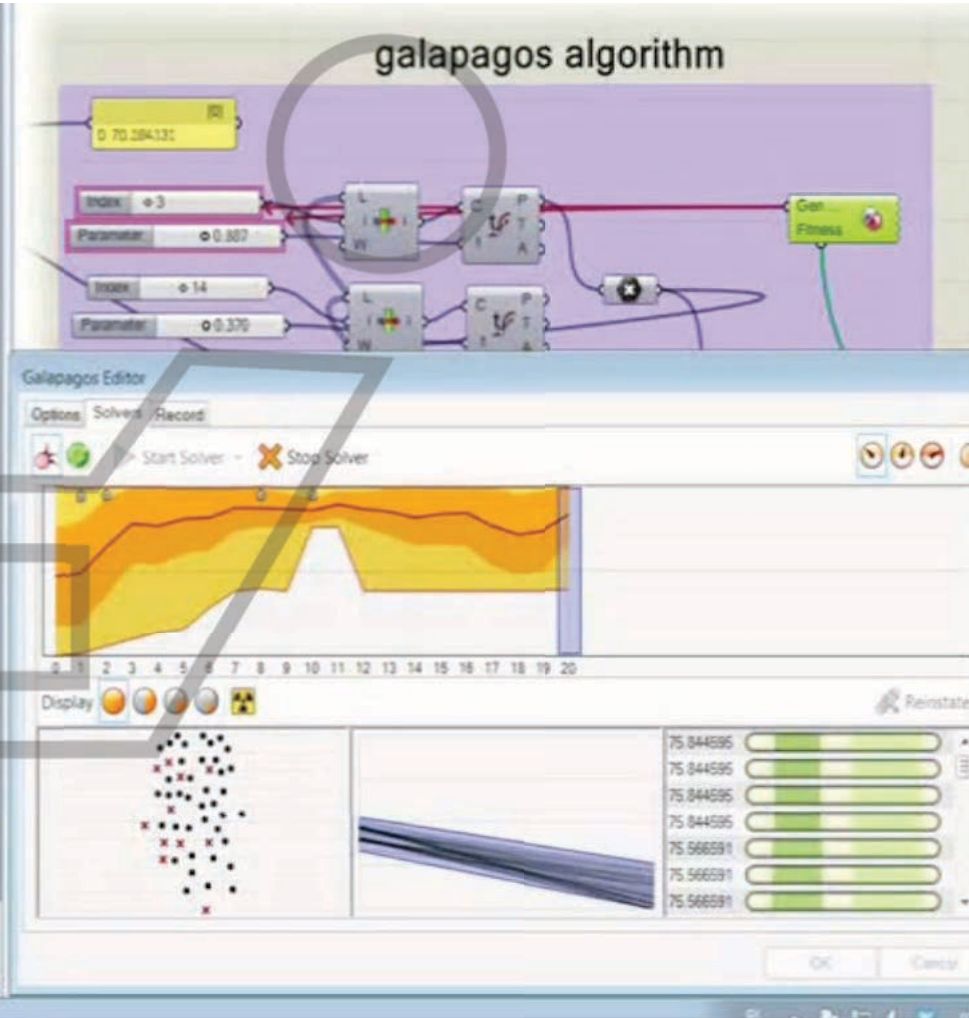
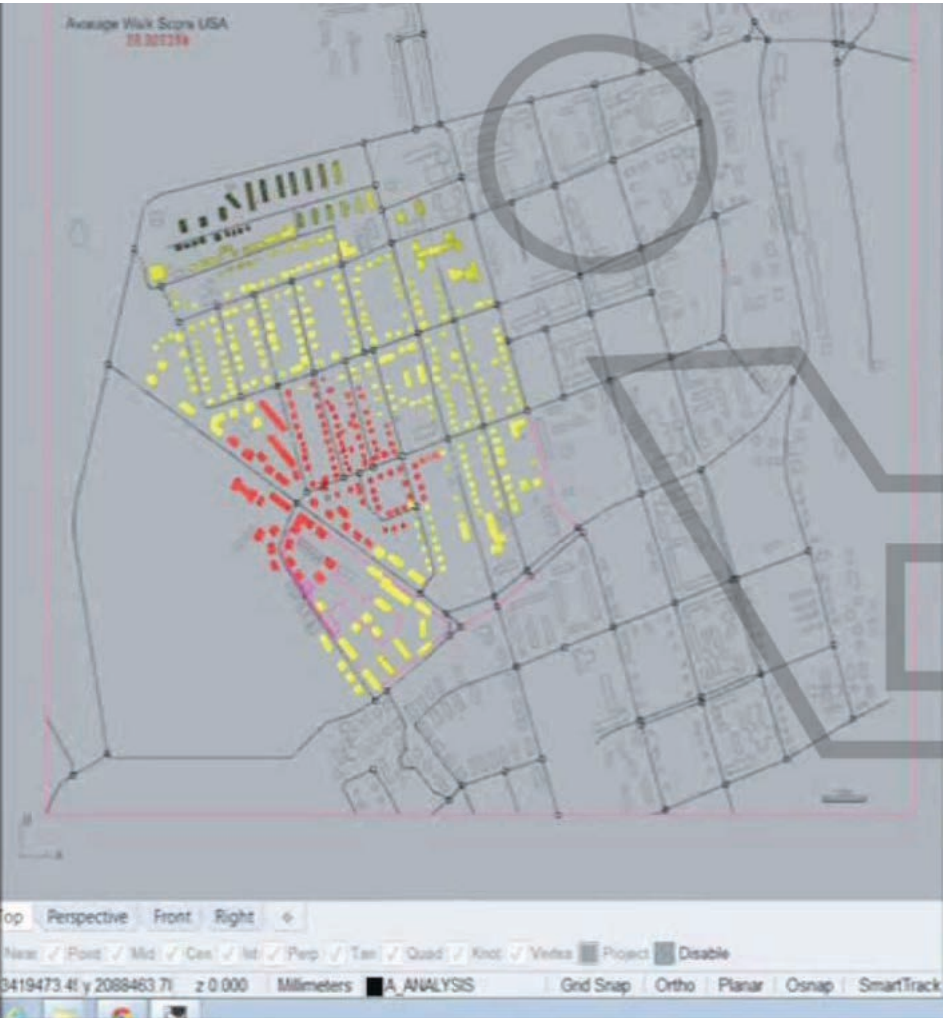
- *formal procedures*
- *evidence-based observation*
- *benchmarking*

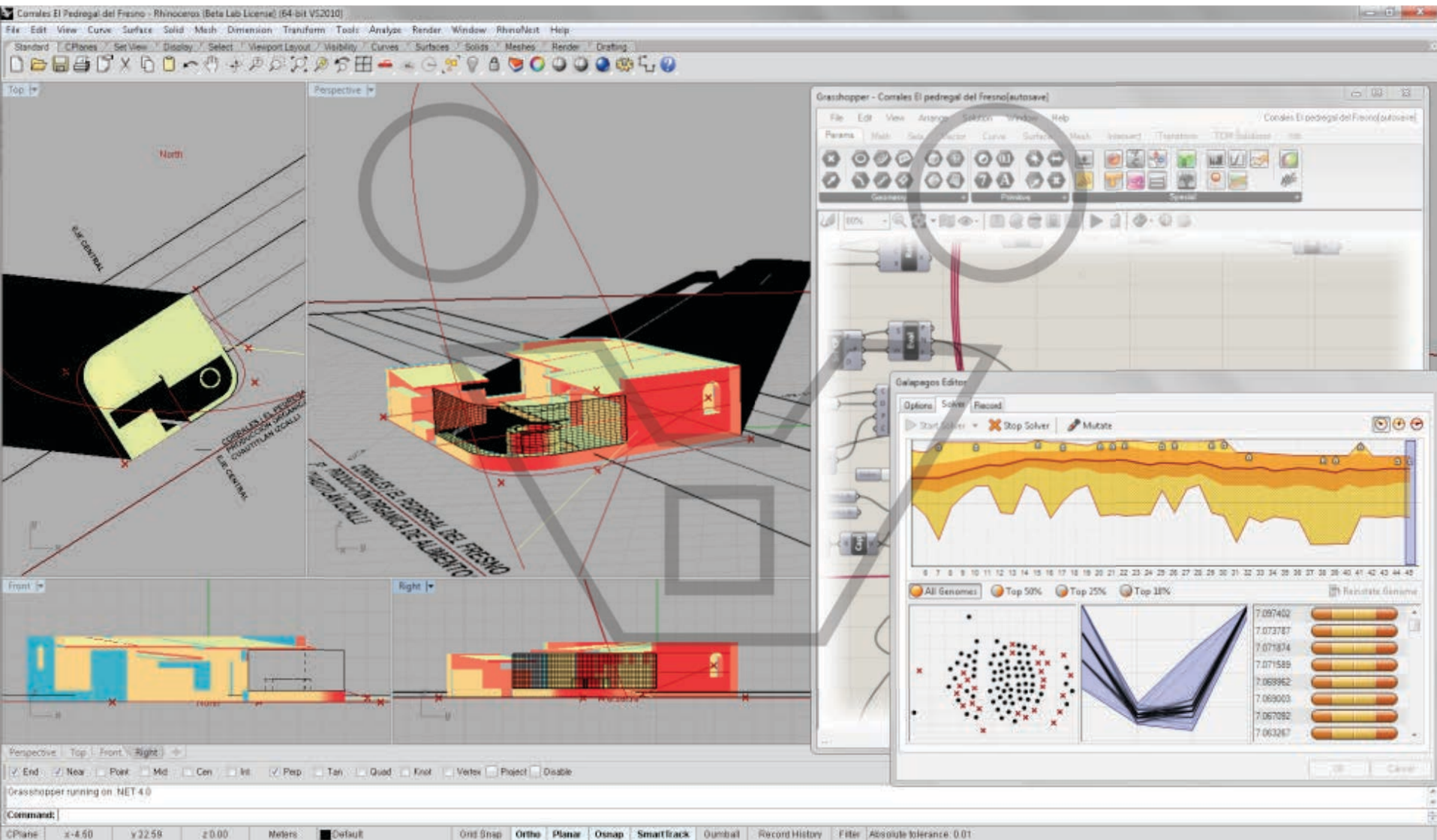


Computational Design for modeling simulation

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,...

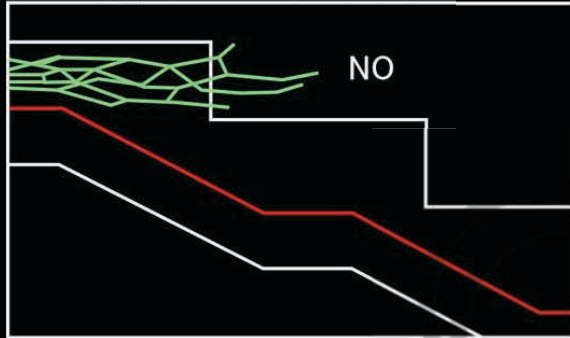
Evolutionary computation = a procedure based on trial and error problem solvers with automatic metaheuristic or stochastic optimization



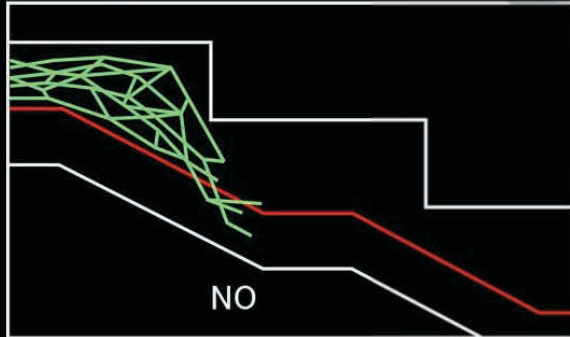


GROWING PROCESS:

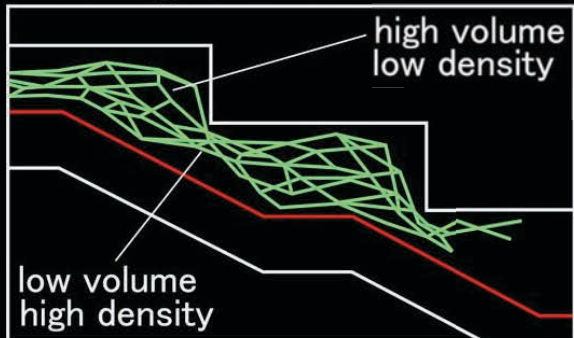
solving the condition:



solving the condition:

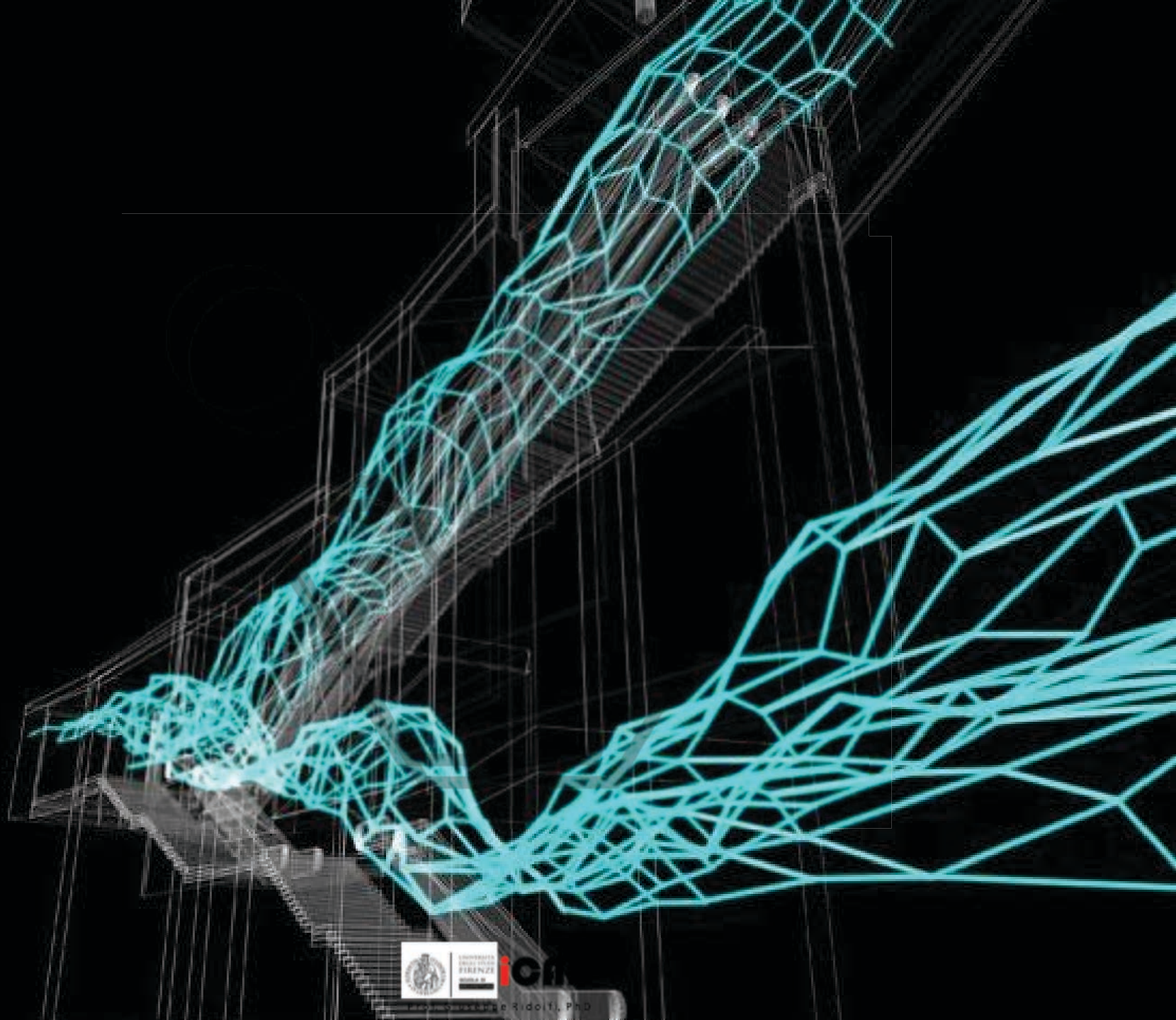


following the direction:



Watanabe, Iidabashi Station







“For me, it is calculus that was the subject of the issue and it is the discovery and implementation of calculus by architects that continue to drive the field in terms of formal and constructed complexity” (G. Lynn)

“ We are at the point that is possible to inform matter for predictable behaviors. Informing matter is not anymore and only the production of materials with predictable or definitive forms; materials do not come to live through designing forms, assigning meaningful, visible and understandable forms to matter, assigning univocity, and worshipping the aura. Today, mastering the matter, is an activity that takes place at the structural level, dealing with relationships, parameters, forces, and energy fields expressed and formulated through the numerical *matema*.

With new technological abilities we are now able to produce *materia operata* (materials), and even *materia prima* (matters), that can be invisible, with multiple possible shapes, able to incorporate performative (more than connotative) information.

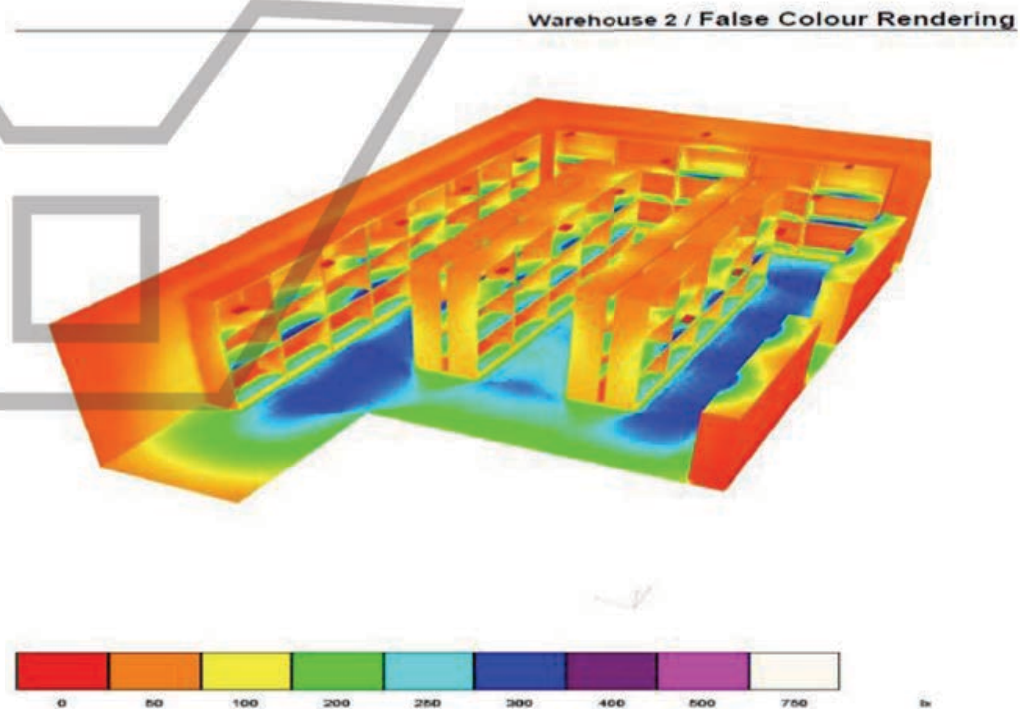
As a result we deal with «performative informed un-materiality»: materials «farcé» of that special untouchable matter that is the knowledge; for this reason we can define objects mainly made of un-materiality, able to incorporate information, memories; able to mutate dynamically presences and attitudes, to respond under complex and interrelated conditions, variables, parameters.”

-G.Ridolfi

MODELING FOR SIMULATION **NUMERICALLY** PERFORMANCE BASED

features: precision
objectivity
replicability
communicability

“... More than that digital tools give us an holistic and visual perception of phenomena in order to have a faster comprehension of a large quantity of aspects” G.Ridolfi

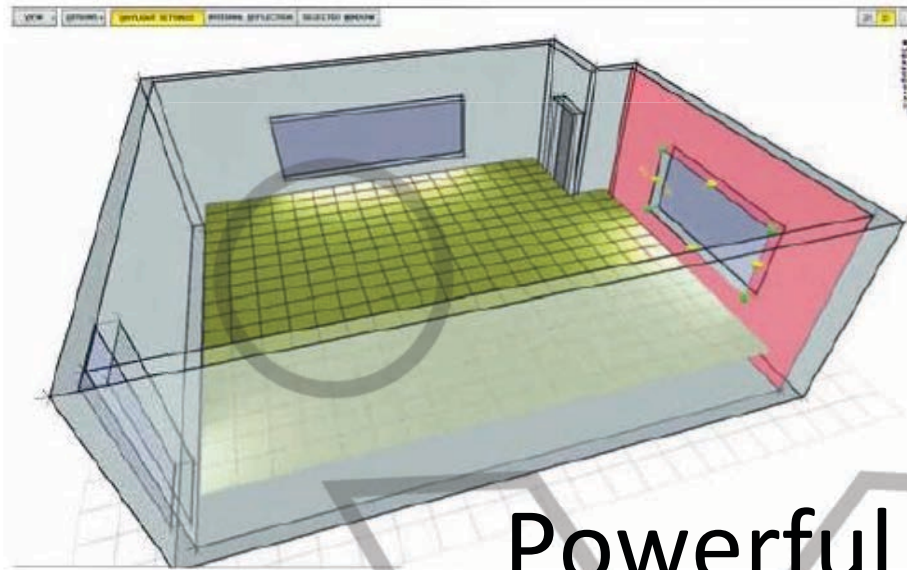


EVIDENCE OF PROOF AND CONTROL OF THE PROCESS

Today there are a lot of software to approach and modeling architectural designing That are very intuitive and give the opportunity also to architects to run some technical analysis that in the past were served to engineering and specialist

As a result architect today can use this tool to inform their project, deciding on evidence of test, controlling the machinery for the fabrication (files to factory)



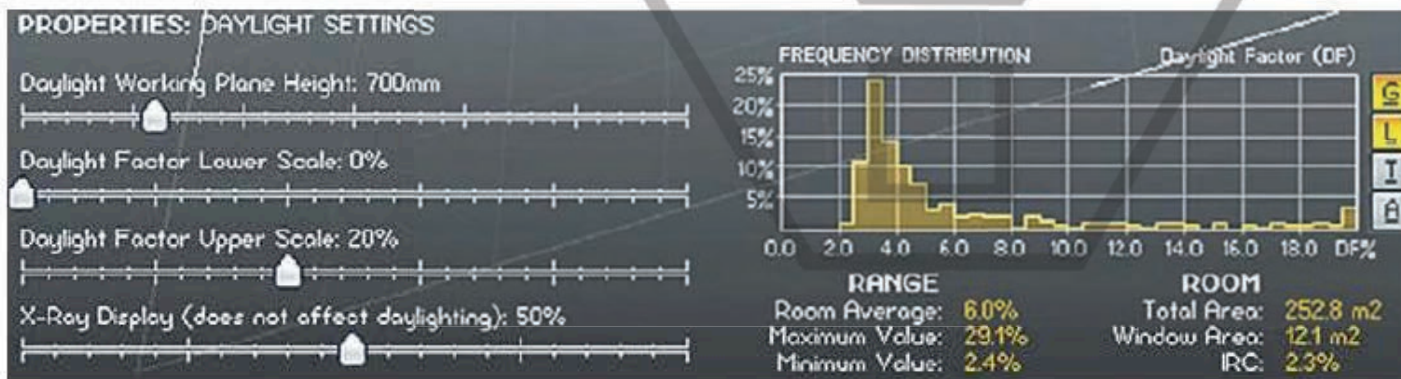


2.3 and 2.4

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

The art of digital modeling for evaluation purpose

MAIN ASPECTS TO CONSIDER IN DIGITAL MODELING FOR SIMULATION

- Extension
- Deepeness
- Operability
- Accuracy
- Reliability

Level of details => run time* vs accuracy

> many tests vs few detailed solutions

**Run time= amount of time that a computer needs to run the task*

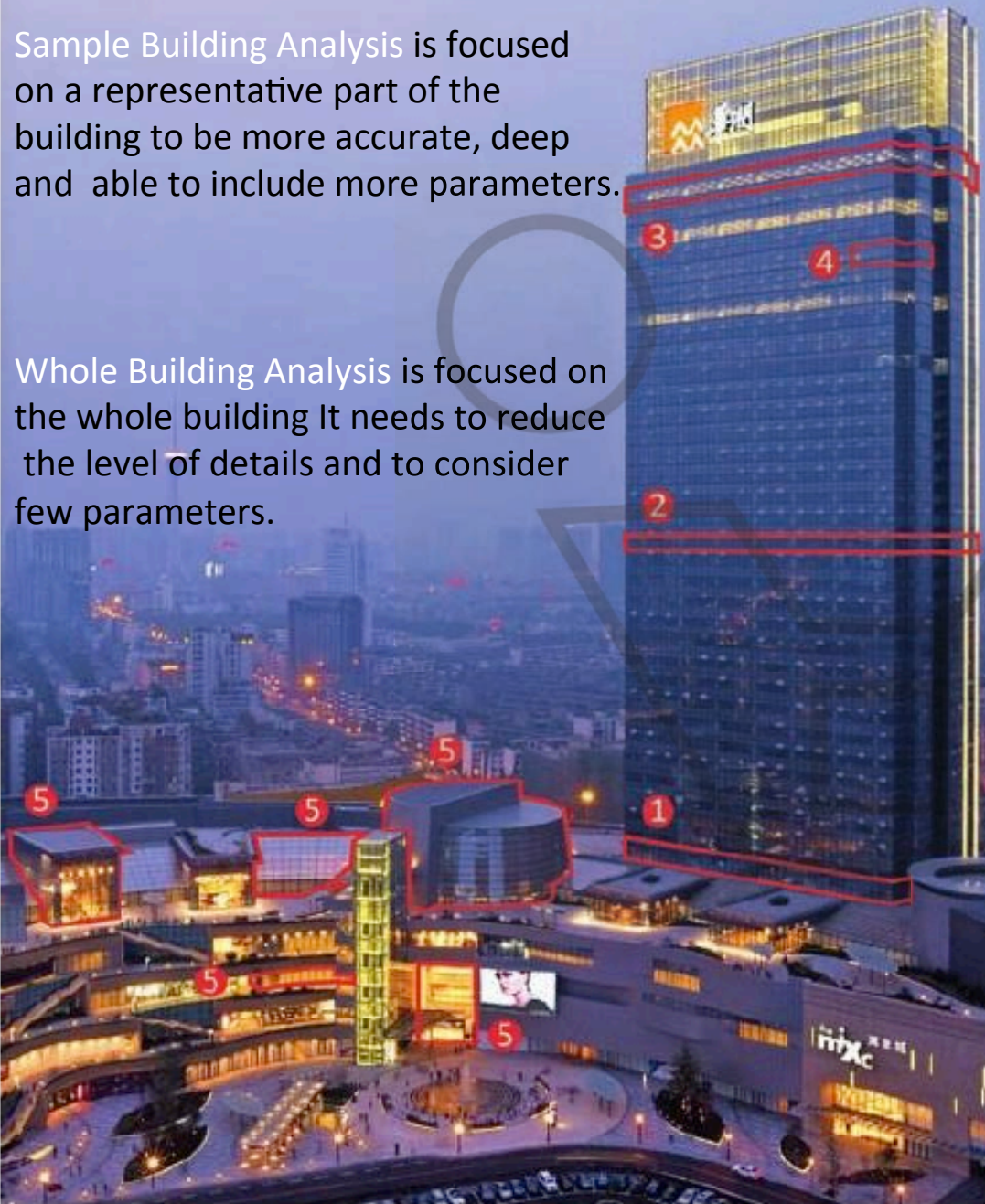


It is important to note that Building Energy Modeling is a computer program and the accuracy of results would largely depend on the inputs provided to the model. In this context, one should be mindful of the expression 'garbage-in-garbage-out'.



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.

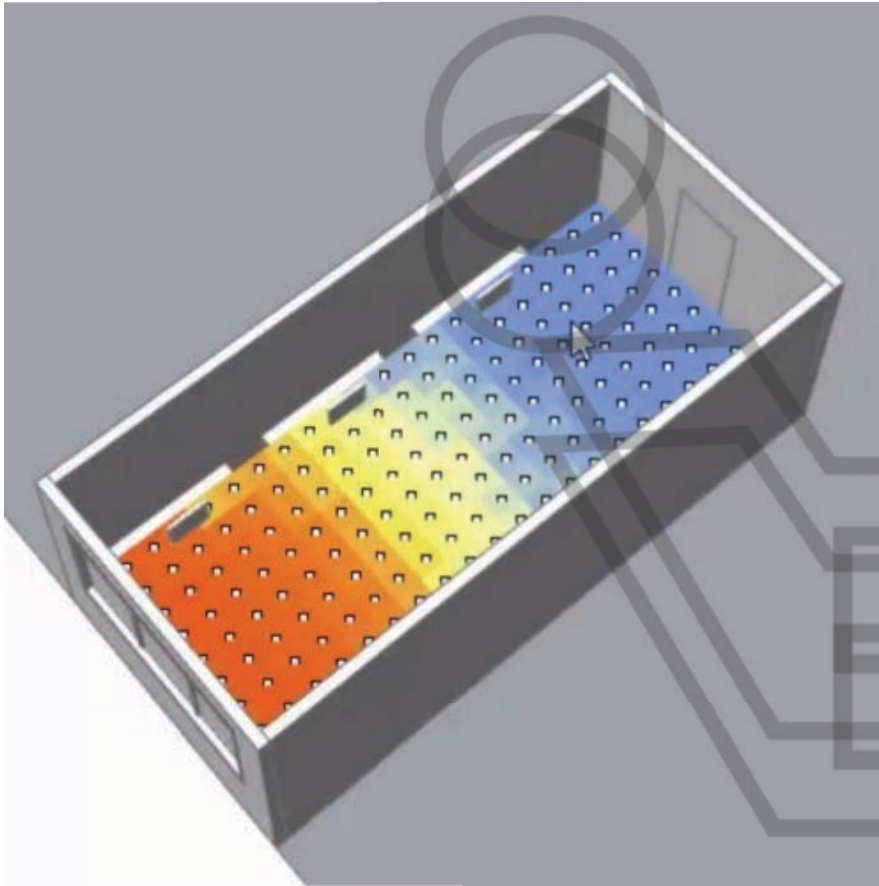


While a whole building energy simulation estimates the performance for an entire building, representative floors are typically modeled, including the lowest (1), middle (2), and top floors (3) of a high-rise, with multipliers being used to account for the other floors. Each atypical floor is modeled 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. Analyze 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

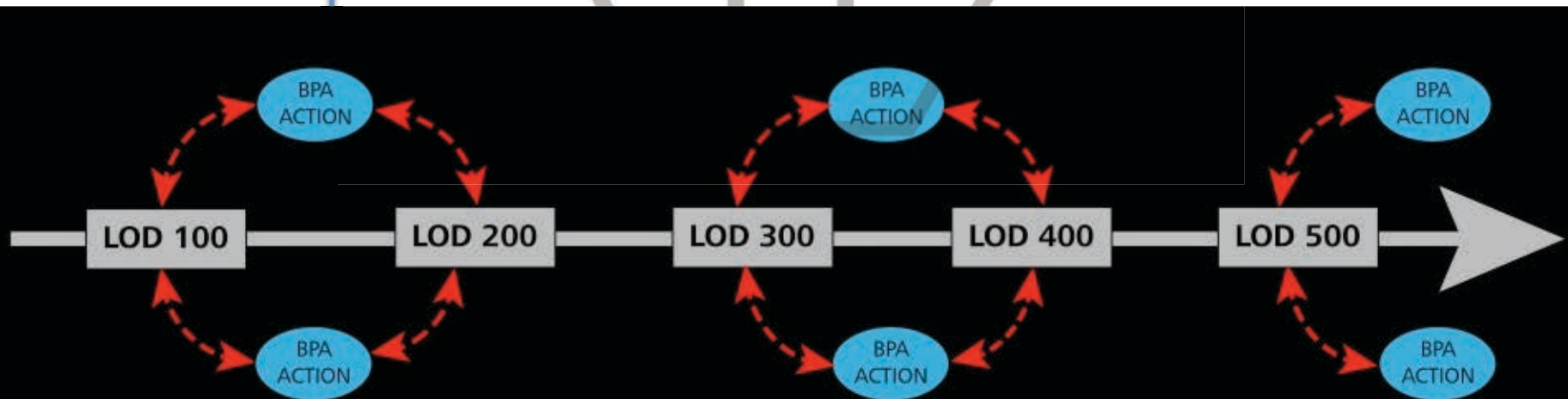
Level of details

Impact of decisions

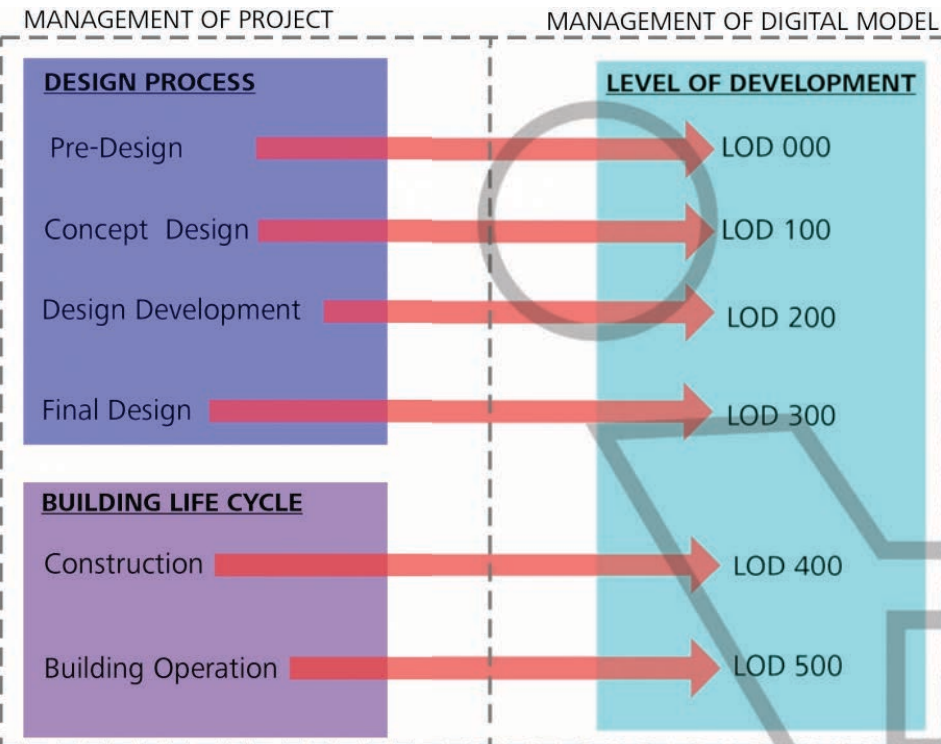


WHICH LEVEL OF DETAIL IS REQUIRED IN THE EARLY STAGE THE BIM PROCESS

Early Stage Design



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



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.

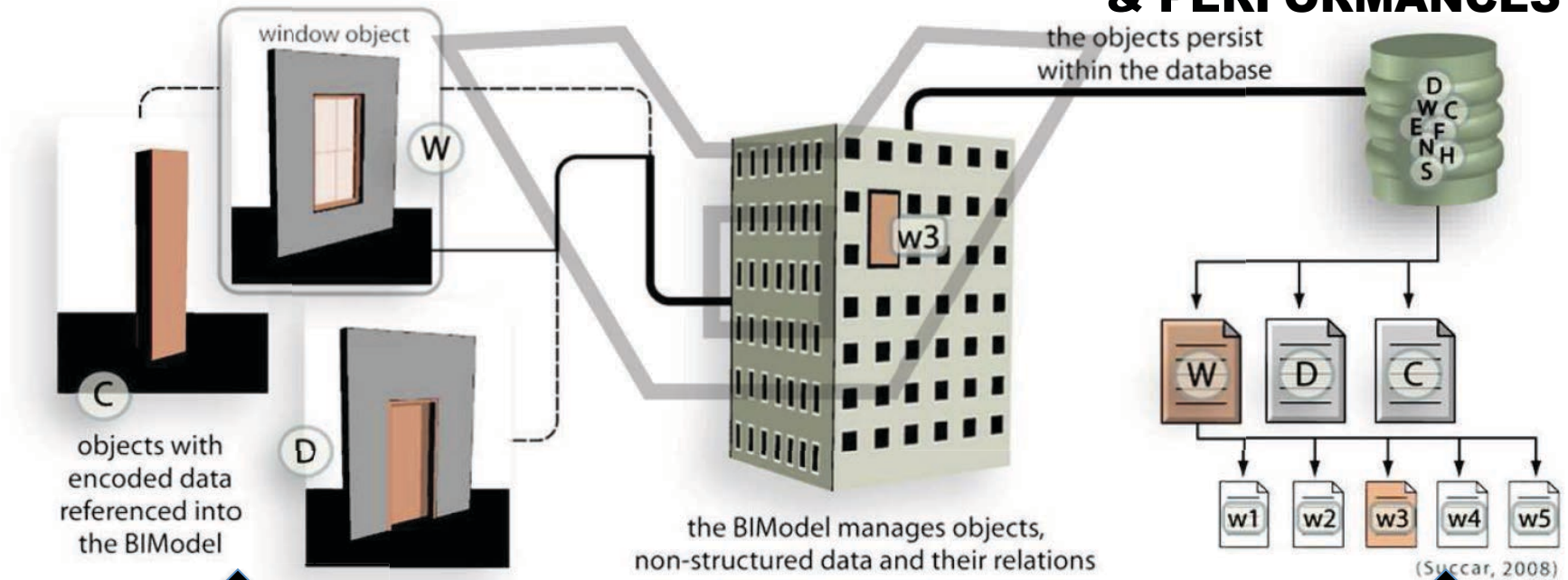
LOD 500: Modeled elements are representative of as installed conditions and can be utilized for ongoing facilities management.

BIM FOR INTEGRATED DELIVERY PROJECT



ELEMENTS / LIBRARIES

DATASET OF FACTS & PERFORMANCES



THE WHOLE MODEL AS A SYSTEM WHERE THE INTERACTION TAKES PLACE

BIM FOR INTEGRATED DELIVERY PROJECT (IPD)

- We need to go with an engineering-integrated process since the early stage
- Bim is not a new and more efficient way of production. BIM is a chance.
- 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.
- It is a way to visualize materiality and for that reason to have an understanding on how the building works.
- BIM and object oriented computing in general are providing us a way to get an holistic approach to design

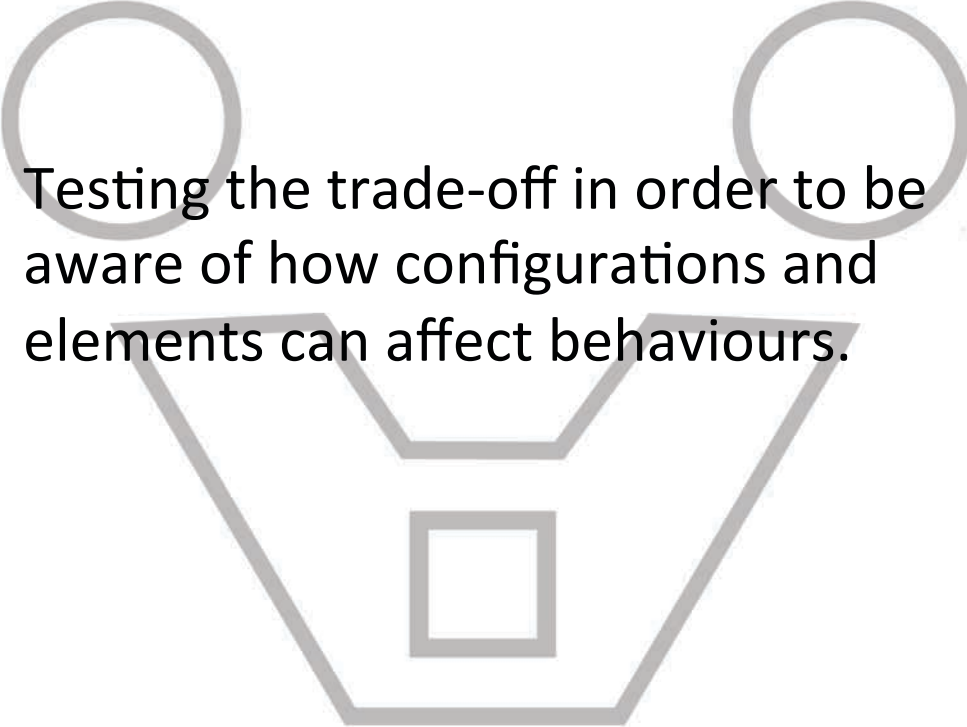
BIM allows us to integrate time, costs, manufacturing, facility management and maintenance information; to check conflicts.

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

BIM SOFTWARE

1. Autodesk provides various BIM software programs such as Revit for architectural design, Mechanical, Electrical and Plumbing (MEP), and structural engineering as well as cloud based solutions such as BIM360. Visit for more information: <http://www.autodesk.com/>.
2. Bentley Systems also provides a suite of BIM tools: <https://www.bentley.com/>.
3. DProfiler by Beck technology: <http://www.beck-technology.com/>.
4. ArchiCAD by Graphisoft: <http://www.graphisoft.com/>.
5. Vectorworks Designer by Nemetschek: <http://www.nemetschek.net/>.
6. Tekla Structures: <http://www.tekla.com/>.
7. Google Sketchup Pro: <http://www.sketchup.google.com/>.
8. Affinity by Trelligence: <http://www.trelligence.com/>.
9. Vico Office: <http://www.vicosoftware.com/>.
10. Digital Project by Gehry technologies: <http://www.gehrytechnologies.com/>.



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



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

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

Ethical responsibility about us and the environment we live

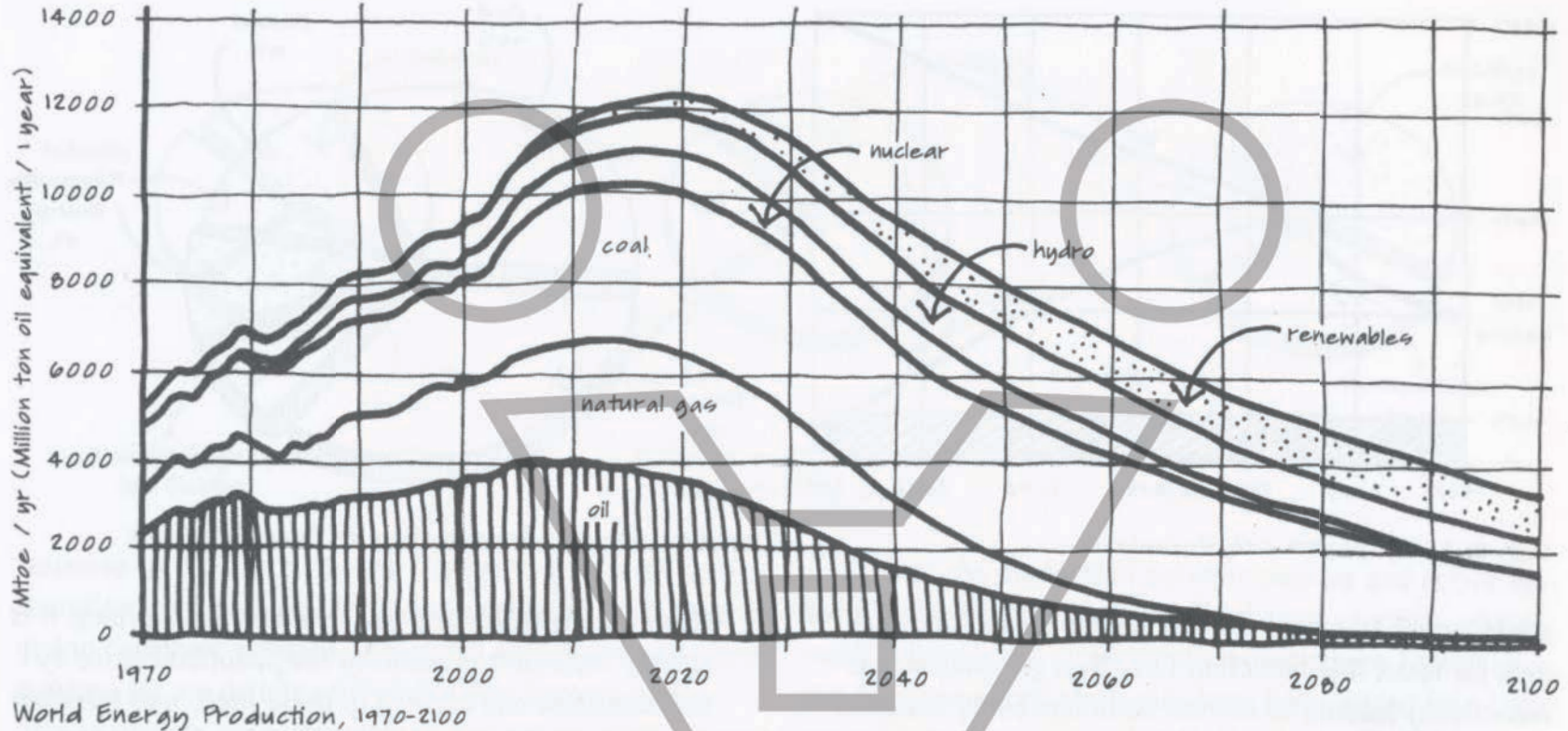
Because the built environment and constructions are one of the largest factor that affect our living

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 responsibility

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



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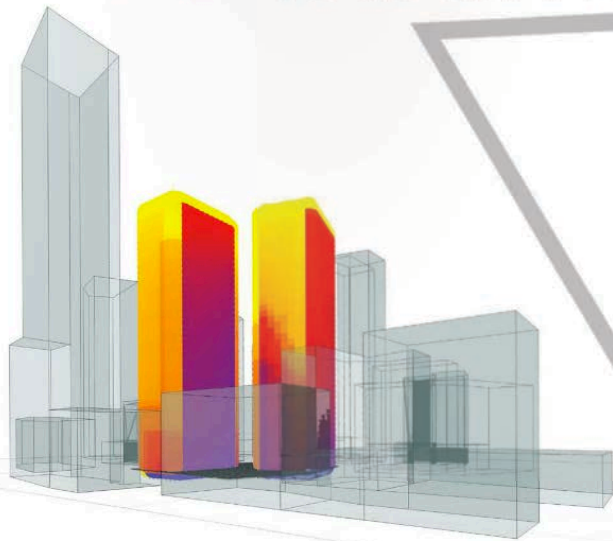
ENVIRONMENTAL DESIGN USING MASS COMPUTATIONAL MODELING



Kjell Anderson

DESIGN ENERGY SIMULATION FOR ARCHITECTS

GUIDE TO 3D GRAPHICS



ROUTLEDGE

Green Energy and Technology

Nilesh Y. Jadhav

Green and Smart Buildings

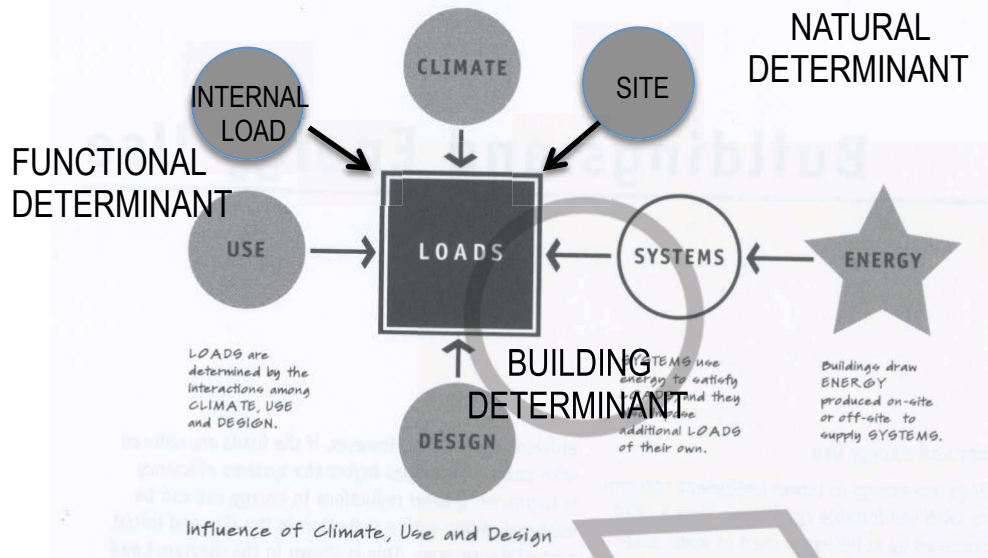
Advanced Technology Options

 Springer

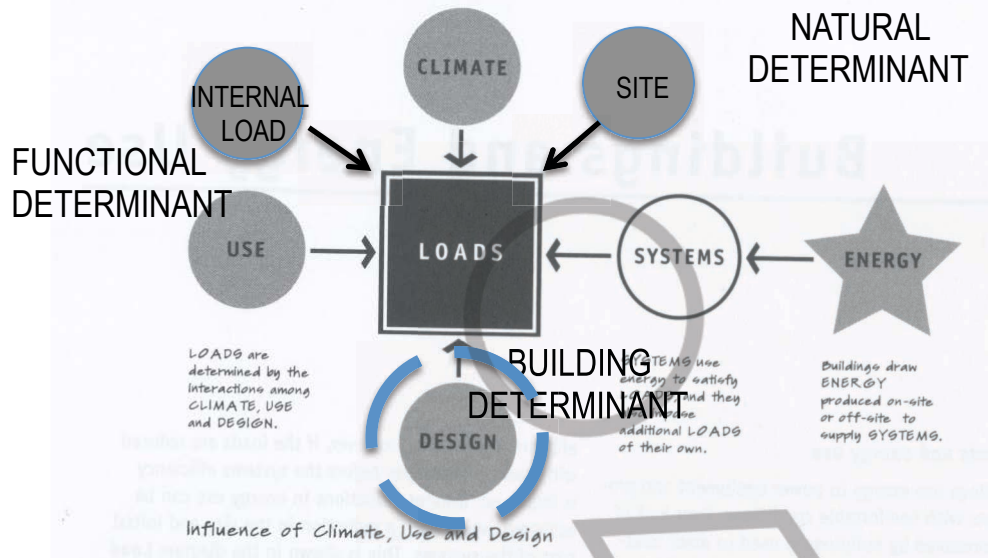
Class Text-books

For other resources check Mailab class portal out

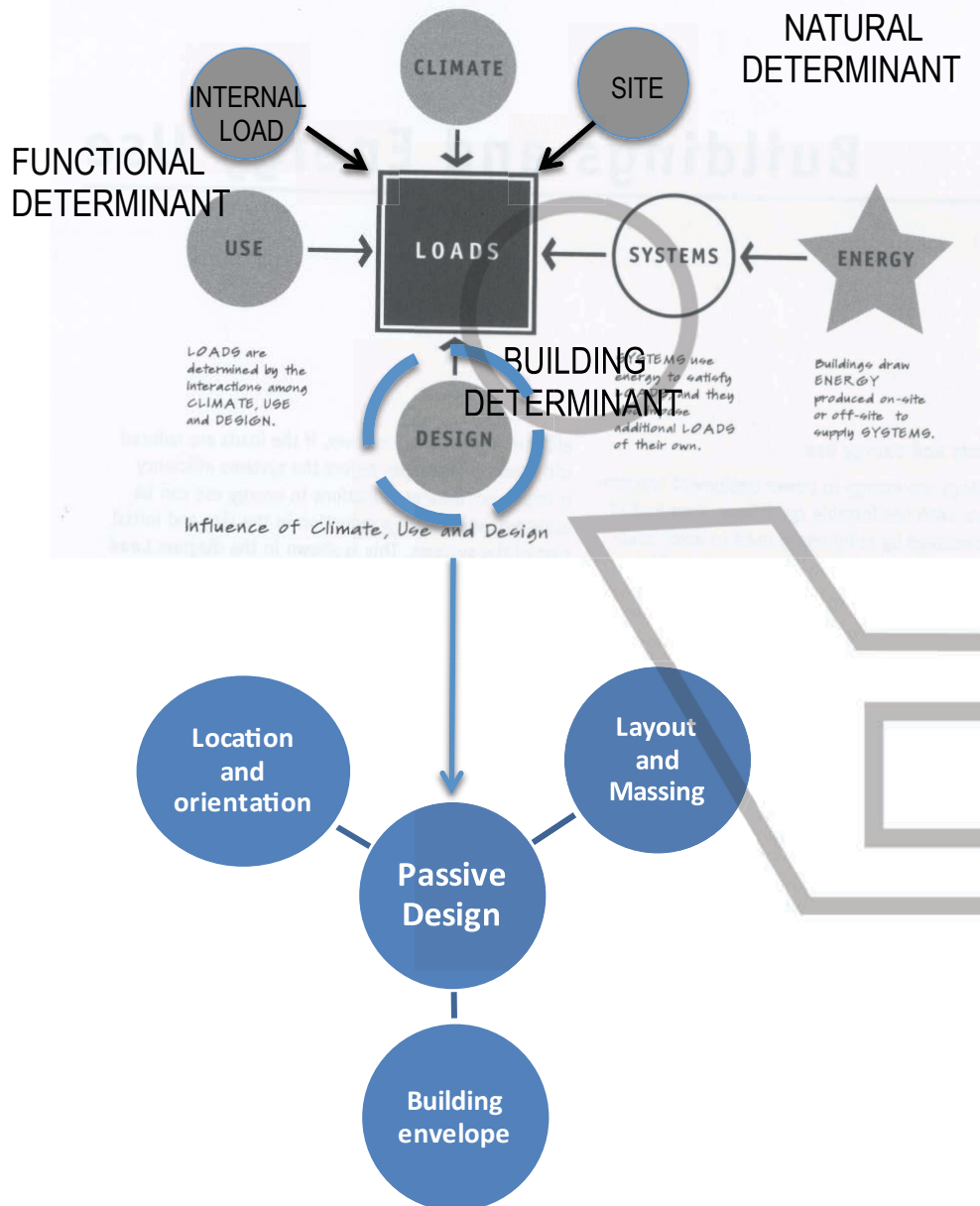
ENVIRONMENTAL SYSTEM DETERMINANTS



ENVIRONMENTAL SYSTEM DETERMINANTS



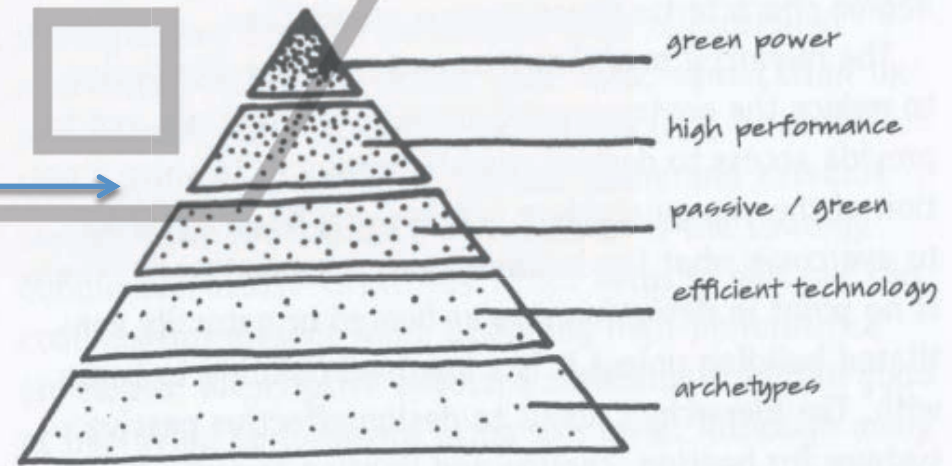
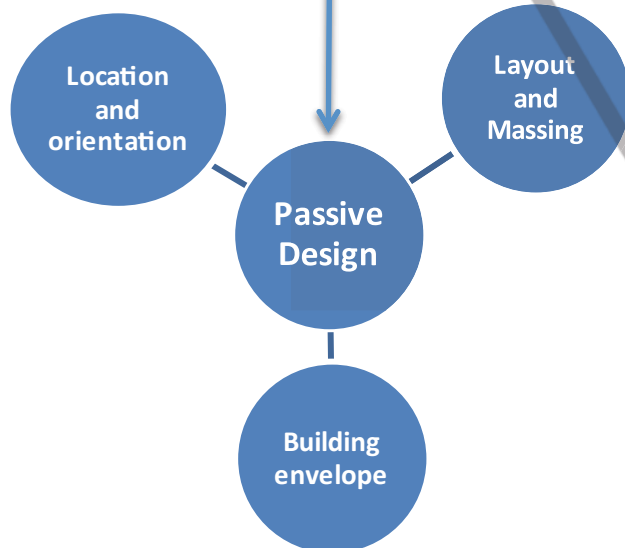
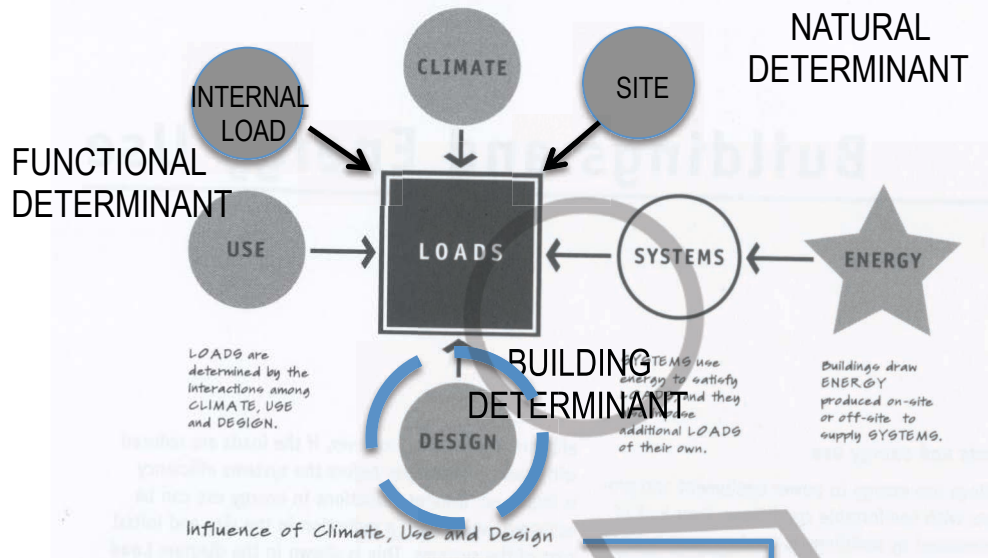
MODELING FOR PASSIVE DESIGN



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:

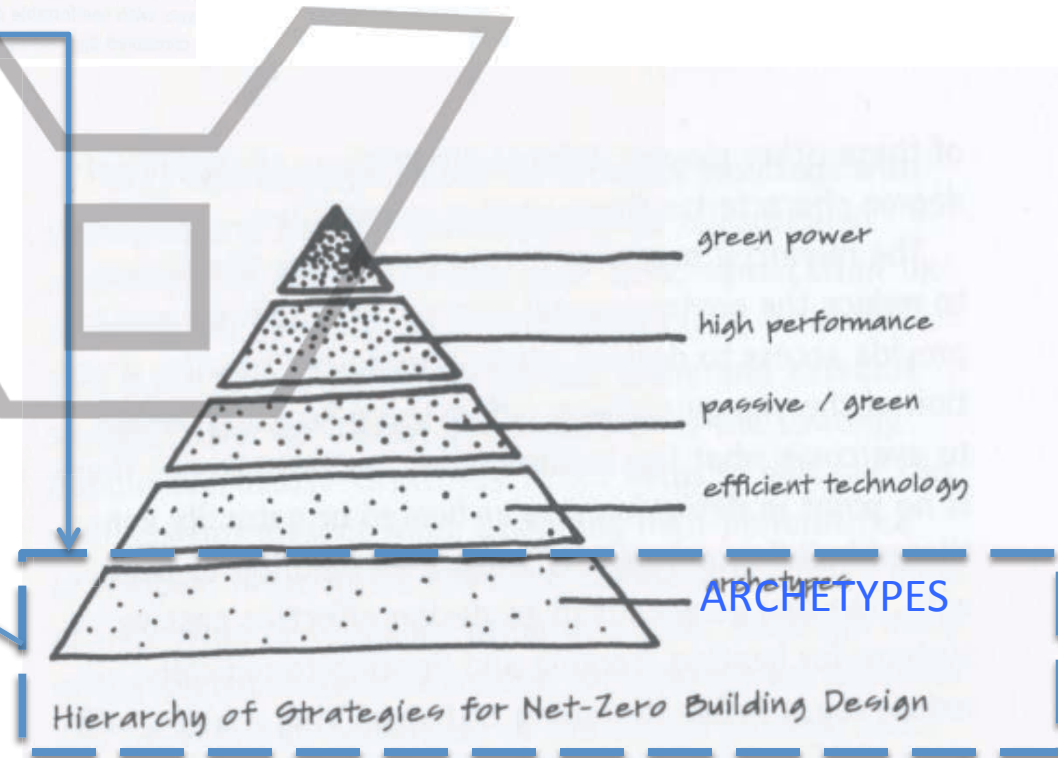
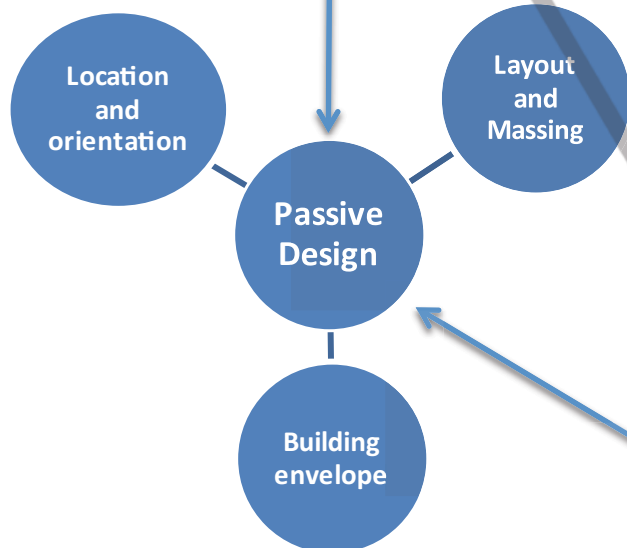
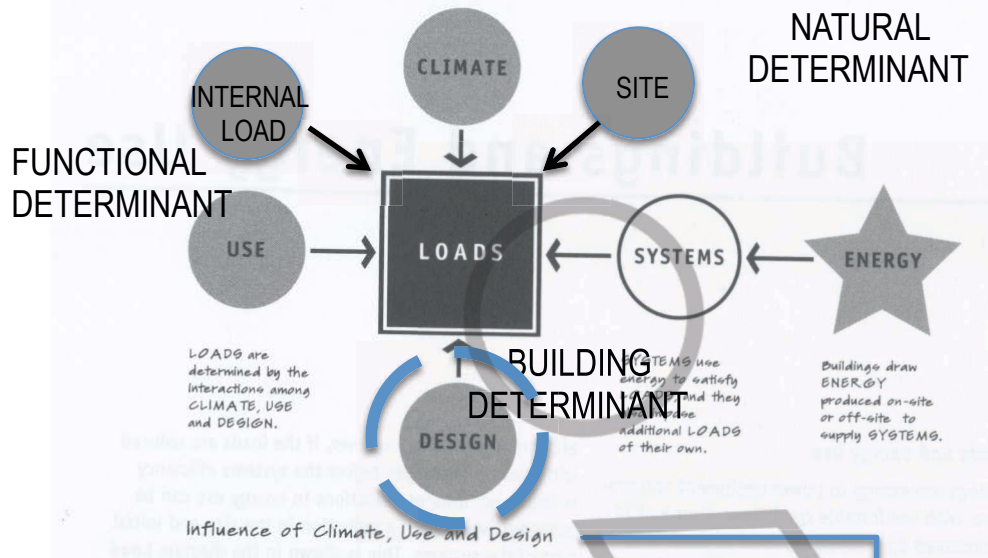
- **Day lighting**: can reduce the energy used for artificial lighting but excessive and improper exposure may result in glare and other forms of visual discomfort
- **Natural ventilation**: can reduce mechanical ventilation energy to move air around but can result in hygiene issues and over-cooling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

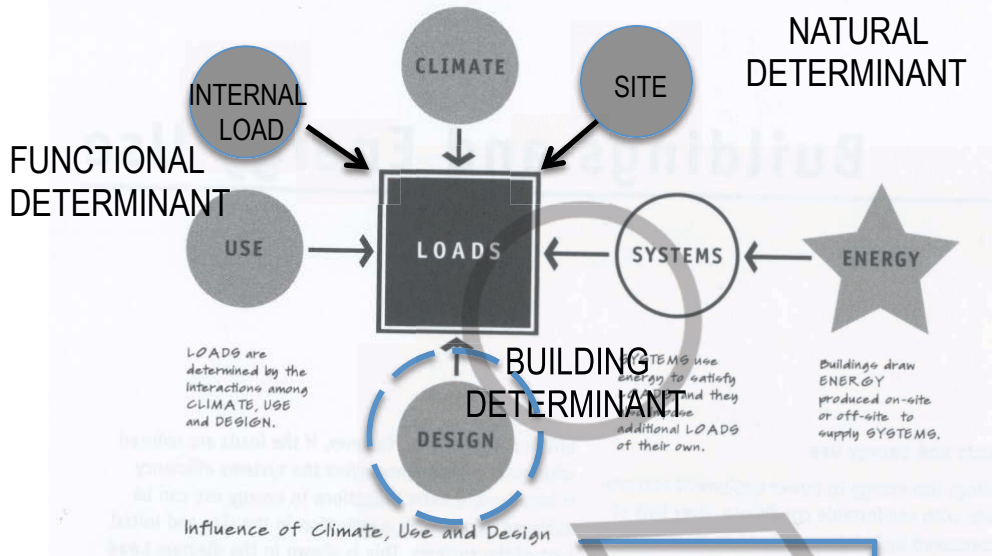
MODELING FOR PASSIVE DESIGN



Hierarchy of Strategies for Net-Zero Building Design

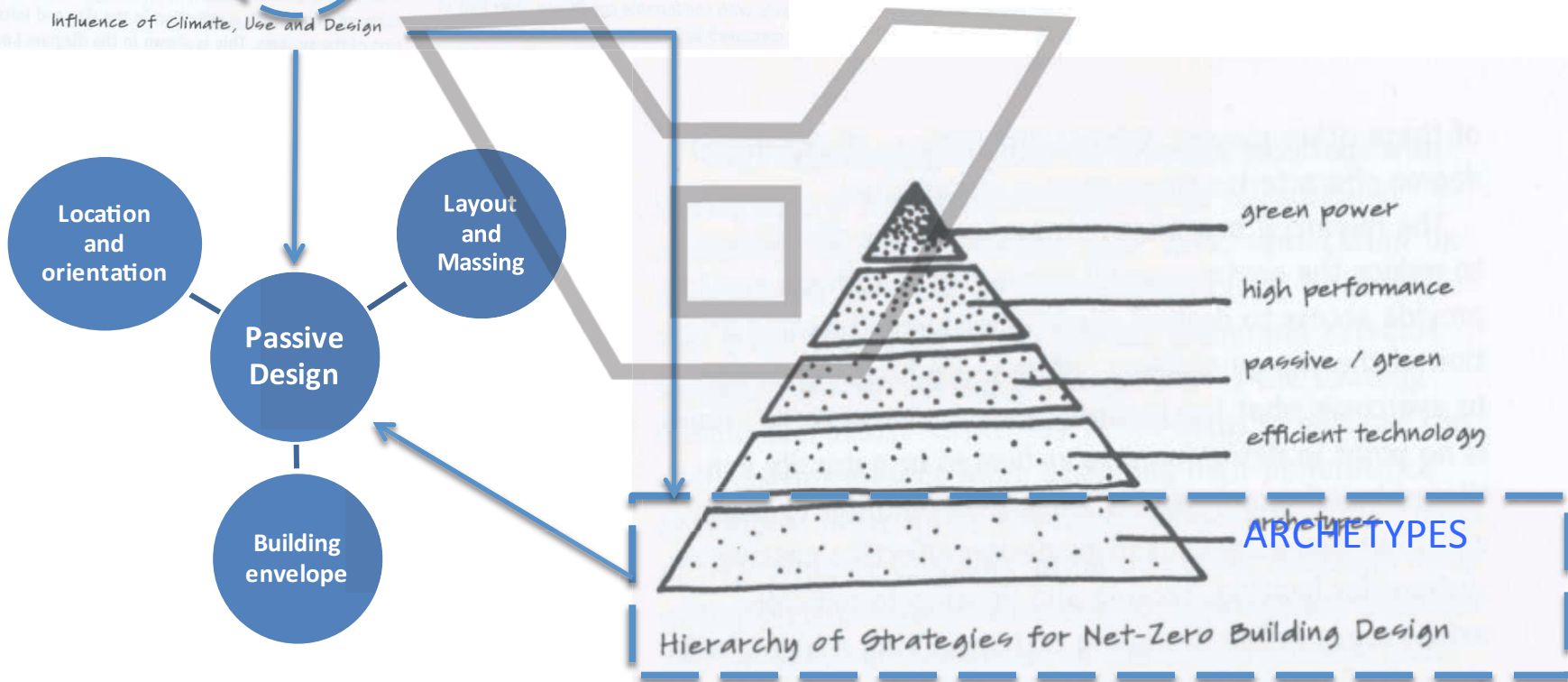
MODELING FOR PASSIVE DESIGN





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





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).

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.

USING MASS COMPUTATIONAL MODELING FOR PRELIMINARY ENERGY ASSESSMENT

Energy modeling and simulation tools allow the design team to evaluate the energy performance of the building in the virtual environment considering its geometrical model, design parameters, occupancy schedules and local weather conditions.

WHAT & HOW TO MODEL:

- ENERGY
- CLIMATE
- BUILDING
- SITE
- USERS' BEHAVIOUR COMFORT

AVAILABLE COMPUTATIONAL TOOLS FOR ENERGY MODELING

ENERGY ANALYSIS SOFTWARE

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

ENERGY MODELING AND SIMULATION SOFTWARE

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

TOOLS USING ENERGY PLUS AND RADIANCE

- Dymola: <http://www.3ds.com/products-services/catia/products/dymola>.
- Autodesk Revit (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



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.



HOW TO EVALUATE ENERGY PERFORMANCE

GREEN METRICS , CERTIFICATION & TARGETING

HOW TO EVALUATE ENERGY PERFORMANCE

GREEN METRICS & CERTIFICATION

Baseline solution or standardized metrics

Voluntary certifications

international sustainable building certification program

- LEED - Leadership in Energy and Environmental Design- U.S. Green Building Council (USGBC),
- NZE - Nearly Zero Energy > Net Zero Energy
- LBC - Living Building Challenge, 2006, International Living Future Institute.
- 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)
- GREENGUARD, Greenguard Environmental Institute,
- Green Globes operates in the US by the Green Building Initiative.
- PASSIVEHAUS, 1988 Adamson Lund University (Sweden) + Wolfgang Feist dell'Institut für Umwelt und Wohnen (D)

National certification by Law in Italy

- D. Lgs. 19 agosto 2005, n. 192 (attuativo della direttiva 2002/91/CE)
- L. 2006/32/CE (recepita in Italia dal D.Lgs. 115/2008, che introduce le UNI TS 11300)

2030 Framework for climate and energy



ZEPHIR

PASSIVHAUS
ITALIA

Affiliato iPHA



iPHA
Affiliate

is a voluntary standard

based on **EU** (often 4,75 kBtu/ft²) codes to 2020 [53943.6 Kwatt/mq]

- Fabbisogno termico per riscaldamento $\leq 15 \text{ kWh}/(\text{m}^2\text{a})$
oppure: Carico termico specifico $\leq 10 \text{ W}/\text{m}^2$
- Fabbisogno frigorifero per raffrescamento $\leq 15 \text{ kWh}/(\text{m}^2\text{a})$
- Tenuta all'aria $n_{50} \leq 0,6 \text{ h}^{-1}$
- **Fabbisogno di energia primaria $\leq 120 \text{ kWh}/(\text{m}^2\text{a})$**
- Basso surriscaldamento estivo (n. gg. $< 10\%$ con $T_i > 25^\circ\text{C}$)

Mentre è **consigliato** ma non obbligatorio soddisfare questi altri parametri:

- Progettazione senza ponti termici $< 0,01 \text{ W}/\text{mK}$
- Serramenti a taglio termico $U_w \leq 0,8 \text{ W}/\text{m}^2\text{K}$
- Impianti ad alta efficienza; ventilazione interna con recupero di calore superiore al 75%
- Ridotte dispersioni termiche per approntamento e distribuzione ACS
- Utilizzo efficiente della corrente elettrica.

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 losses.

For example for coal is considered a reduction of 50%

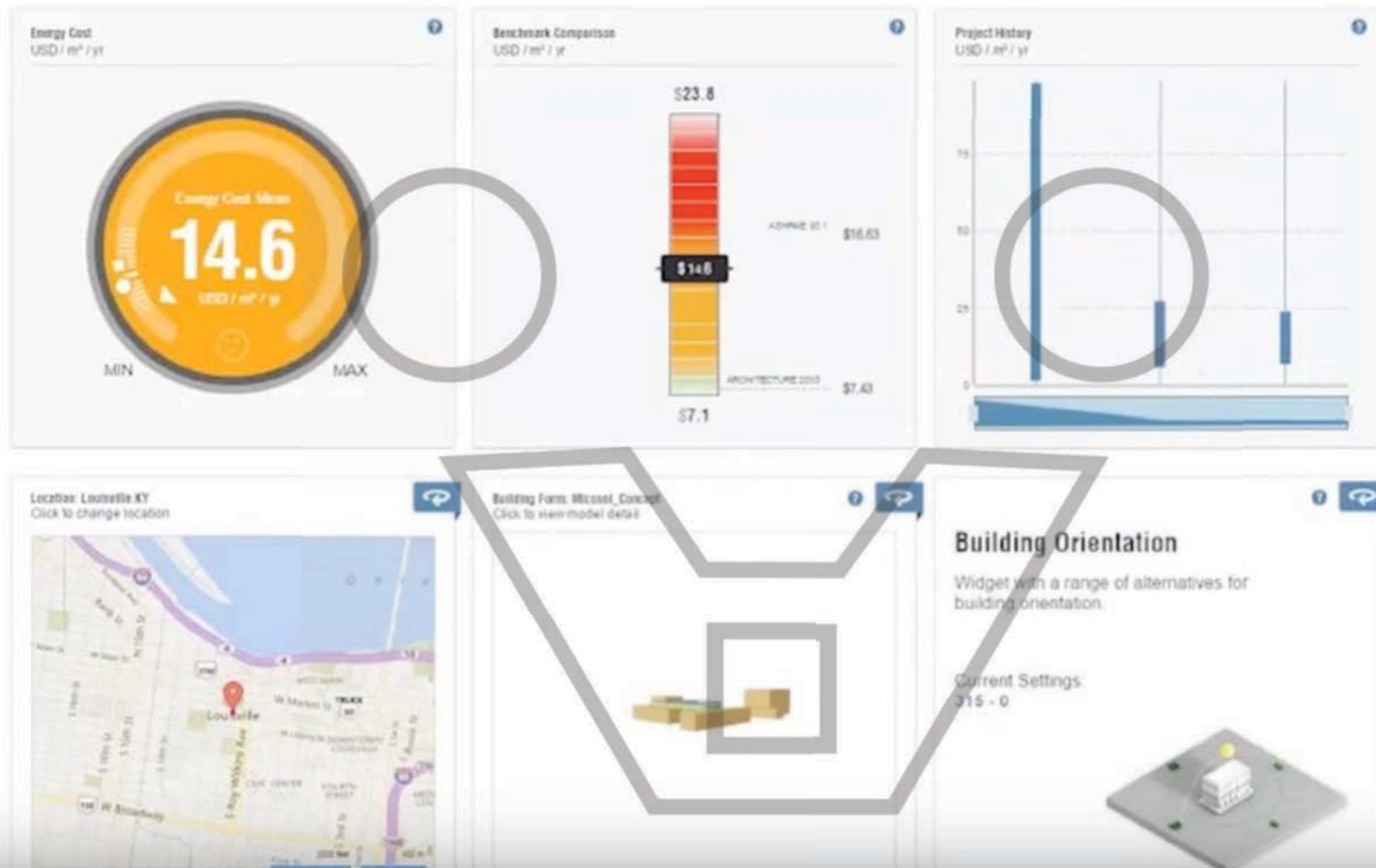
But the evaluation of CO₂ emissions is more meaningful

EUI - ANNUAL ENERGY USE INTENSITY = EDI - EPI

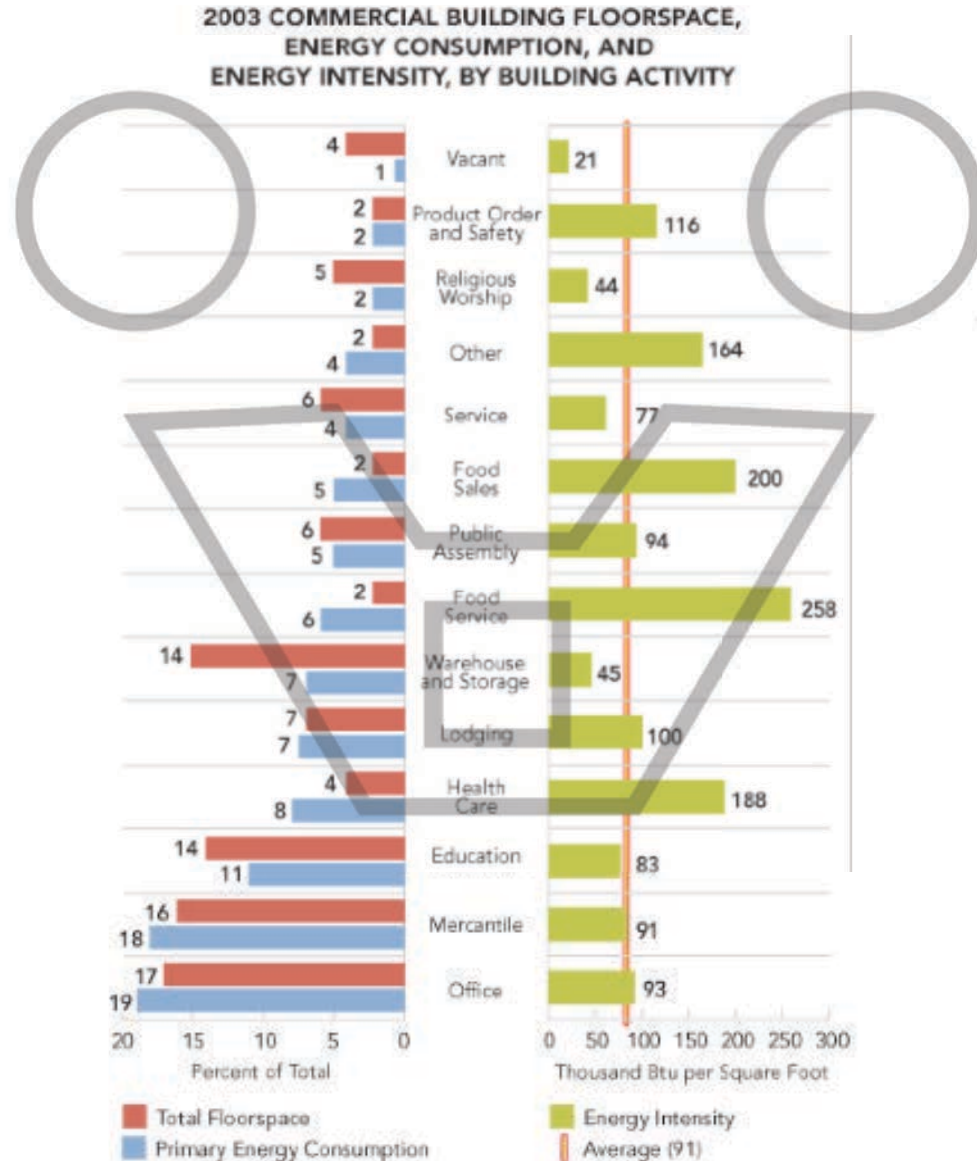
Energy Demand Intensity (EDI)

Energy Production Intensity (EPI)

In any case we have to understand that EUI parameter doesn't return any guarantee concerning Co2 emissions



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/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")

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.

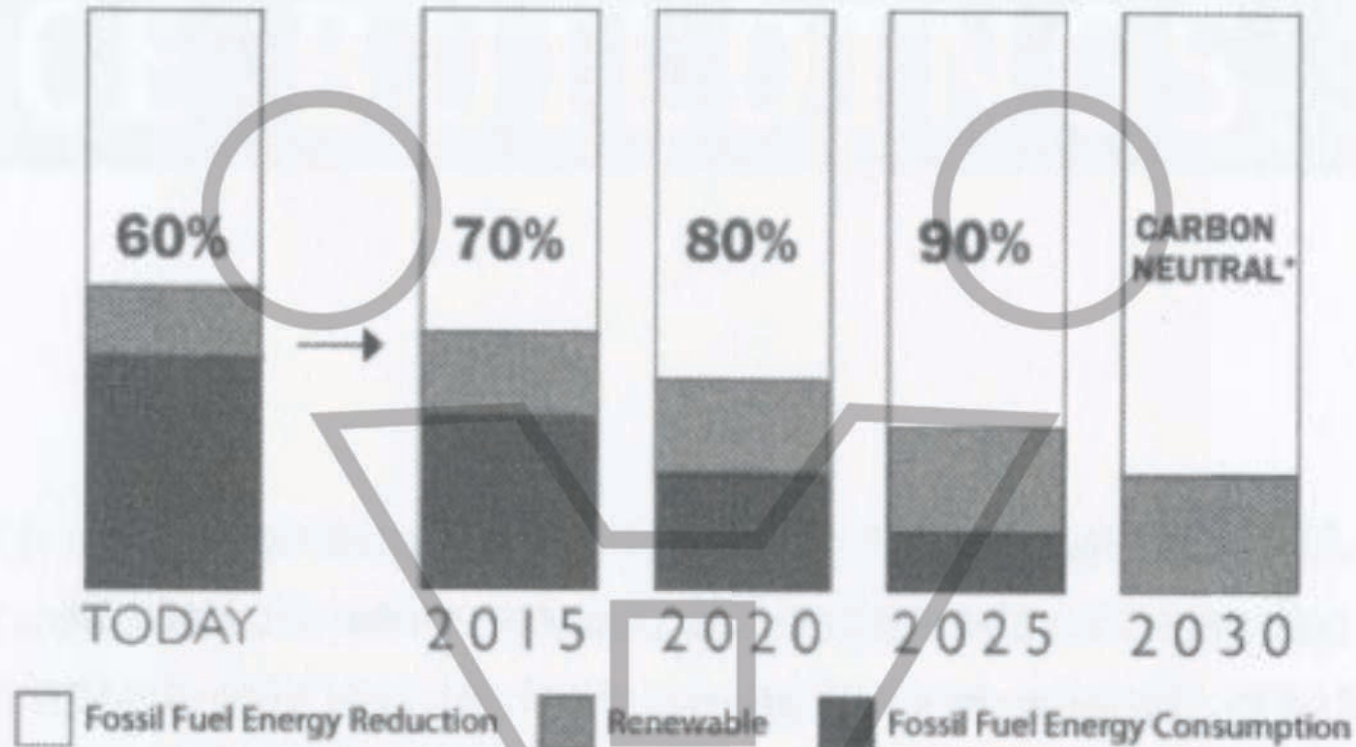
Typical values: Below are some average EUIs for three building types in the US. (These are meant to give a rough idea of EUI ranges; actual values can vary widely based upon location & specific space uses.)

	Source EUI (power plant's energy consumption)	Site EUI (building energy consumption)	2030 Challenge target (60% reduction, site EUI)
Office	148 kBtu/ft ² /yr 467 kWh/m ² /yr	67 kBtu/ft ² /yr 211 kWh/m ² /yr	27 kBtu/ft ² /yr 85 kWh/m ² /yr
K-12 Education	141 kBtu/ft ² /yr 445 kWh/m ² /yr	58 kBtu/ft ² /yr 183 kWh/m ² /yr	23 kBtu/ft ² /yr 73 kWh/m ² /yr
Single-family residence	68 kBtu/ft ² /yr 215 kWh/m ² /yr	46 kBtu/ft ² /yr 145 kWh/m ² /yr	18 kBtu/ft ² /yr 57 kWh/m ² /yr

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



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.

Targets based on U.S. Commercial Building National Average

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

Energy Use Intensity (EUI) Targets, U.S. Commercial Buildings, National Averages, kBtu/ft²-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 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	Ketchikan, 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/ft²-yr

na = not available in EPA "Target Finder"

Hotel (large) 12,202 sf / 6 story			Residence Hall / Dormitory 100,000 sf / 4 story			Mid-Rise Apartment 33,740 sf / 4 story			Warehouse (unrefrigerated) 52,045 sf / 1 story			Warehouse (refrigerated) 52,045 sf / 1 story			Courthouse, federal 395,000 sf.			Bank / Financial Institution 4,100 sf / 1 story branch			Supermarket / Grocery 45,000 sf / 1 story			Retail 24,962 sf / 1 story			Strip Mall 22500 sf / 1 story			House of Worship 17,000 sf / 1 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%	med	70%	90%	med	70%	90%
111	33	11	102	31	10	na	na	na	27	8	3	174	52	17	107	32	11	112	34	11	384	115	38	72	22	7	na	na	na	29	9	3
74	22	7	72	22	7	na	na	na	21	6	2	139	42	14	88	26	9	92	28	9	274	82	27	63	19	6	na	na	na	21	6	2
99	30	10	92	28	9	39	12	4	23	7	2	149	45	15	105	32	11	110	33	11	280	84	28	73	22	7	56	17	6	26	8	3
98	29	10	88	26	9	39	12	4	24	7	2	127	38	13	103	31	10	108	32	11	264	79	26	73	22	7	58	17	6	25	8	3
118	35	12	118	35	12	38	11	4	30	9	3	180	54	18	112	34	11	117	35	12	410	123	41	77	23	8	57	17	6	34	10	3
92	28	9	77	23	8	38	11	4	24	7	2	94	28	9	99	30	10	104	31	10	230	69	23	71	21	7	62	19	6	20	6	2
86	26	9	58	17	6	31	9	3	24	7	2	62	19	6	90	27	9	95	29	10	229	69	23	59	18	6	44	13	4	8	2	1
113	34	11	105	32	11	36	11	4	30	9	3	147	44	15	108	32	11	113	34	11	371	111	37	75	23	8	57	17	6	30	9	3
93	28	9	67	20	7	33	10	3	27	8	3	56	17	6	94	28	9	99	30	10	245	74	25	65	20	7	53	16	5	13	4	1
95	29	10	82	25	8	42	13	4	26	8	3	80	24	8	101	30	10	106	32	11	228	68	23	75	23	8	74	22	7	22	7	2
108	32	11	94	28	9	37	11	4	31	9	3	98	29	10	104	31	10	109	33	11	322	97	32	75	23	8	64	19	6	25	8	3
102	31	10	82	25	8	38	11	4	31	9	3	58	17	6	100	30	10	105	32	11	275	83	28	73	22	7	69	21	7	20	6	2
123	37	12	112	34	11	47	14	5	42	13	4	102	31	10	122	37	12	128	38	13	257	77	26	109	33	11	85	26	9	36	11	4
112	34	11	101	30	10	41	12	4	34	10	3	78	23	8	106	32	11	111	33	11	319	96	32	79	24	8	72	22	7	27	8	3
118	35	12	113	34	11	na	na	na	38	11	4	56	17	6	109	33	11	114	34	11	320	96	32	86	26	9	na	na	na	31	9	3
128	38	13	126	38	13	54	16	5	45	14	5	102	31	10	126	38	13	132	40	13	270	81	27	115	35	12	99	30	10	41	12	4
115	35	12	107	32	11	48	14	5	36	11	4	64	19	6	108	32	11	113	34	11	318	95	32	83	25	8	89	27	9	29	9	3
132	40	13	133	40	13	59	18	6	48	14	5	78	23	8	128	38	13	133	40	13	266	80	27	120	36	12	111	33	11	43	13	4
124	37	12	130	39	13	na	na	na	41	12	4	56	17	6	113	34	11	118	35	12	340	102	34	91	27	9	na	na	na	36	11	4
135	41	14	163	49	16	76	23	8	45	14	5	57	17	6	120	36	12	125	38	13	373	112	37	99	30	10	156	47	16	44	13	4

Energy Use Intensity (EUI) Targets, by Building Type and Climate Zone, kBtu/ft²-yr

na = not available in EPA "Target Finder"

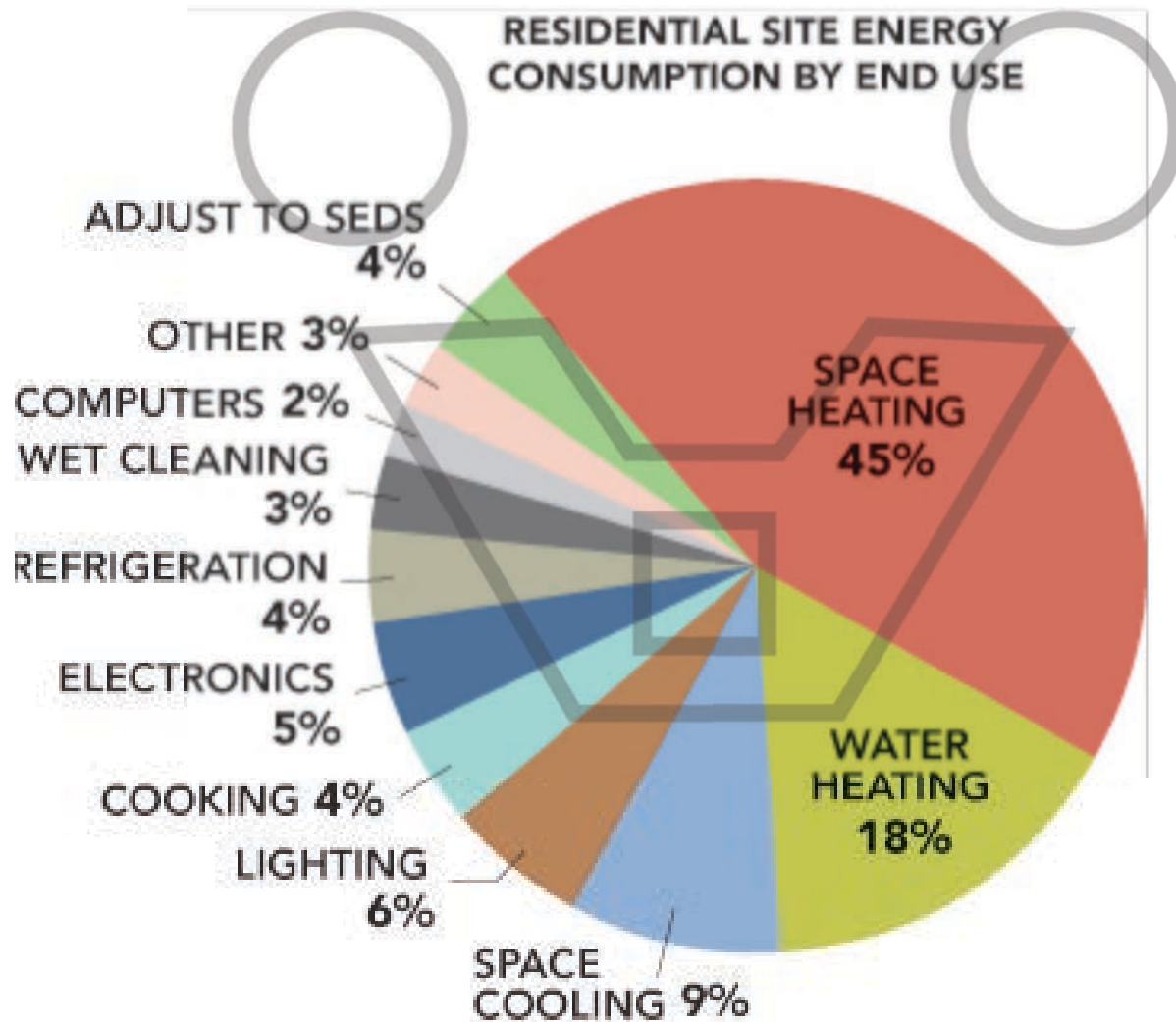
Commercial Space / Building Type	Site EUI		
	med	70%	90%
ATLANTIC			
Wholesale Trade	436.1	130.8	43.6
Retail Trade	525.0	157.5	52.5
Transportation & Warehousing	319.5	95.8	31.9
Information & Cultural Industries	558.4	167.5	55.8
Offices	405.6	121.7	40.6
Educational Services	444.5	133.3	44.4
Healthcare & Social Assistance	738.9	221.7	73.9
Arts, Entertainment & Recreation	497.3	149.2	49.7
Accommodation & Food Service	719.5	215.9	72.0
Other Services	391.7	117.5	39.2
QUEBEC			
Wholesale Trade	527.8	158.3	52.8
Retail Trade	563.9	169.2	56.4
Transportation & Warehousing	452.8	135.8	45.3
Information & Cultural Industries	780.6	234.2	78.1
Offices	452.8	135.8	45.3
Educational Services	561.2	168.3	56.1
Healthcare & Social Assistance	905.6	271.7	90.6
Arts, Entertainment & Recreation	661.2	198.3	66.1
Accommodation & Food Service	894.5	268.4	89.5
Other Services	505.6	151.7	50.6
ONTARIO			
Wholesale Trade	463.9	139.2	46.4
Retail Trade	469.5	140.8	46.9
Transportation & Warehousing	394.5	118.3	39.4
Information & Cultural Industries	444.5	133.3	44.4
Offices	397.3	119.2	39.7
Educational Services	452.8	135.8	45.3
Healthcare & Social Assistance	697.3	209.2	69.7
Arts, Entertainment & Recreation	502.8	150.8	50.3
Accommodation & Food Service	666.7	200.0	66.7
Other Services	436.1	130.8	43.6

Commercial Space / Building Type	Site EUI kWh/m ² , yr		
	med	70%	90%
MANITOBA			
Wholesale Trade	433.4	130.0	43.3
Retail Trade	527.8	158.3	52.8
Transportation & Warehousing	394.5	118.3	39.4
Information & Cultural Industries	538.9	161.7	53.9
Offices	422.3	126.7	42.2
Educational Services	486.2	145.8	48.6
Healthcare & Social Assistance	780.6	234.2	78.1
Arts, Entertainment & Recreation	458.4	137.5	45.8
Accommodation & Food Service	794.5	238.4	79.5
Other Services	463.9	139.2	46.4
SASKATCHEWAN			
Wholesale Trade	566.7	170.0	56.7
Retail Trade	725.1	217.5	72.5
Transportation & Warehousing	497.3	149.2	49.7
Information & Cultural Industries	711.2	213.4	71.1
Offices	563.9	169.2	56.4
Educational Services	600.0	180.0	60.0
Healthcare & Social Assistance	786.2	235.9	78.6
Arts, Entertainment & Recreation	583.4	175.0	58.3
Accommodation & Food Service	827.8	248.4	82.8
Other Services	563.9	169.2	56.4
ALBERTA			
Wholesale Trade	413.9	124.2	41.4
Retail Trade	500.0	150.0	50.0
Transportation & Warehousing	369.5	110.8	36.9
Information & Cultural Industries	508.4	152.5	50.8
Offices	380.6	114.2	38.1
Educational Services	425.0	127.5	42.5
Healthcare & Social Assistance	616.7	185.0	61.7
Arts, Entertainment & Recreation	463.9	139.2	46.4
Accommodation & Food Service	725.1	217.5	72.5
Other Services	391.7	117.5	39.2

Energy Use Intensity (EUI) Targets, Canadian
Commercial Buildings, Provincial Averages, kWh/m²/yr

Derived from Natural Resources Canada, Office of Energy
Efficiency, Comprehensive Energy Use Database.
Multiply kWh x 277.7 to get GJ

EVALUATION IN RELATIONSHIP WITH BASELINE SOLUTION based on current average benchmark



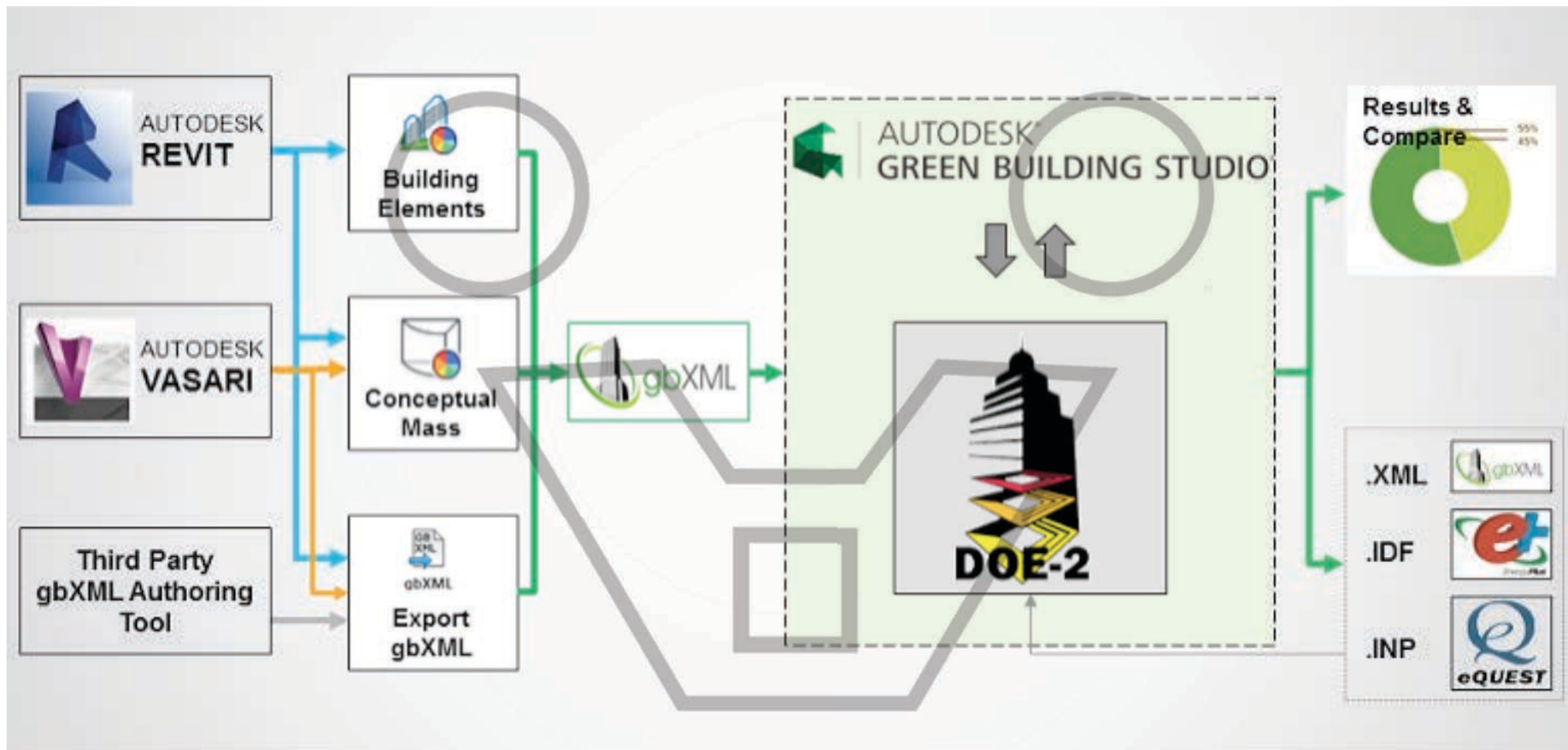
Other parameters used in energy modeling

Solar Heat Gain Coefficient (SHGC)

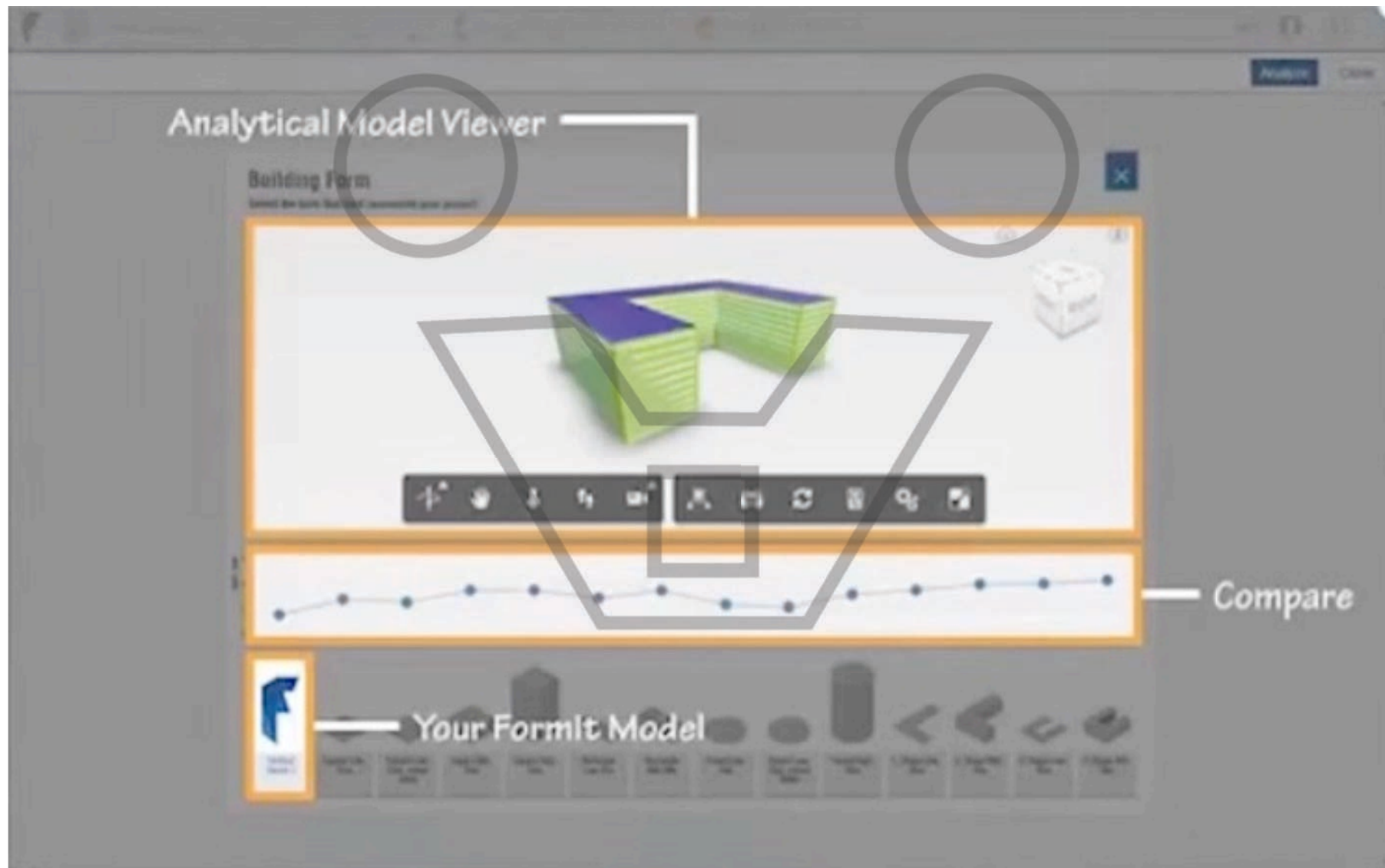
The Solar Heat Gain Coefficient (SHGC) is a ratio of the heat transmitted through the building envelope into the building to the heat that is reflected away. SHGC is a dimensionless parameter and can theoretically range from zero to one, with one representing that all of the heat being transmitted through the envelope, and zero representing none of the incident solar heat being transmitted inside. A low SHGC would be desirable for buildings with high cooling load (e.g. tropical and hot climates), whereas a high SHGC would be beneficial for buildings with passive heating requirements (e.g. cold climate conditions).

Infiltration or Air Leakage

Infiltration or air leakage is caused by air entering or leaving the building due to unintentional gaps in the building envelope. The outside air infiltrated into the inner space would cool or heat interior spaces through convection and make the envelope insulation redundant. The air leakage from inside to outside would result in energy wastage and overload on air treatment facilities such as heating or cooling as the treated air would escape to the surroundings instead of heating or cooling the space.



EVALUATION IN RELATIONSHIP WITH DESIGN ALTERNATIVES



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

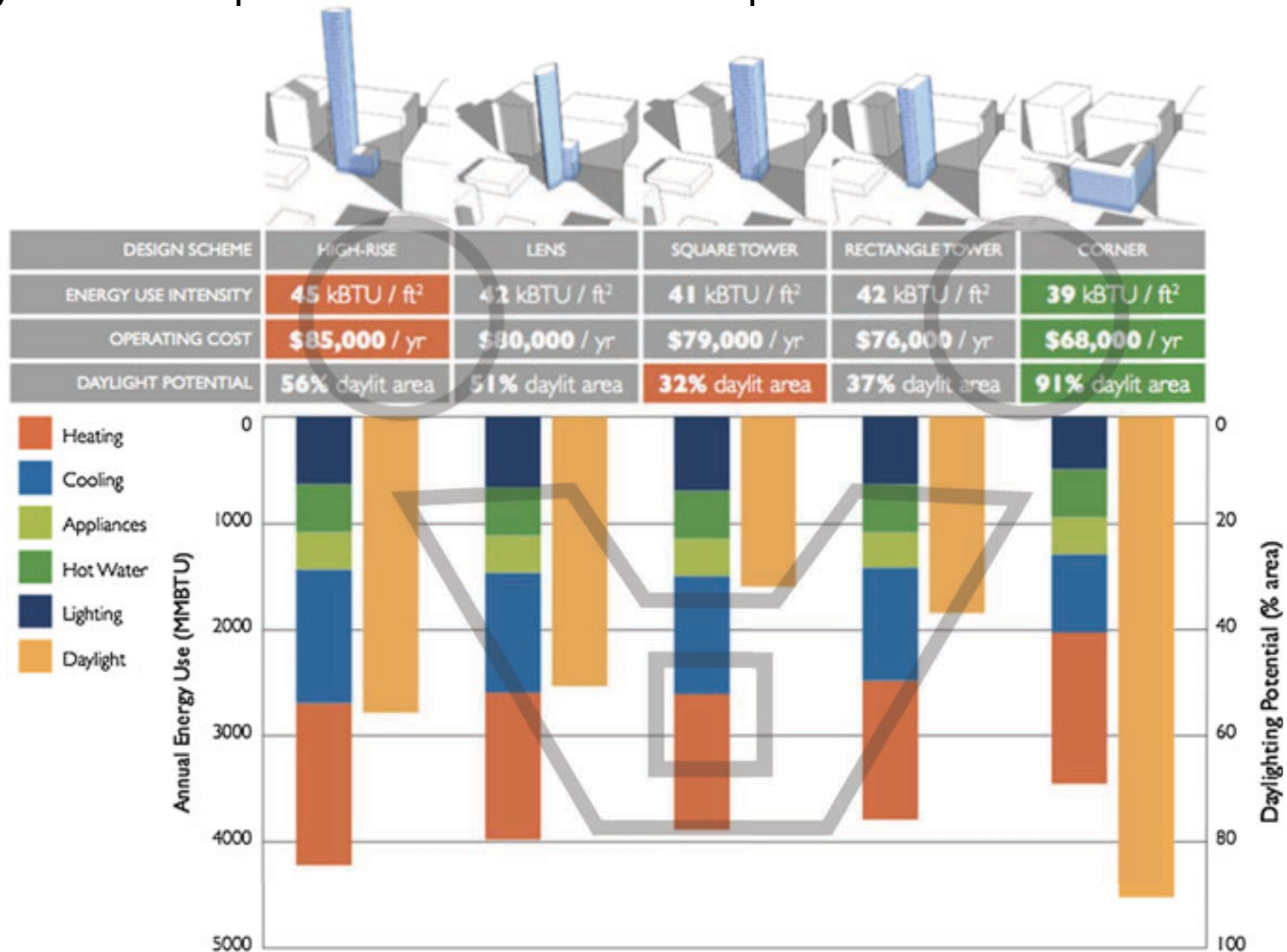


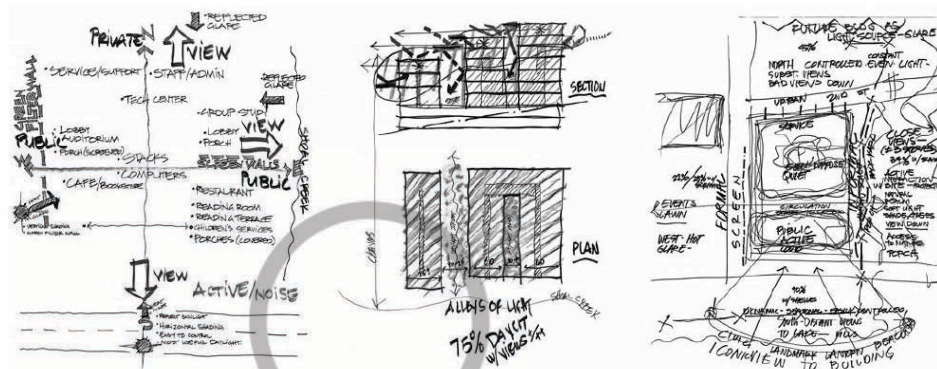
Fig. 4.4 Massing options and implication on building performance (Sefaira 2013)



5.2

For the kick-off eco-charrette for the Ever Vail project, nearly 40 people representing all disciplines gathered to thrash out ideas to achieve sustainable project goals. The masterplan for Ever Vail achieved LEED for Neighborhood Development (Pilot) Platinum Stage 2 certification.

Note: Photos, renderings, and data are courtesy of Vail Resorts Development Company and may not be reproduced without permission.



5.5

Early diagrams by Lake Flato Architects explore the site and massing options.

Source: Courtesy of Lake Flato Architects and Austin Central Library.

Daylight Programming Matrix

Noon Sun Angles: June 66° Sept/Mar: 42° Dec: 19° Primary Design Sky Condition: overcast

Program Element	Occupancy Time and Duration	Is Daylight Important?	Are Views to the Exterior Important?	Is Direct Sunlight Control Needed?	Is Glare Control Crucial?	Is Space Darkening Required?	Design Illumination?	Ideal Daylight Aperture Strategy?	Ideal Solar Orientation?	Organization on Site?
open office	8am-6pm	Y	Y	Y	Y	N	20fc 2amb 35fc task	side/top	N or S	—
private office	8am-6pm	Y	Y	Y	Y	N	20fc 2amb 35fc task	side/top	any; individual controls	adjacent to open office
large conf.	10am-6pm	Y	Y	Y	Y	Y	30fc	side		interior, with views
lobby/recept.	8am-5pm	Y	Y	± reception desks		N	15fc 2amb	side/top	N or S	grand floor
training space	8am-5pm	N	Y	Y	Y	Y	20fc	side		interior, with views

Results for Estimated Energy Use			
Energy	Design	Target	Median Building
Energy Performance Rating (1-100)	N/A	99	50
Energy Reduction (%)	N/A	90	0
Source Energy Use Intensity (kBtu/Sq. Ft./yr)	N/A	89	222
Site Energy Use Intensity (kBtu/Sq. Ft./yr)	N/A	41	103
Total Annual Source Energy (kBtu)	N/A	10,659,154	26,647,885
Total Annual Site Energy (kBtu)	N/A	4,947,347	12,368,369
Total Annual Energy Cost (\$)	N/A	\$ 68,324	\$ 170,811
Pollution Emissions			
CO ₂ -eq Emissions (metric tons/year)	N/A	745	1,861
CO ₂ -eq Emissions Reduction (%)	N/A	60%	0%

Facility Information

81658
United States

Facility Characteristics

Space Type	Gross Floor Area (Sq. Ft.)
Hotel	120,000
Total Gross Floor Area	120,000

Estimated Design Energy

Energy Source	Units	Estimated Total Annual Energy Use	Energy Rate (\$/Unit)
Electricity - Grid Purchase	kBtu	N/A	\$ 0.020/kBtu
Natural Gas	kBtu	N/A	\$ 0.009/kBtu

* The Median Building is equivalent to an EPA Energy Performance Rating of 56.

Source: Data adapted from DOE-EIA. See EPA [Technical Description](#).

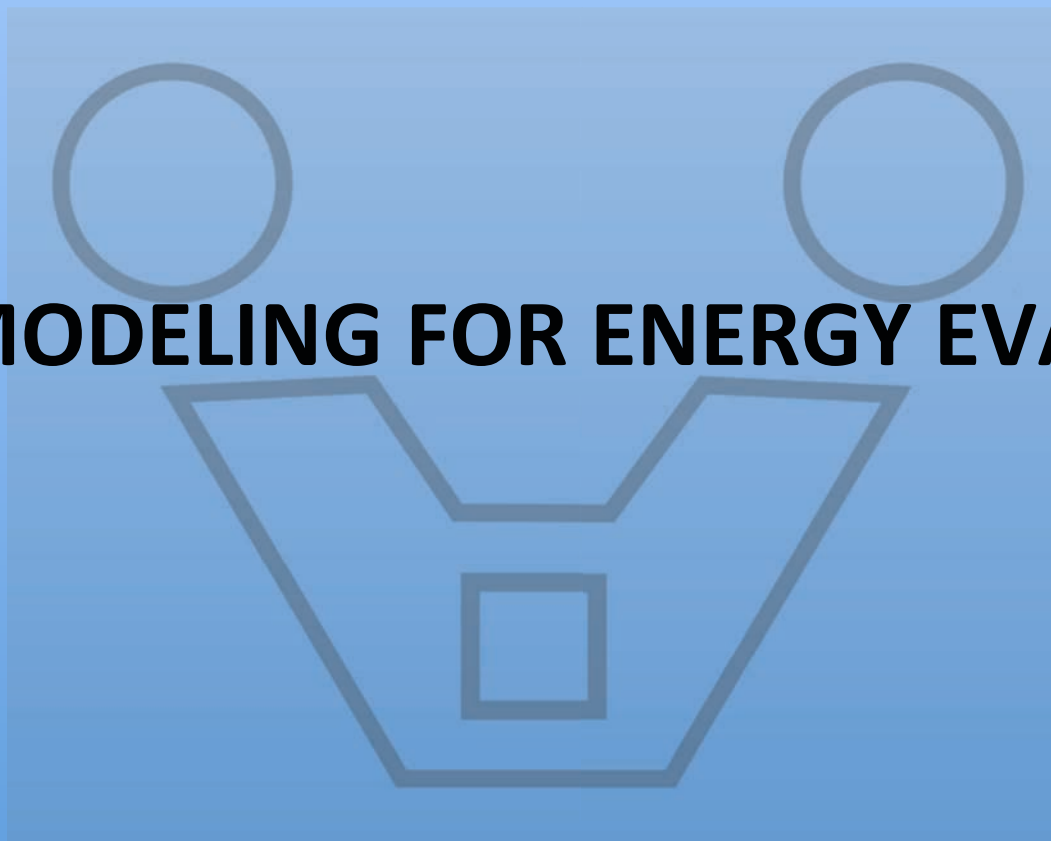
5.3

Target-Finder output for a hotel in Vail, Colorado. Target-Finder displays several types of metrics: Site, Source, Cost, and Carbon Emissions. This information is based on the Commercial Building Energy Consumption Survey (CBECS) data.

Source: https://www.energystar.gov/index.cfm?fuseaction=target_finder.



MASS MODELING FOR ENERGY EVALUATION



Thinking in terms of both analysis and context

Form is often conventionally understood in architectural terms as the pattern that configures parts within the whole. Many, if not most, ways of understanding these formal patterns involve techniques of analysis that break down, dissect or deconstruct the larger whole into its constituent elements or their fundamental arrangements and relationships. The analytic method is a valid approach, from which one can learn much about buildings. It can be thought of as moving from higher to lower levels of complexity in the maps. Analysis is true and correct in that it describes one portion or aspect of design, however, alone it is incomplete and insufficient in two ways:

- 1) The *emergent qualities* unique to the whole are never found via analysis, only those qualities found in the parts.
- 2) Atomistic analysis misses *how the whole is simultaneously a part* of something larger.

The *yin* of analysis's *yang* is holism and contextualism. To understand anything as a whole, one has to look for what is unique to the whole and not found in the parts. The *contextual method* looks for the larger whole to which a part contributes. One way this is often done in design is by mapping the pattern that defines the whole, that is representing the *relationships* among the parts. In addition to breaking it down, one can understand the whole by placing it within its larger, containing context where it becomes a part of a whole larger than itself.

Designing is mapping the pattern that defines the whole, that is representing the relationships among the parts

The contextual method represents relationships between the parts.
It can comprehend the wholeness

Building Layout and Massing

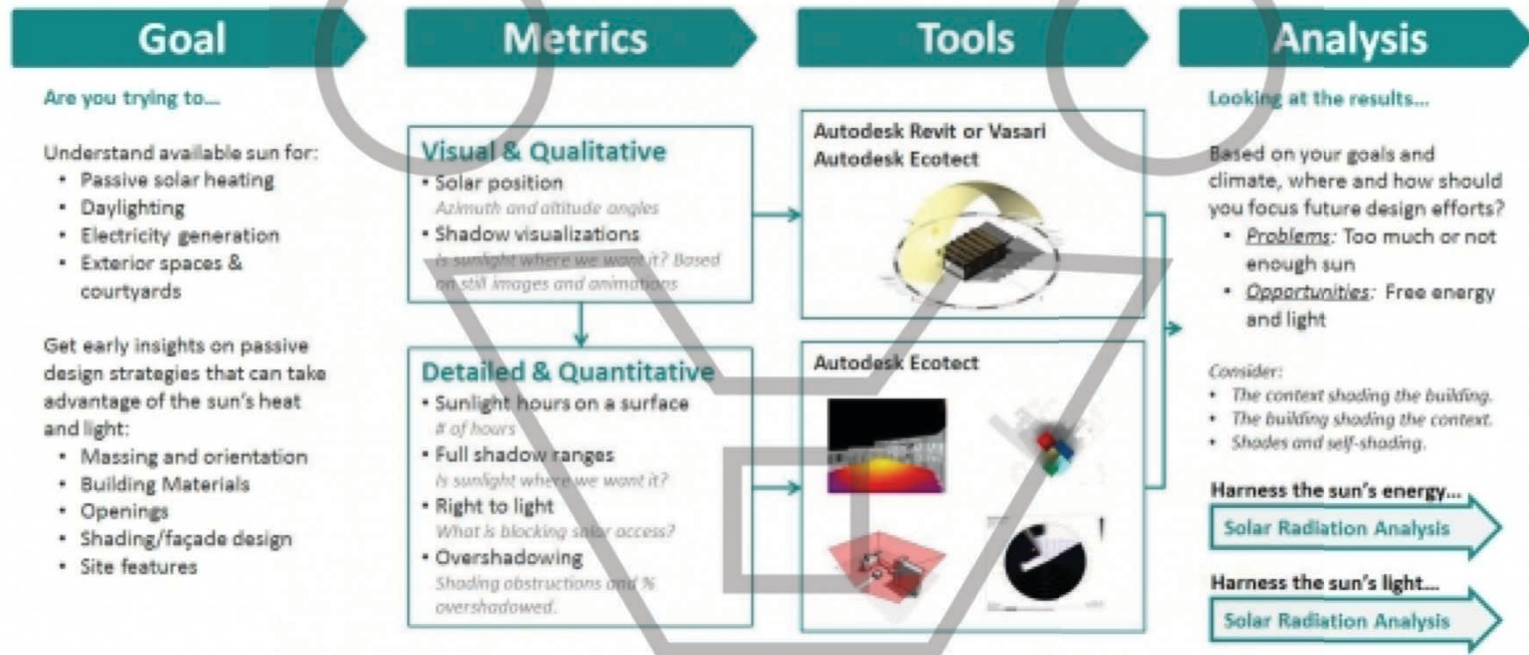
“Massing” is the architectural term used when determining the overall layout (e.g. compact or spread-out), shape (e.g. square, rectangle, oval), size (e.g. height, length, width) and form factor (more solid or porous with cut-outs) of the building. Massing choices depend on the project specifics such as the project site and its goals. It should be optimized in the early stages of the building along with its location and orientation. Successful massing for green buildings would help to reduce energy loads for the building by leveraging on the natural effects such as the wind flow patterns and the sun path.

Apart from reducing energy use, a good massing and orientation can also help in rainwater harvesting, integrating the building with urban planning provisions, reducing material usage and in protecting ecologically sensitive elements such as greenery, trees and ponds. Modelling and simulation tools as described in the earlier chapter can be used to assess the performance of the building with various orientation and massing choices. Figure 4.4 shows the impact of different massing options on the building’s energy use intensity, operating costs and daylight potential.



Workflow Part 1: Goals, Metrics, and Analysis Tools

Sun and Shadow Studies for High Performance Building Design



Level 3 – Space & Zone Thermal Properties



Building Type: **Space Type**

Room List:

- Hotel Customer Area
- Meeting Activity Area - Office
- Barber and Beauty Parlor
- Cad Mfg and Cataloguing - Library
- Cleanroom/Chemical Processing - Pharmaceutical
- Conference Center - Restaurant
- Conference Center - Courthouse
- Conference Meeting/Philosophy
- Condo Transition
- Condo Transition - Manufacturing Facility
- Condo with Patient Waiting Room - Hospital/Health
- Court Sports Area - Sports Arena
- Courthouse - Courthouse
- Department Store Sales Area - Retail
- Deli/Deli - Manufacturing Facility
- Dining Area
- Dining Area - Hotel
- Dining Area - Family Dining
- Dining Area - Lounge/Entertainment Dining
- Dining Area - Hotel
- Dining Area - Transportation
- Dining Area - Restaurant
- Dining Area - Out Services
- Dormitory Bedroom
- Dormitory Study Hall
- Dressing/Dressing Room - Restaurant
- Freight and Retail Storage Area - Courthouse

Parameter Value

Energy Analysis

- Area per Person: 0.538 m²
- Sensible Heat Gain per person: 73.27 W
- Latent Heat Gain per person: 58.51 W
- Lighting Load Density: 0.30 W/m²
- Power Load Density: 0.60 W/m²
- Plenum Lighting Contribution: 20.00%
- Occupancy Schedule: School Occupancy - 8 AM to 5 PM
- Lighting Schedule: School Lighting - 7 AM to 5 PM
- Power Schedule: School Lighting - 7 AM to 5 PM

Occupancy

Values: Specified

- Number of People: 58.18712
- Area per Person: 1.538 m²

Heat Gain (per Person)

Values: Specified

- Sensible: 73.27 W
- Latent: 58.51 W

Lighting

Values: Specified

- Load: 288.90 W
- Load Density: 0.30 W/m²

Contribution to plenum (if exists): 20.00%

Power

Values: Specified

- Load: 577.80 W
- Load Density: 0.60 W/m²

Heating Set Point: 21.11 °C

Heating Air Temperature: 32.22 °C

☒ Humidification Control

Humidification Set Point: 0%

Cooling Set Point: 23.33 °C

Cooling Air Temperature: 12.22 °C

☒ Humidification Control

Dehumidification Set Point: 70%

☒ Outdoor Air per Person: 8.00 L/s

☒ Outdoor Air per Area: 1.00 L/(s·m²)

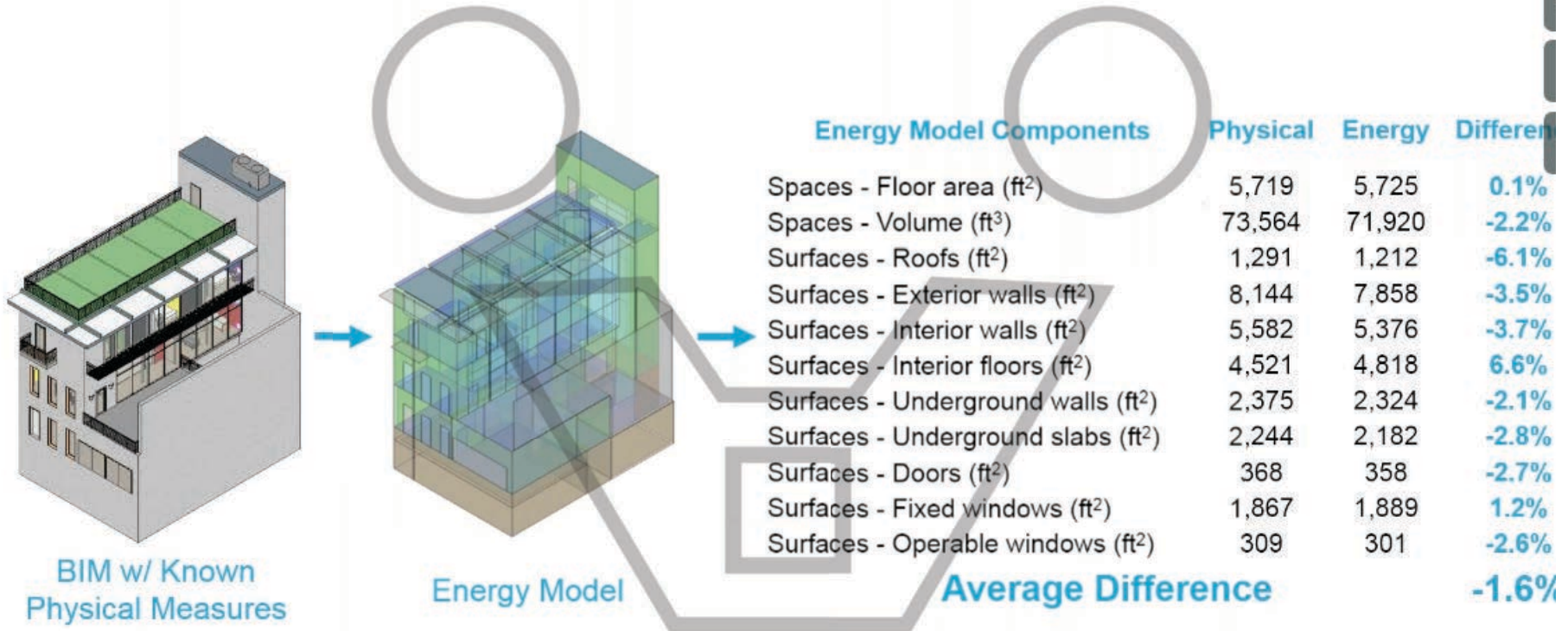
☒ Air Changes per Hour: 0.250000



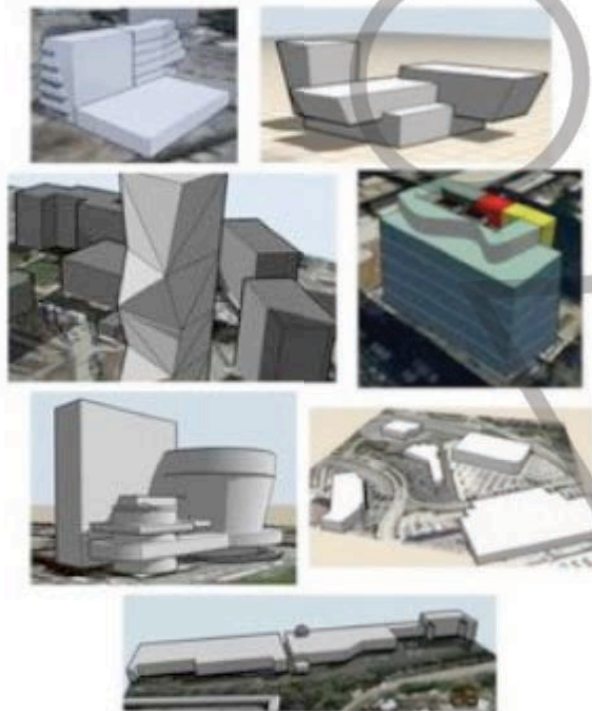
Time	Factor	Time	Factor
12:00 AM	0.00%	12:00 PM	0.00%
1:00 AM	0.00%	1:00 PM	0.00%
2:00 AM	0.00%	2:00 PM	0.00%
3:00 AM	0.00%	3:00 PM	45.00%
4:00 AM	0.00%	4:00 PM	15.00%
5:00 AM	0.00%	5:00 PM	5.00%
6:00 AM	0.00%	6:00 PM	15.00%
7:00 AM	5.00%	7:00 PM	20.00%
8:00 AM	75.00%	8:00 PM	20.00%
9:00 AM	90.00%	9:00 PM	10.00%
10:00 AM	90.00%	10:00 PM	0.00%

ENERGY CONCEPTUAL MASS MODELING: A NEW WAY TO DESIGN

Level 3 – Overall Energy Model Geometry Accuracy



 **Salva** primitives representing 'conceptual mass forms'



FormIt primitives representing 'design detail'



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



Edit Assembly

Family: Basic Wall
Type: Exterior - Brick on CMU
Total thickness: 1' 7 1/2"
Resistance (R): 31.6278 (h·ft²·°F)/BTU
Thermal Mass: 28.6462 BTU/°F

Sample Height: 20' 0"

Layers

	Function	Material	Thickness	Wraps	Str
1	Finish 1 [4]	Brick, Common	0' 3 5/8"	☒	
2	Thermal/Ai	Air	0' 3"	☒	
3	Thermal/Ai	Rigid insulation	0' 3"	☒	
4	Membrane	Damp-proofing	0' 0"	☒	
5	Core Boundar	Layers Above Wrap	0' 0"		
6	Structure [1	Concrete Masonry Unit	0' 7 5/8"	☒	
7	Core Boundar	Layers Below Wrap	0' 0"		

EXTERIOR SIDE

INTERIOR SIDE

Insert Delete Up Down

Default Wrapping

At Inserts: Do not wrap
At Ends: None

Modify Vertical Structure (Section Preview only)

Modify Merge Regions Sweeps
Assign Layers Split Region Reveals

<< Preview OK Cancel Help

Material Browser - Rigid insulation

Search

Project Materials: All

Polystyrene - Expanded - EPS

Identity Graphics Appearance Physical **Thermal**

Information

Properties

Transmits Light

Behavior Isotropic

Thermal Conductivity 0.0202 btu/(hr·ft·°F)

Specific Heat 0.3511 btu/(lb·°F)

Density 1.44 pound per cubic foot

Emissivity 0.95

Permeability 3.4869 grain/(ft²·hr·inHg)

Porosity 0.01

Reflectivity 0.00

Electrical Resistivity 4.0000E+15 Ω·m

Rigid insulation

OK Cancel Apply



PROGETTAZIONE DEI SISTEMI COSTRUTTIVI | prof. arch. G.Ridolfi, PhD

Construction Types

Analysis Properties

By default, analysis properties are generated from information in model elements.
Properties of Analytic Constructions are used when override is selected or model information is missing.

Category	Override	Analytic Construction
Roofs	☒	4 in lightweight concrete (U=0.2245 BTU/(h·ft ² ·°F))
Exterior Walls	☒	8 in lightweight concrete block (U=0.1428 BTU/(h·ft ² ·°F))
Interior Walls	☒	Frame partition with 3/4 in gypsum board (U=0.2595 BTU/(h·ft ² ·°F))
Ceilings	☒	8 in lightweight concrete ceiling (U=0.2397 BTU/(h·ft ² ·°F))
Floors	☒	Passive floor, no insulation, tile or vinyl (U=0.5210 BTU/(h·ft ² ·°F))
Slabs	☒	Un-insulated solid (U=0.1243 BTU/(h·ft ² ·°F))
Doors	☒	Metal (U=0.6520 BTU/(h·ft ² ·°F))
Exterior Windows	☒	Large double-glazed windows (reflective coating) - industry (U=0.5145 B
Interior Windows	☒	Large single-glazed windows (U=0.6498 BTU/(h·ft ² ·°F), SHGC=0.86)
Skylights	☒	Large double-glazed windows (reflective coating) - industry (U=0.5628 B



All

None

Shading factor for exterior windows: 0

OK

Cancel

Conceptual Constructions

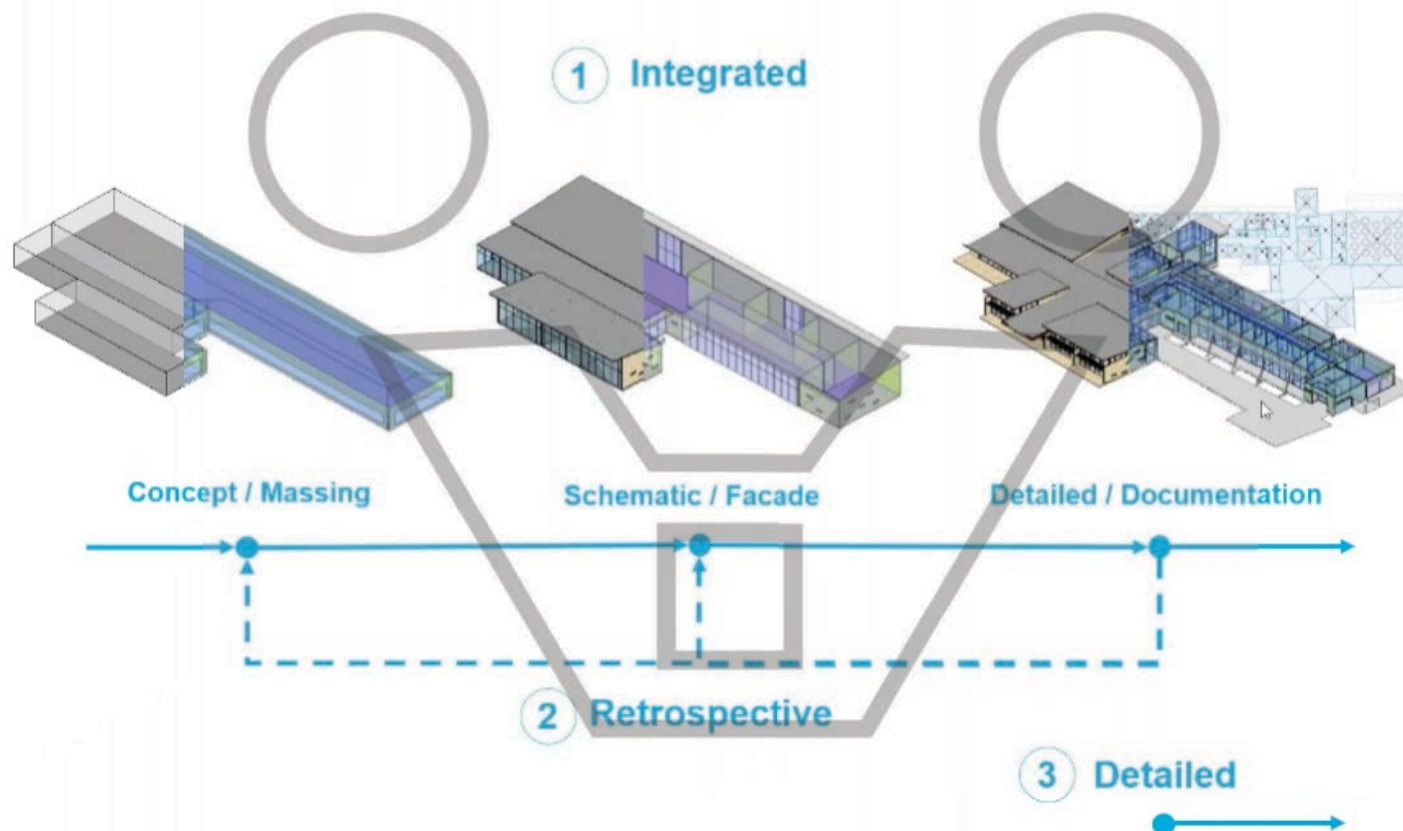
Mass Model	Constructions
Mass Exterior Wall	Lightweight Construction – Typical Mild Climate Insulation
Mass Interior Wall	Lightweight Construction – No Insulation
Mass Exterior Wall - Underground	High Mass Construction – Typical Mild Climate Insulation
Mass Roof	Typical Insulation - Cool Roof
Mass Floor	Lightweight Construction – No Insulation
Mass Slab	High Mass Construction – No Insulation
Mass Glazing	Double Pane Clear – No Coating
Mass Skylight	Double Pane Clear – No Coating
Mass Shade	Basic Shade
Mass Opening	Air

OK

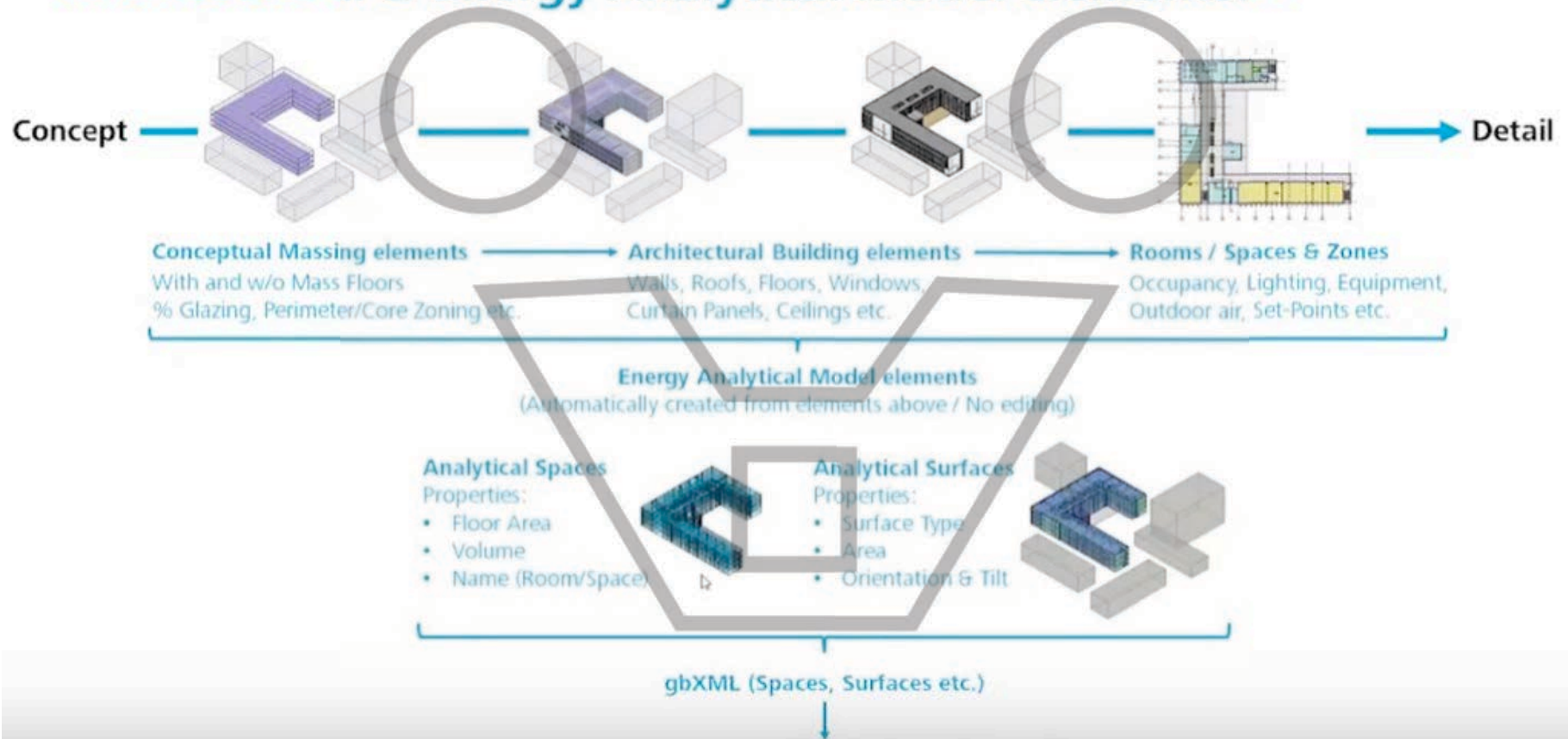
Cancel

Help

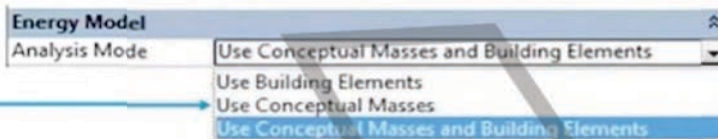
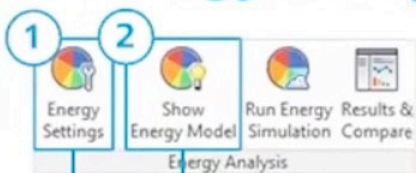
Level 3 Overview – Scales from Concept to Detail



Architectural & Energy Analytical Model elements...



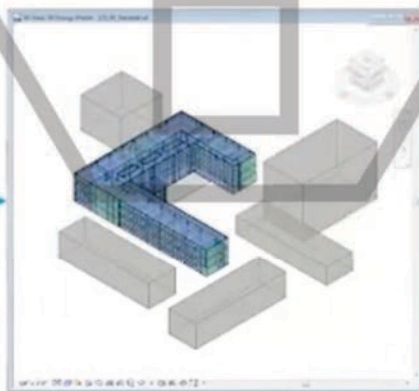
Energy Analysis with Revit 2016...



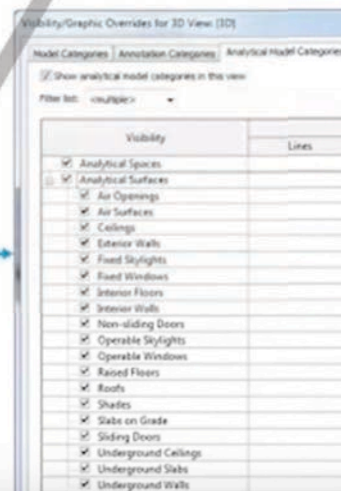
New mode of automatic Energy Analytical Model creation and analysis that uses **Conceptual Massing AND Building elements combined**.



3D View



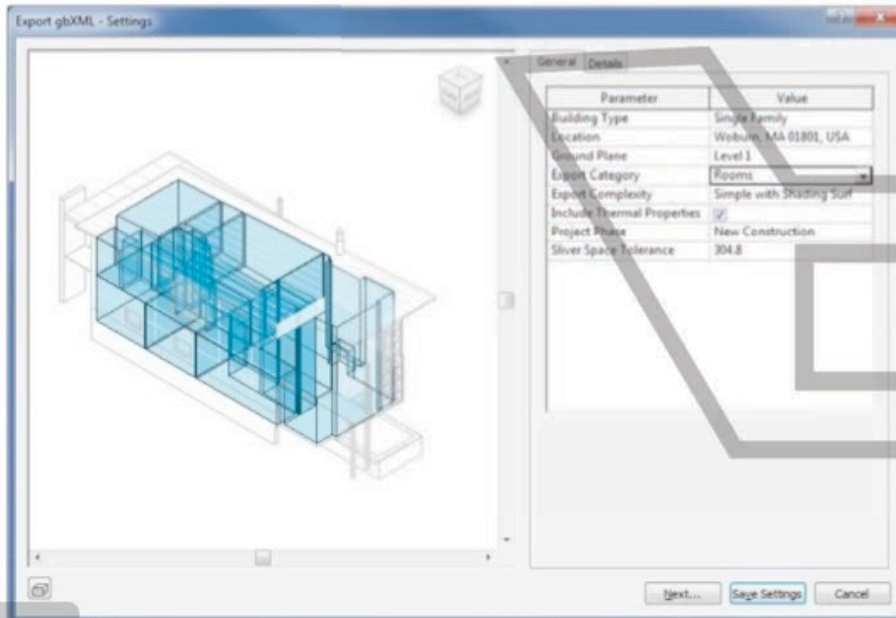
3D Energy Model View



New Revit elements; **Analytical Spaces and Surfaces** used to represent the Energy Analytical Model directly in **Revit views and schedules**.

What is Green Building XML (gbXML)?

An open XML schema that allows for the exchange of building data from modeling to analysis software tools and back



- Interoperability is the key to successfully using BIM software tools
- It minimizes the human involvement and translation errors