ARCHITECTURE and ENVIRONMENT LAB | ENVIRONMENTAL DESIGN

Computational Materiality for Sustainable Architectures and Comprehensive Skins

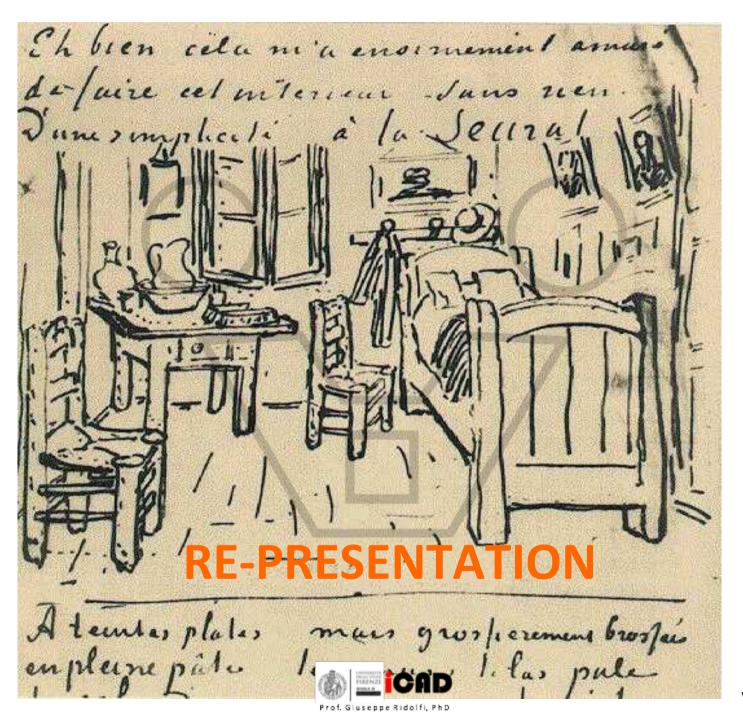## MODELING CLIMATE, SITE, and ARCHITECTURE

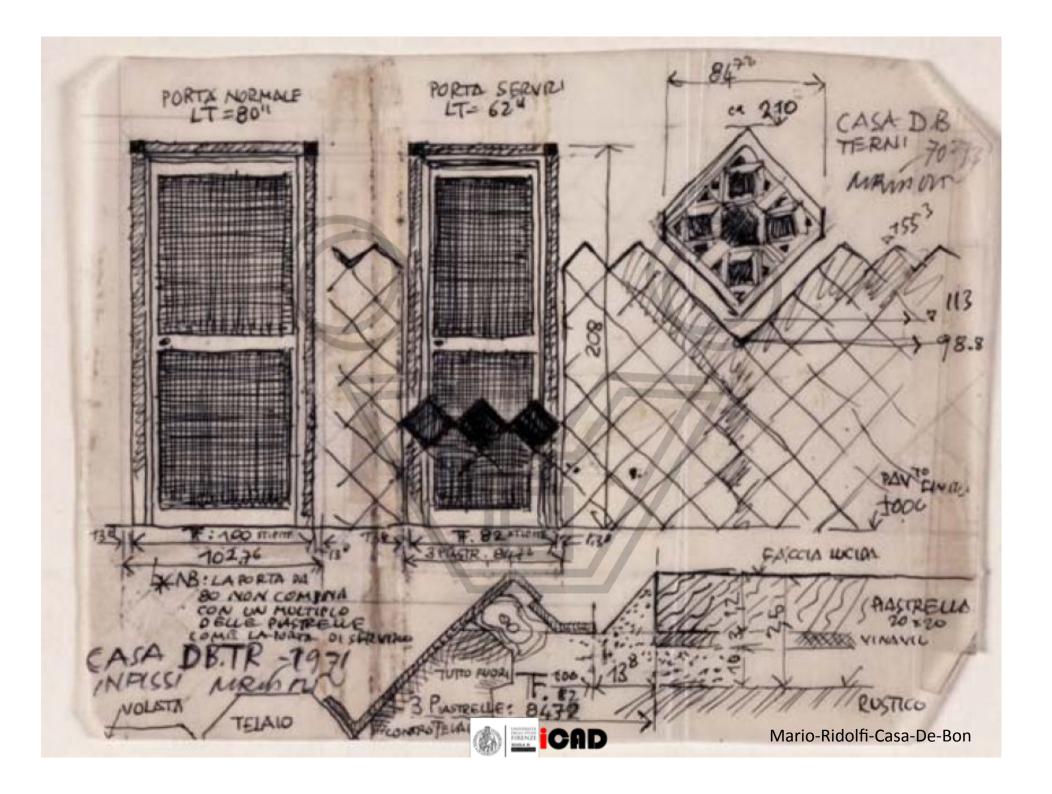## GREEN METRICS AND DIGITAL OPTIONEERING IN THE EARLY STAGE
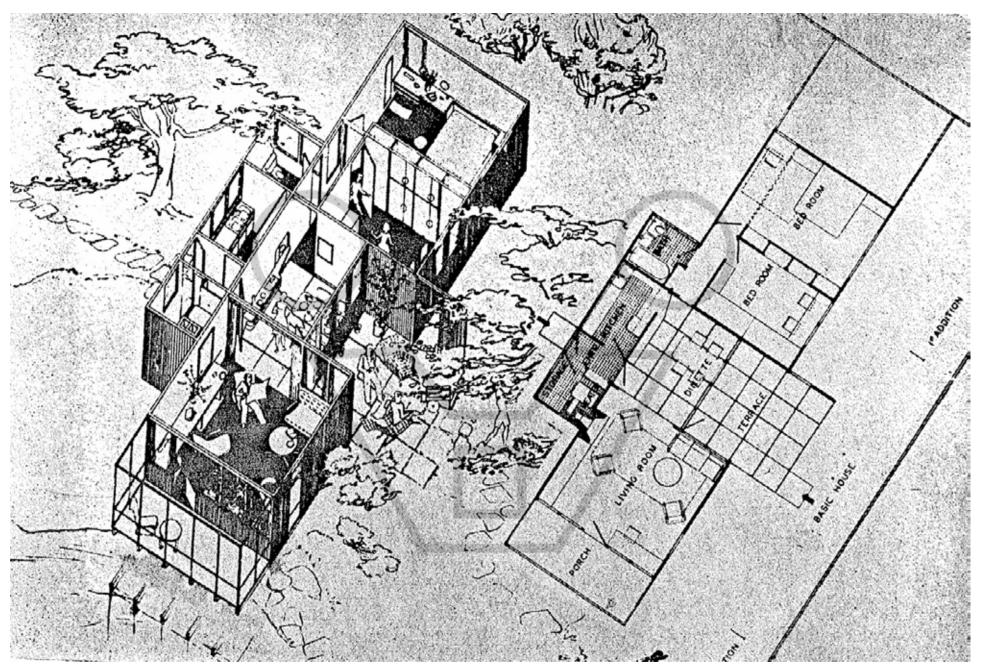
Prof. Arch. Giuseppe Ridolfi, PhD

LECTURE #02

SKETCHING • DRAWING • DRAFTING • MODELING • DESIGNING •

Prof. Giuseppe Ridolfi, PhD

RE-PRESENTATION

Van Gogh's Studies

PORTA NORMALE
LT = 80"

PORTA SERVIZI
LT = 62"

CASA D.B
TERNI
MARMO

84⁷²

cm 210

155³

113

98.8

208

F. 100 riene
102,76

13⁵

13"

F. 82
3 Piastr. 84/2

1,38

PAV⁷⁰ LINEARE
100C

FACCIA LUCIDA

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

PIASTRELLA
70 x 20
VINAVIL

CASA DB.TR - 1971
INFISSI MARMO

NOLATA   TELAIO

TUTTO FUORI
F. 100
82

3 Piastrelle: 84/2

13⁸

CONTROTELAIO

RUSTICO
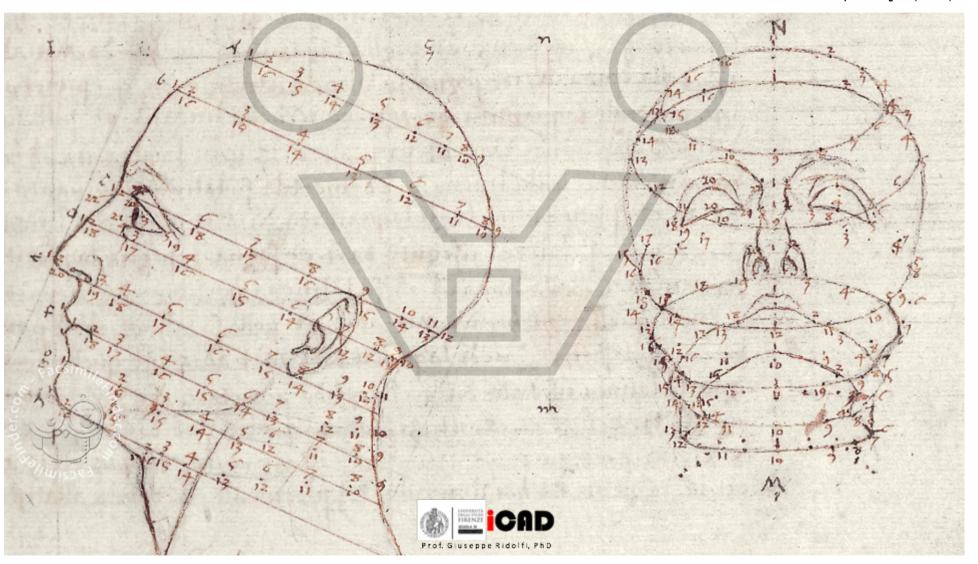
Mario-Ridolfi-Casa-De-Bon

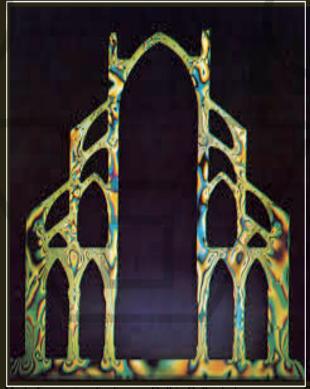Walter Gropius «the Expansible House»

INVESTIGATION • RESEARCH
LEARNING • KNOWING
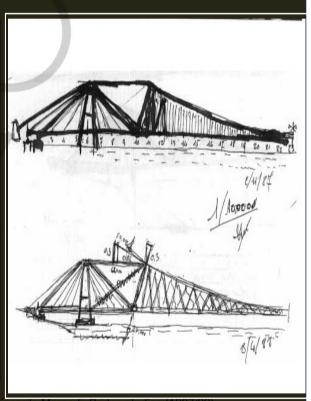
Piero della Francesca. De Prospettiva Pingendi (1472-76)

MODELING: the Language of Design

Leonardo da Vinci. Anatomical drawings (around 1510)

R. Mark. Force visualization on Gothic Cathedral design, polarized light and plexiglass ('70s)

Riccardo Morandi. Bridge studies (1987/89)

Simulation of materiality in order to understand how it works

Prof. Giuseppe Ridolfi, PhD

"What real function the pea has in the whistle"

Stuart Ruskin (1819-1900)

iCAD

Prof. Giuseppe Ridolfi, PhD

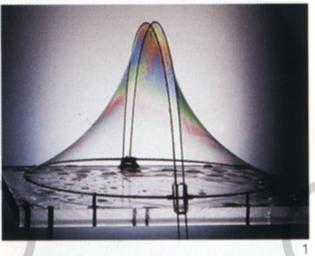# "Design is not just what it looks like and feels like. Design is how it works."

S. Jobs (1955-2011)

PERFORMANCE DESIGN

Prof. Giuseppe Ridolfi, PhD
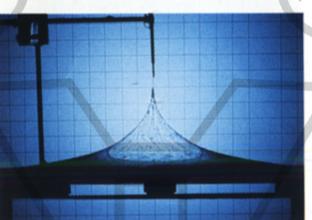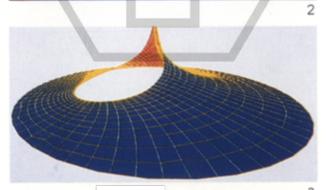
VISUALIZING MATTER

Functionality and
Performance Design
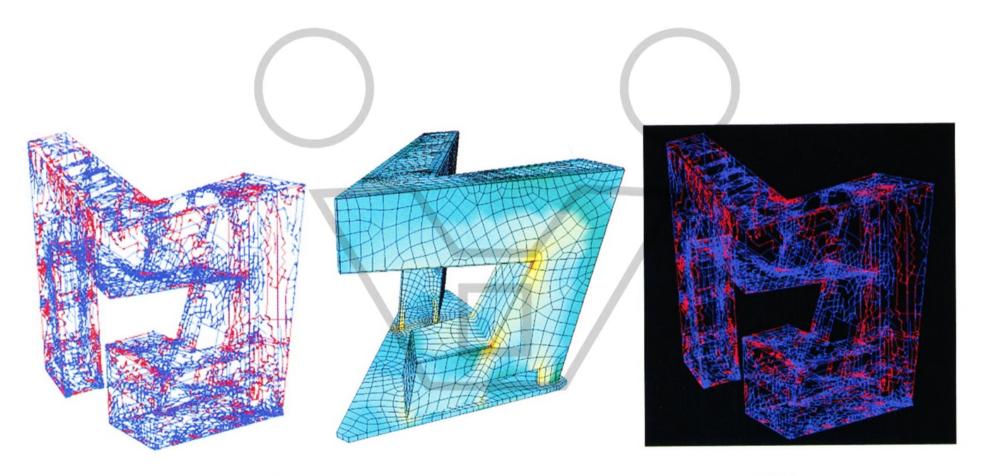
1 Soap film model of an arch-supported membrane.

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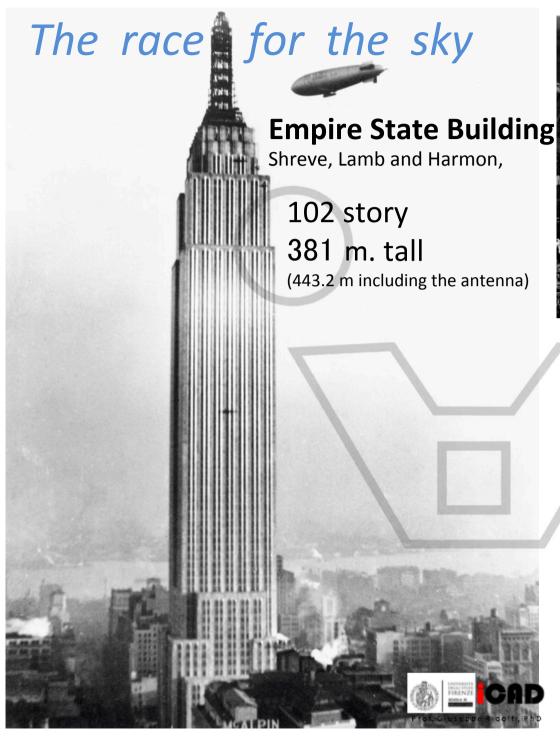
AKT, South Bank Pavilion (Zaha Hadid). Load paths. © Adams Kara Taylor (AKT).

OPTIONEERING

Prof. Giuseppe Ridolfi, PhD

The race for the sky

Empire State Building

Shreve, Lamb and Harmon,

102 story
381 m. tall
(443.2 m including the antenna)

20 months including:

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

iCAD
Prof. Giuseppe Ridolfi, PhD

Empire State Building

Fast tracking

Project Management (P/M) or

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 the16th 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

iCAD
UNIVERSITÀ DEGLI STUDI FIRENZE

Prof. Giuseppe Ridolfi, PhD

Computational Design
as a scientific research

Prof. Giuseppe Ridolfi, PhD
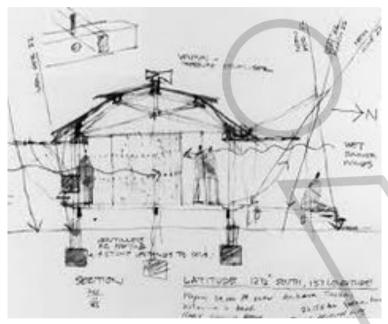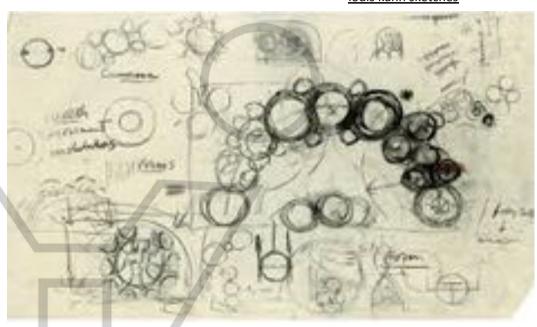
MODELING FOR SIMULATION

" 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

louis kahn sketches
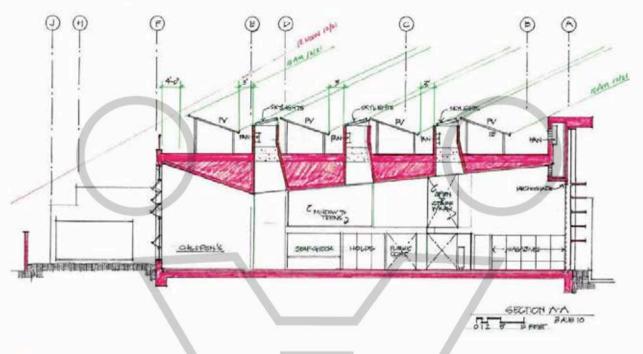
Decision-Making through:
-*rules of thumb*
-*individual intuition*
-*experience & tacit knowledge*

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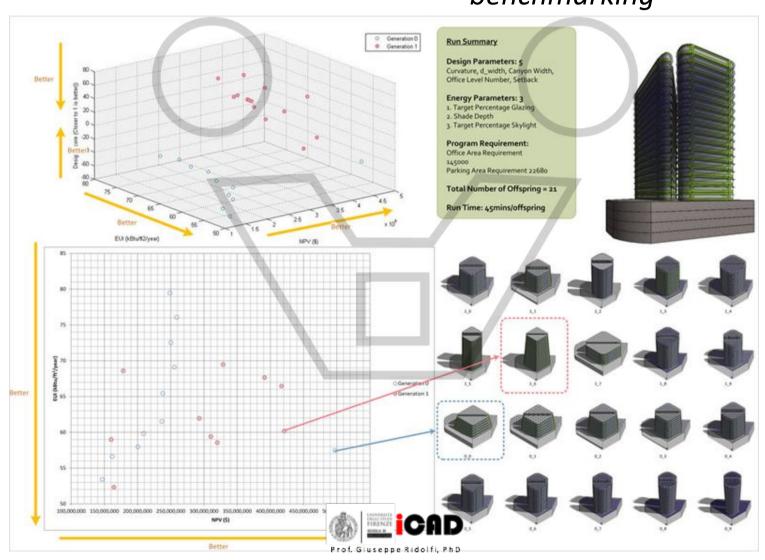
Source: Concept sketch by Edward Dean, courtesy of Harley Ellis Devereaux Architects.

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

Prof. Giuseppe Ridolfi, PhD

Computational Design as a scientific research

Decision-Making through:
-*formal procedures*
-*evidence-based observation*
-*benchmarking*
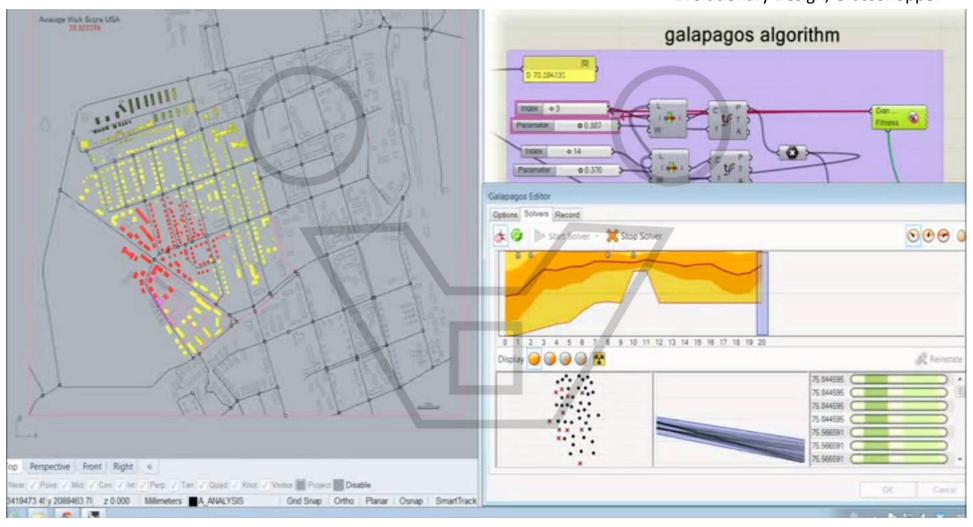
Computational Design for modeling simulation

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 stocastic optimization
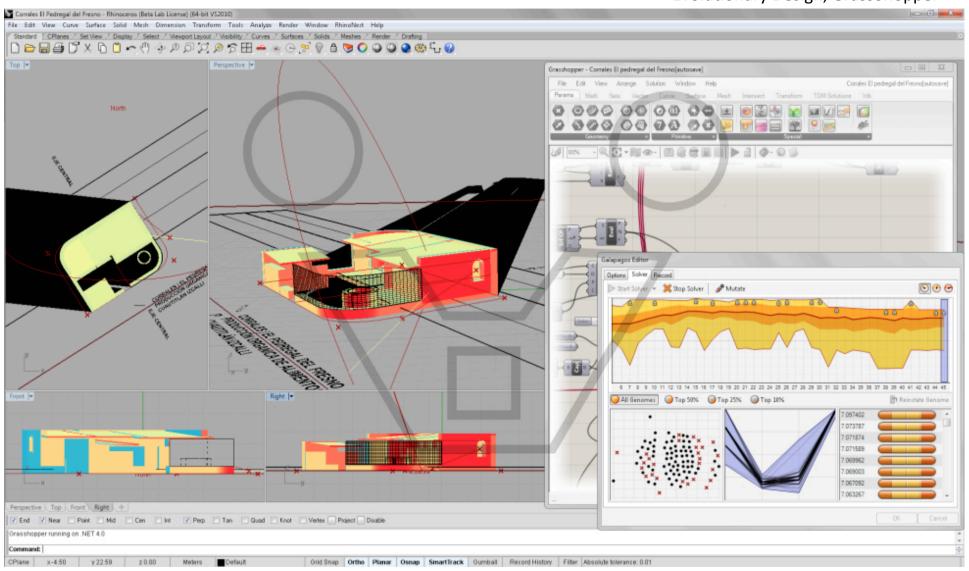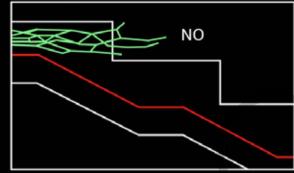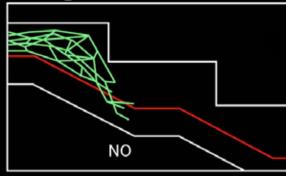
GROWING PROCESS:

solving the condition:

NO

solving the condition:

NO
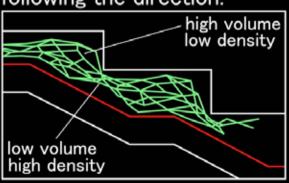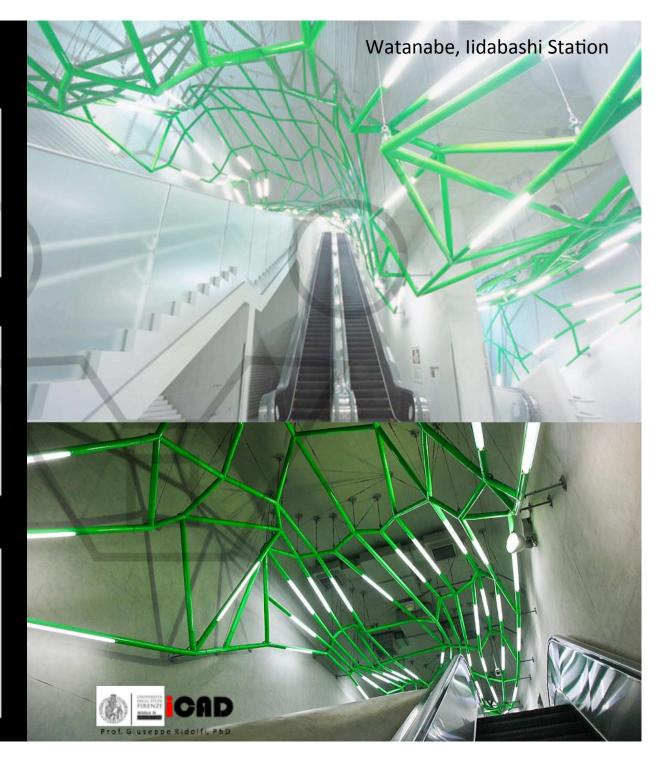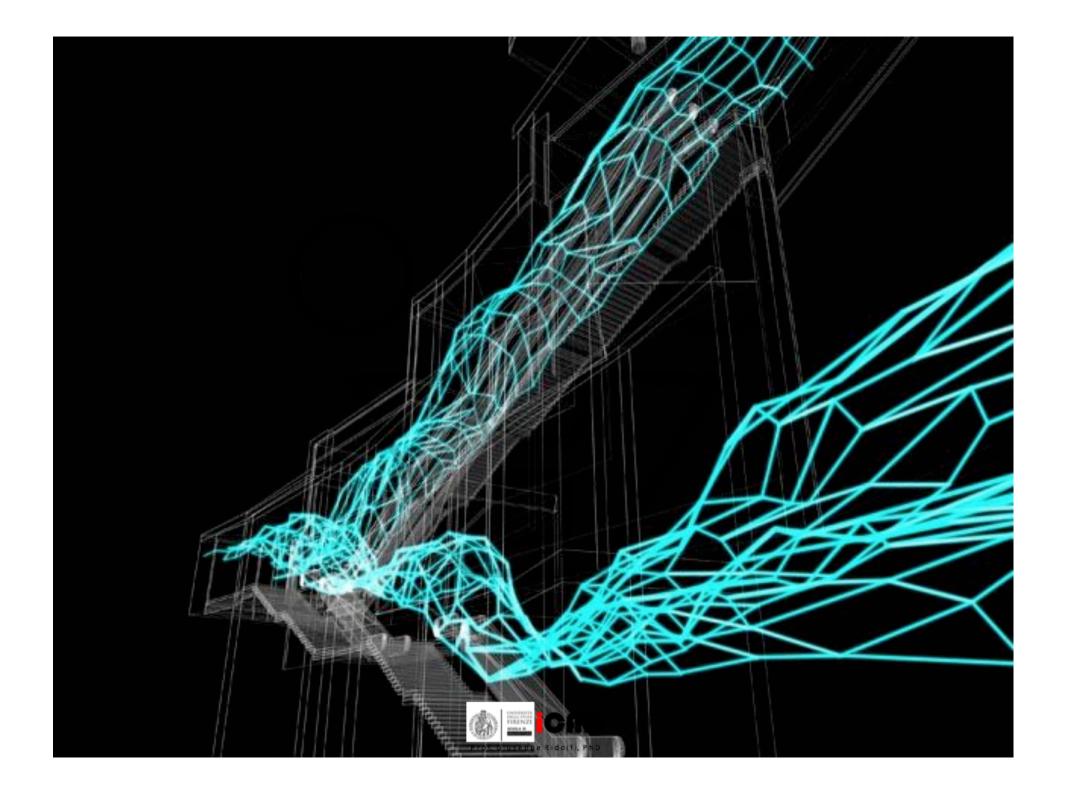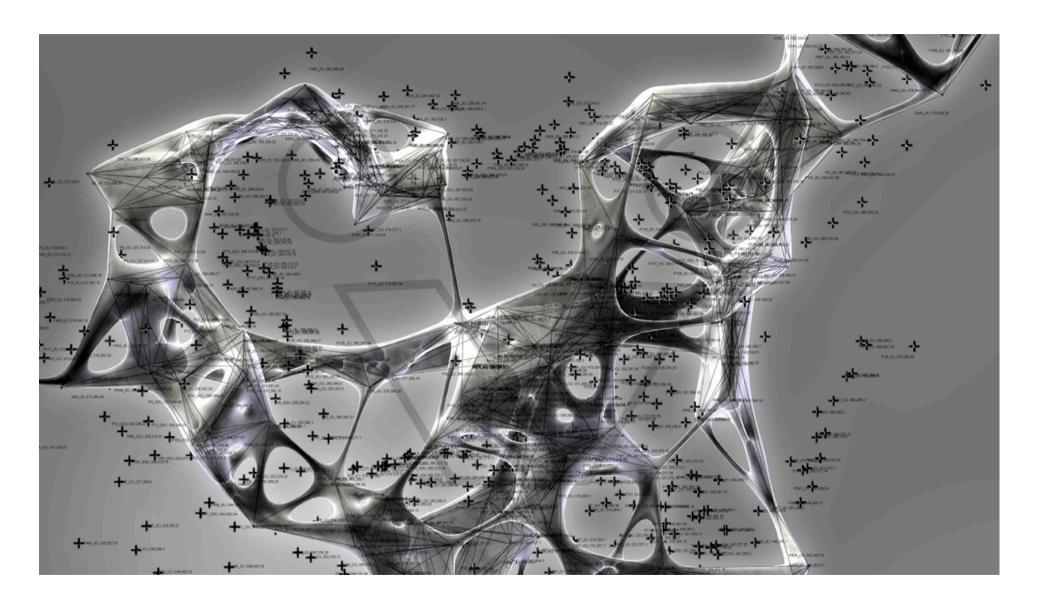
following the direction:

high volume
low density

low volume
high density

Watanabe, Iidabashi Station

Giuseppe Ridolfi, PhD

"For me, it is calculus that was the subject of the issuu 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.
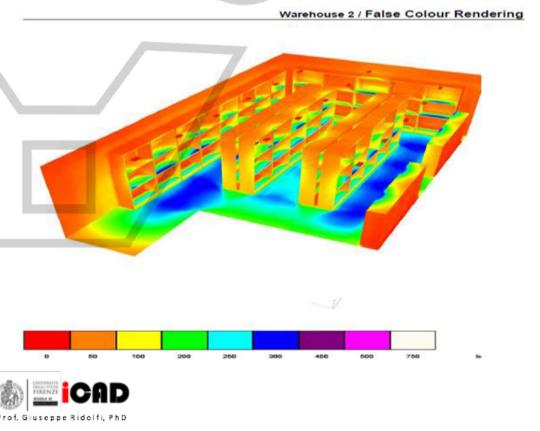
As a result we deal with «performative informed un-materiality»: materials «farcé» of that special untouchable matter that is the knowledge; for this reason we can define objects mainly made of un-materiality, able to incorporate information, memories; able to mutate dynamically prese   d attitudes, to respond under complex and interrelated conditions, variables, a   eters.

MODELING FOR SIMULATION NUMERICALLY PERFORMANCE BASED

features: precision
objectivity
replicability
communicability

Warehouse 2 / False Colour Rendering
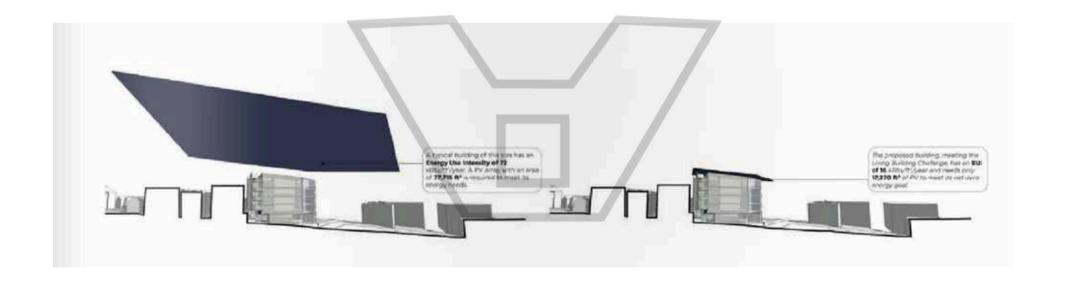
More than that digital tools give us an holistic and visual perception of fenomena in order to have a faster comprehension of a large quantity of aspects.
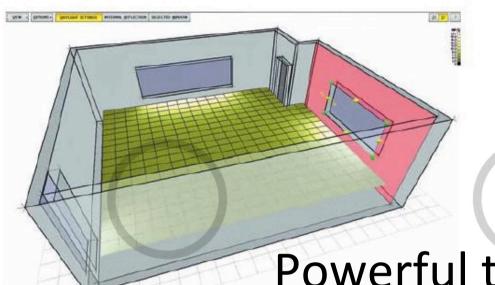
EVIDENCE OF PROOF AND CONTROL OF THE PROCESS

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 enginnering 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)
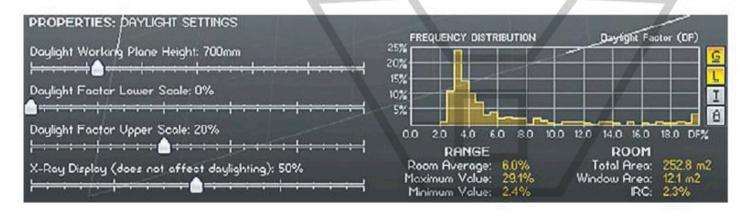
Powerful tools for gamers

PLAYING OPTIONS
AND
UNDERSTANDING
CAUSALITY

http://andrewmarsh.com

The art of digital modeling for evaluation purpose

**MAIN ASPECTS TO CONSIDER
IN DIGITAL MODELING
FOR SIMULATION**

- Extension
- Deepeness
- Operability

- Accuracy
- Reliability
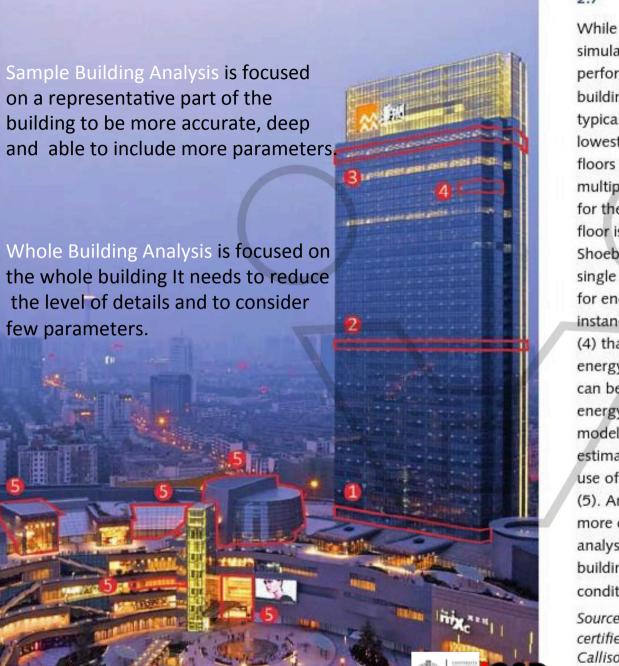
**Level of details => run time* vs accuracy
> many tests vs few detailed solutions**

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

iCAD

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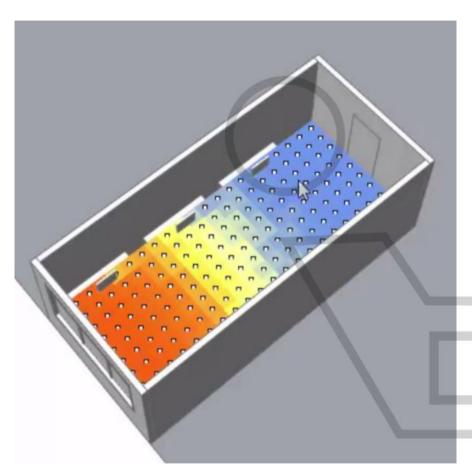
It is important to note that Building Energy Modeling is a computer program and the accuracy of results would largely depend on the inputs provided to the model.
In this context, one should be mindful of the expression *'garbage-in-garbage-out'.*

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.

2.7

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

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

SHOEBOX ANALYSIS

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

2-Set adiabatic perimeters

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

4. Run analysis

5. Analize and evaluate

OTHER TYPES OF MODELING FOR SIMULATION
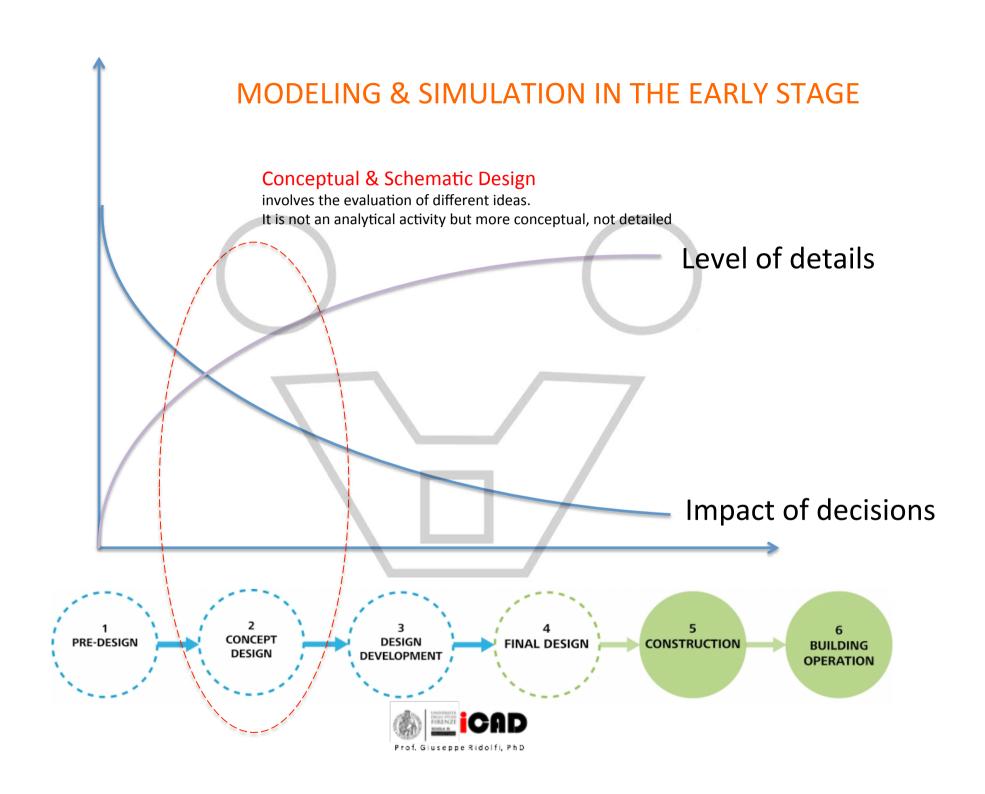
STATIC

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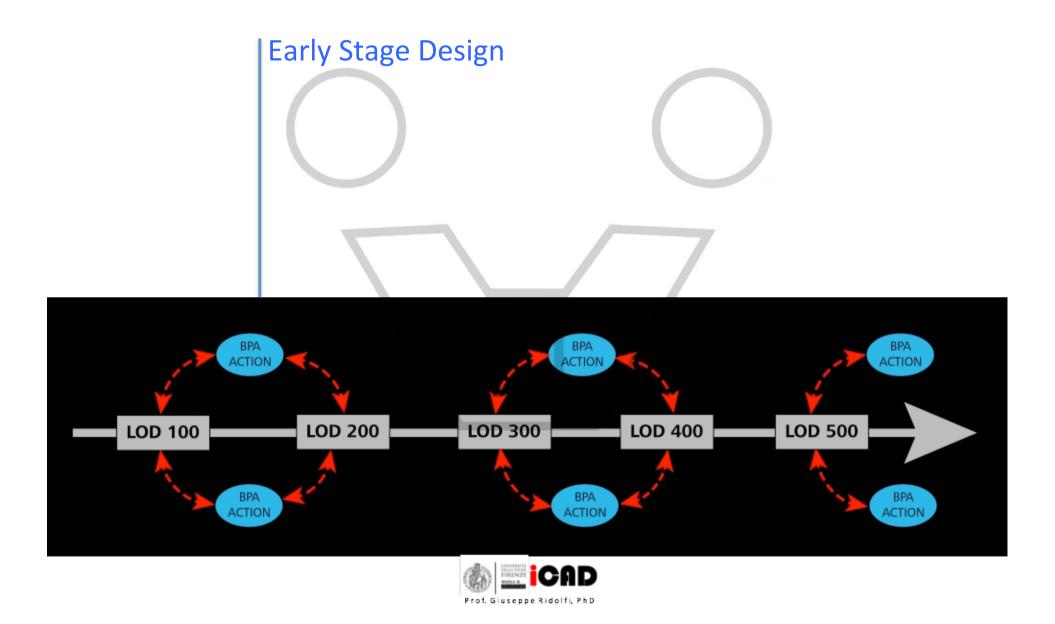
TIME-STEP analysis = over a period of time hour season, year

POINT-IN-TIME (PIT) analysis= in a precise single moment segment like hottest hours
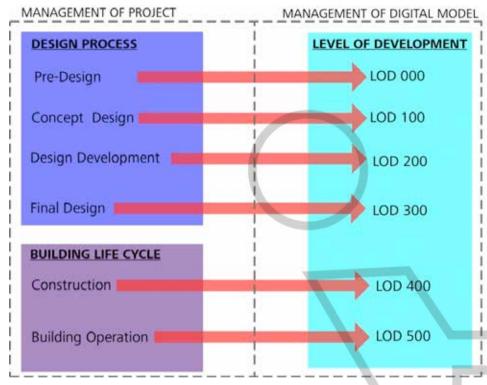
MODELING & SIMULATION IN THE EARLY STAGE

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

Level of details

Impact of decisions

| 1 PRE-DESIGN | 2 CONCEPT DESIGN | 3 DESIGN DEVELOPMENT | 4 FINAL DESIGN | 5 CONSTRUCTION | 6 BUILDING OPERATION |

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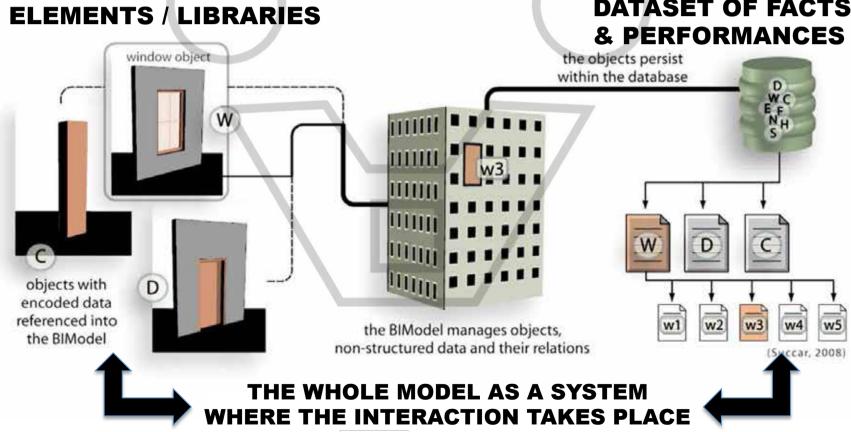
LOD 400: Continuation of LOD 300 with enough information added to facilitate fabrication, assembly, and installation.

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

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

Prof. Giuseppe Ridolfi, PhD

BIM FOR INTEGRATED DELIVERY PROJECT

Status of AEC industry before the implementation of BIM (manual, 2D or 3D CAD)

PRE-BIM

BIM Stage 1: object-based **MODELLING**

BIM Stage 2: model-based **COLLABORATION**

BIM Stage 3: network-based **INTEGRATION**

Integrated Project Delivery, the long-term goal of BIM implementation

IPD

(Succar, 2008)

ELEMENTS / LIBRARIES

window object

W

C — objects with encoded data referenced into the BIModel

D

the BIModel manages objects, non-structured data and their relations

w3

DATASET OF FACTS & PERFORMANCES

the objects persist within the database

W D C

w1 w2 w3 w4 w5

(Succar, 2008)

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 a chance. Is not a new and more efficent way of production
➢ It is a way to integrated specialisms, to have a comprehensive view of the whole
➢ Building and more than that a view to anticpate 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 deisng

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

It's a way to be aware about our decisions

BIM SOFTWARE

1. Autodesk provides various BIM software programs such as Revit for archi- tectural 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 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 environment
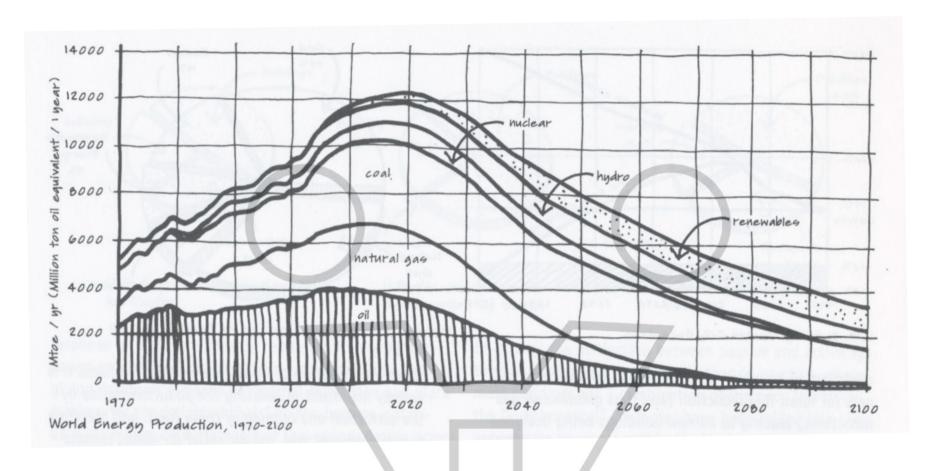
Inside the US Constructio, Buildings sector represents:
49% Energy consumption
77% Electricity consumption
47% Carbon Dioxide emission

14000

12000

10000

8000

6000

4000

2000

0

Mtoe / yr (Million ton oil equivalent / 1 year)

nuclear

coal

hydro

renewables

natural gas

oil

1970   2000   2020   2040   2060   2080   2100

World Energy Production, 1970-2100
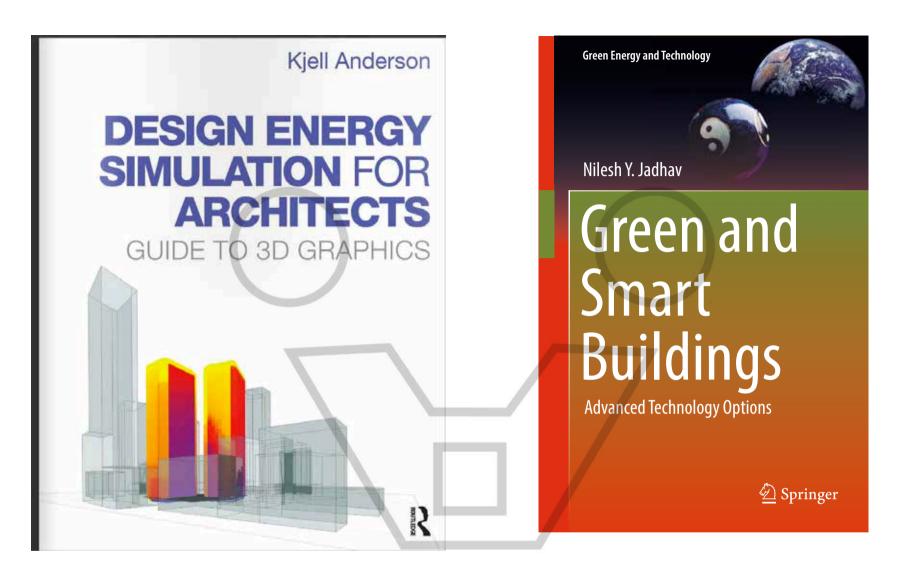
For architects reducing impacts is a big ethical responsability

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

ENVIRONMENTAL DESIGN
USING MASS COMPUTATIONAL MODELING

Prof. Giuseppe Ridolfi, PhD
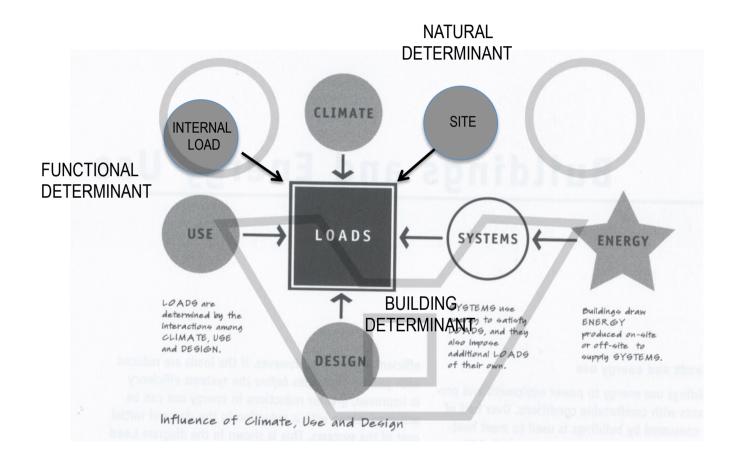
Class Text-books
For other resources check Mailab class portal out

Prof. Giuseppe Ridolfi, PhD
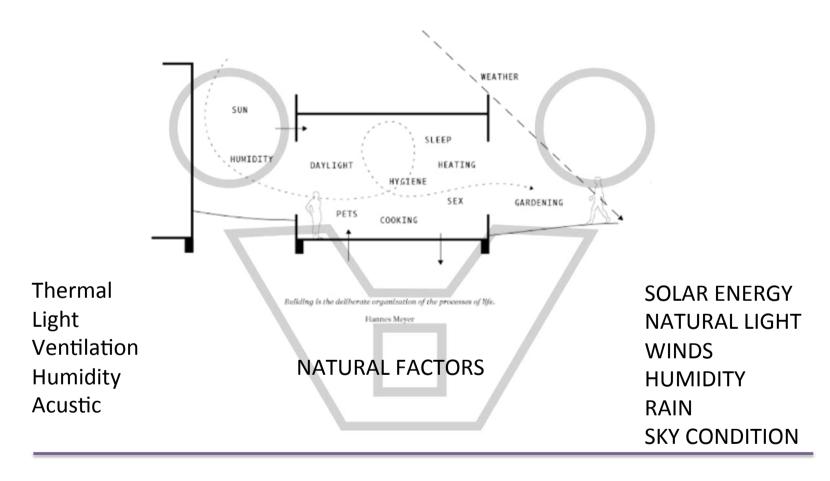
ENVIRONMENTAL SYSTEM DETERMINANTS

Modeling Climate, Weather, Site, Users and Architectures.

Environmental elements that affect people's comfort

Thermal
Light
Ventilation
Humidity
Acustic

NATURAL FACTORS

SOLAR ENERGY
NATURAL LIGHT
WINDS
HUMIDITY
RAIN
SKY CONDITION

View
Security
....
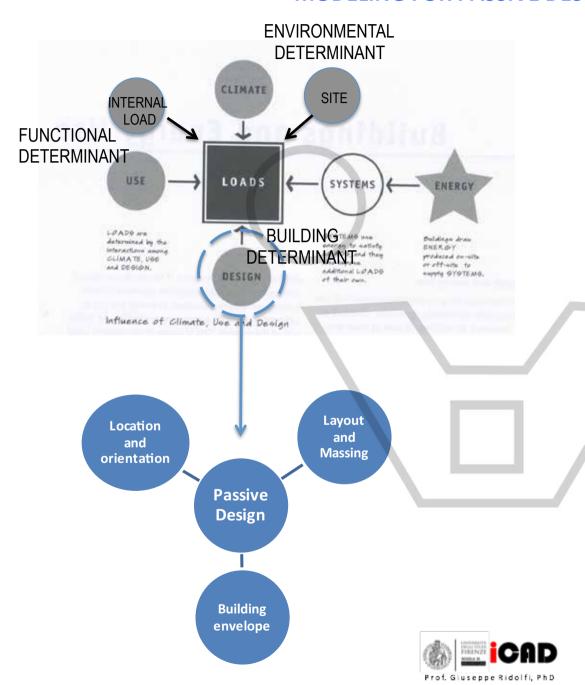
NOT NATURAL FACTORS

MODELING FOR PASSIVE DESIGN

ENVIRONMENTAL DETERMINANT

FUNCTIONAL DETERMINANT

BUILDING DETERMINANT

Influence of Climate, Use and Design

Location and orientation

Layout and Massing

Passive Design

Building envelope
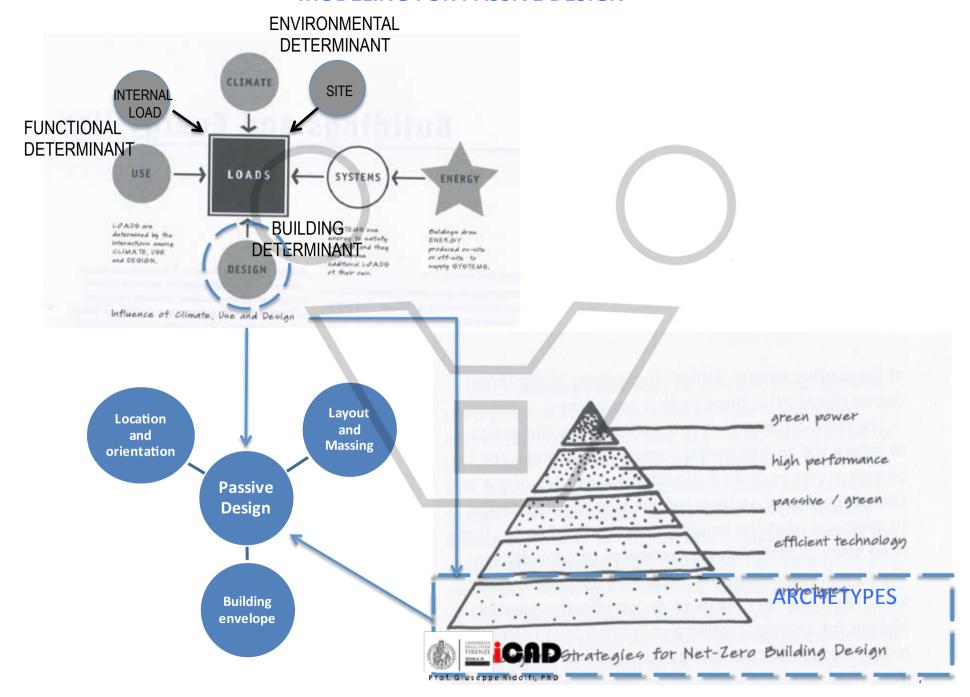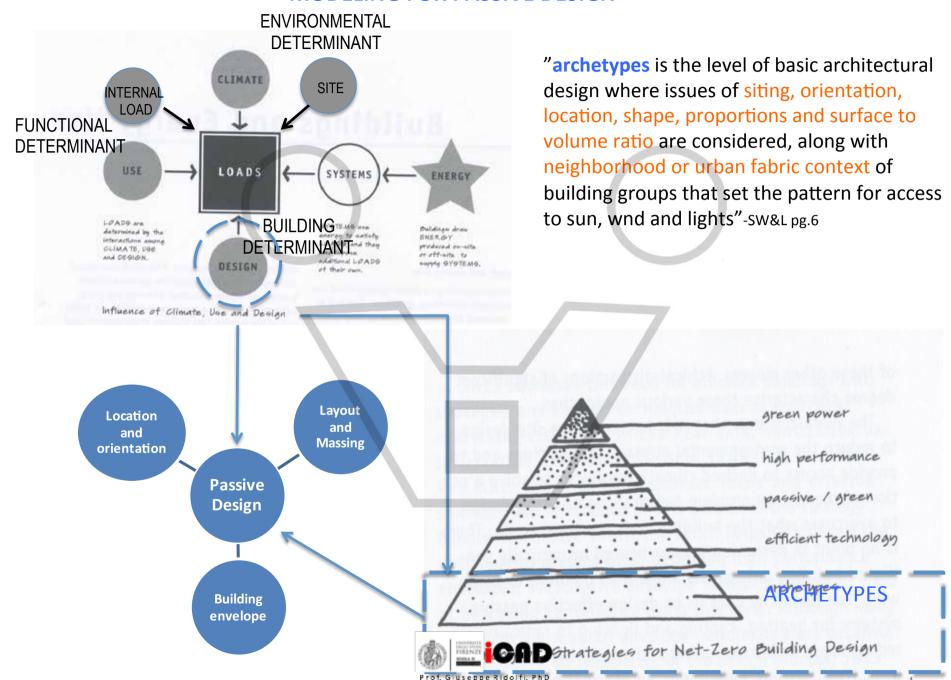
The term 'Passive Design' here refers to design strategies, technologies and solutions that effectively take advantage of the environmental conditions outside the building to maximise the energy and cost savings while ensuring the core building facilities and provisions (such as indoor comfort, safety, 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.

iCAD

Prof. Giuseppe Ridolfi, PhD

MODELING FOR PASSIVE DESIGN

ENVIRONMENTAL DETERMINANT

CLIMATE

SITE

INTERNAL LOAD

FUNCTIONAL DETERMINANT

USE

LOADS

SYSTEMS

ENERGY

LOADS are determined by the interactions among CLIMATE, USE and DESIGN.

SYSTEMS use energy to satisfy and they additional LOADS of their own.

Buildings draw ENERGY produced on-site or off-site to supply SYSTEMS.

BUILDING DETERMINANT

DESIGN

Influence of Climate, Use and Design

Location and orientation

Layout and Massing

Passive Design

Building envelope

green power

high performance

passive / green

efficient technology

archetypes

ARCHETYPES

iCAD Strategies for Net-Zero Building Design

Prof. Giuseppe Ridolfi, PhD

MODELING FOR PASSIVE DESIGN

ENVIRONMENTAL
DETERMINANT

FUNCTIONAL
DETERMINANT

BUILDING
DETERMINANT

INTERNAL LOAD · CLIMATE · SITE · USE · LOADS · SYSTEMS · ENERGY · DESIGN

LOADS are determined by the interactions among CLIMATE, USE and 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, wnd and lights"-SW&L pg.6

Passive Design

- Location and orientation
- Layout and Massing
- Building envelope

green power

high performance

passive / green

efficient technology

archetypes

ARCHETYPES

Strategies for Net-Zero Building Design

Prof. Giuseppe Ridolfi, PhD

Massing contribution to a passive design

1. Building location and orientation on the site
2. Building layout and form
3. Building envelope
(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/.
- 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).

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

06:31

Table 3.3 Typical input parameters required 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 systems • Specialty systems (e.g. fume exhausts) • Renewable-energy systems

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

Table 3.2 Benefits of energy modeling at various stages of building development (adapted from AIA 2012)

Building stage	Energy modeling outputs
Concept design	✓ Define goals and requirements of the project based on early modeling results ✓ Experiment with options for building orientation, massing and envelope constructions ✓ Explore ways to reduce loads ✓ Get the design team together to assess integrated system performance and make design decisions based on the results
Schematic design	✓ Create a baseline energy model ✓ Test the effectiveness of different energy conservation measures and options before selection and implementation ✓ Determine the most cost effective solution to reduce energy consumption to the lowest
Design development	✓ Finalize baseline model to compare against proposed design ✓ Create proposed models with system alternatives to choose from ✓ Provide annual energy use charts and other performance metrics for comparing baseline versus proposed design ✓ Evaluate specific products and technologies with refined data and details
Construction documents	✓ Create documentation needed to accompany energy model results for code compliance and for green certification requirements such as LEED
Commissioning and post-occupancy	✓ Use results of the as-built model for commissioning ✓ Collect metered operating data to create a calibrated model to share with outcome-based database
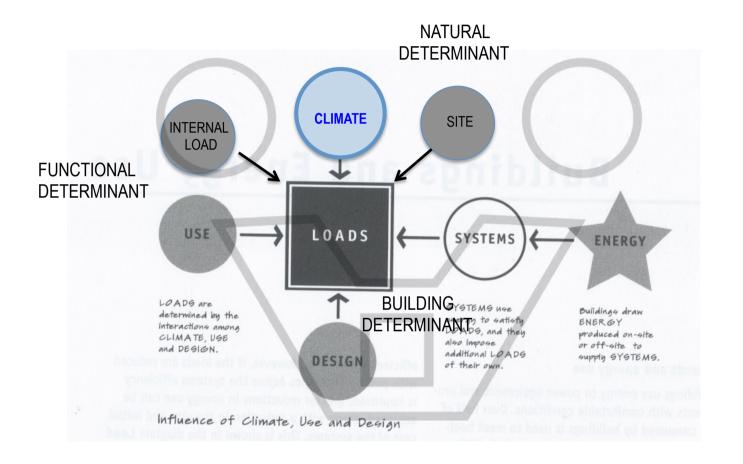
The output of the energy modeling software are values of physical aspects affecting users' comfort and natural resourses trade-off

Prof. Giuseppe Ridolfi, PhD

WORKING WITH BUILDING ENERGY MODELING IN THE EARLY STAGE
• THERMAL ASPECTS

iCAD

Prof. Giuseppe Ridolfi, PhD
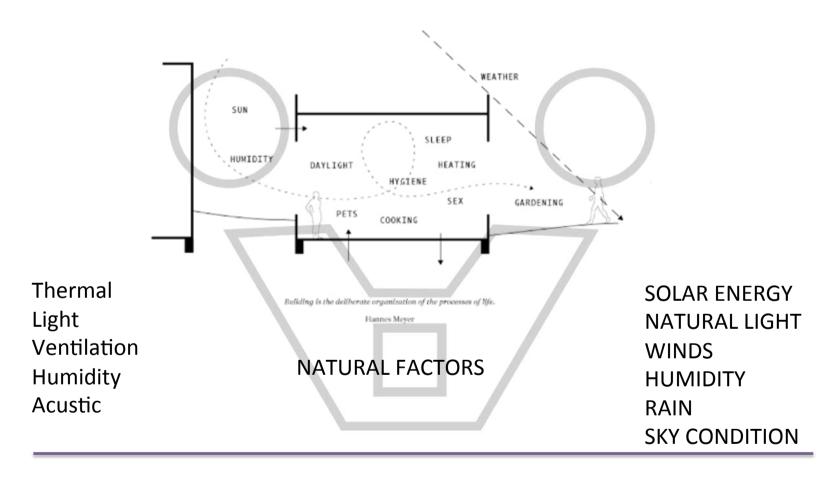
THERMAL ASPECTS: CLIMATE

NATURAL DETERMINANT

INTERNAL LOAD

CLIMATE

SITE

FUNCTIONAL DETERMINANT

USE → LOADS ← SYSTEMS ← ENERGY

BUILDING DETERMINANT

DESIGN

LOADS are determined by the interactions among CLIMATE, USE and DESIGN.

SYSTEMS use to satisfy LOADS, and they also impose additional LOADS of their own.

Buildings draw ENERGY produced on-site or off-site to supply SYSTEMS.

Influence of Climate, Use and Design

Modeling Climate, Weather, Site, Users and Architectures.

Environmental elements that affect people's comfort

WEATHER

SUN

HUMIDITY

DAYLIGHT

SLEEP

HEATING

HYGIENE

SEX

GARDENING

PETS

COOKING

Building is the deliberate organisation of the processes of life.

Hannes Meyer

Thermal
Light
Ventilation
Humidity
Acustic

NATURAL FACTORS

SOLAR ENERGY
NATURAL LIGHT
WINDS
HUMIDITY
RAIN
SKY CONDITION

View
Security
....

NOT NATURAL FACTORS

CLIMATE
a physical, socio-cultural, and technological determinant

Environmental parameters affecting thermal comfort:

- **SOLAR ENERGY**
- **VENTILATION**
- **HUMIDITY**

-   radiant temperature

-   air temperature

HOW TO MEASURE SOLAR ENERGY ?

RADIATION=W/m2

We collect data near airports and other stations

Wheather data includes:
- Annual weather files (8760 hours of the year) used to compute Energy Use Intensity (EUI)
- TMY (Typical metereological year) that is encapsulated in the .epw files mantained by *Energy Efficiency and Renewable Energy (EERE)*
- Peak condition files used to dimension mechanical
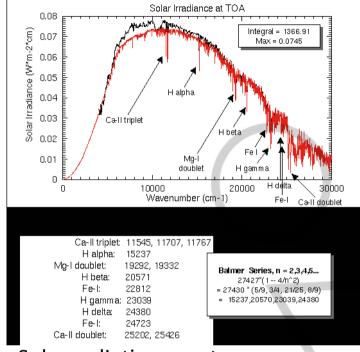
Wheather data also includes:
- geographical coordinates
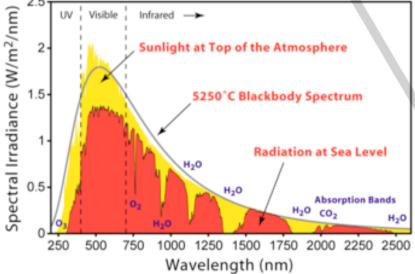
Environmental parameters affecting thermal comfort: SOLAR ENERGY

Solar radiation* at the top of the atmosphere.

Solar radiation spectrum

*) *Radiation* occurs when an object emits electro magnetic energy.
Irradiation is the energy absorber by an object/surface
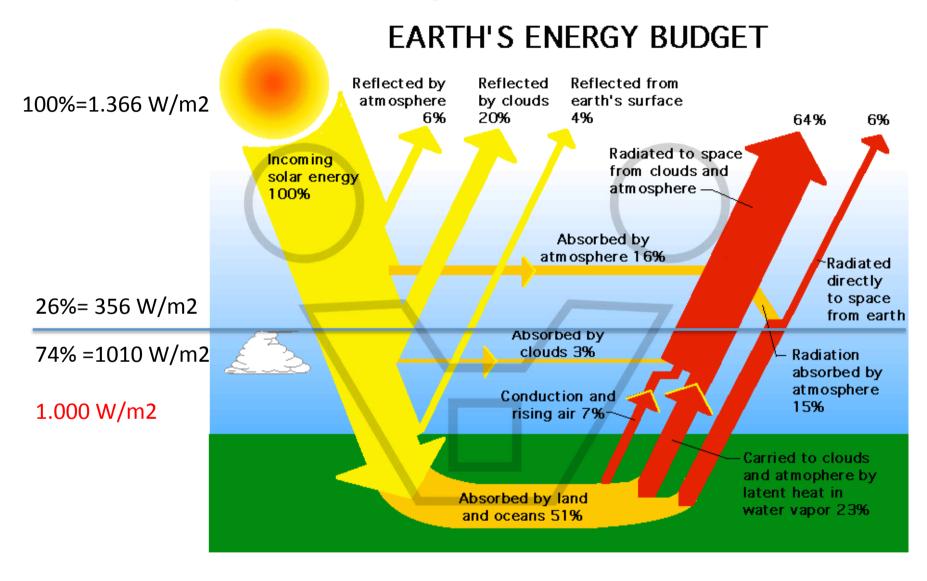
1366 W/m² (solar costant)

1 W = 3,416 Btu.

Considering the earth surface,
the total solar energy is= 174 PW
Peta= million of billions

Environmental parameters affecting thermal comfort: SOLAR ENERGY

EARTH'S ENERGY BUDGET

100%=1.366 W/m2

26%= 356 W/m2

74% =1010 W/m2

1.000 W/m2

Reflected by atmosphere 6%

Reflected by clouds 20%

Reflected from earth's surface 4%

64%

6%

Incoming solar energy 100%

Radiated to space from clouds and atmosphere

Radiated directly to space from earth

Absorbed by atmosphere 16%

Absorbed by clouds 3%

Radiation absorbed by atmosphere 15%

Conduction and rising air 7%

Carried to clouds and atmophere by latent heat in water vapor 23%

Absorbed by land and oceans 51%

Environmental parameters affecting thermal comfort: SOLAR ENERGY

Site Inventory: Physical Attributes 121
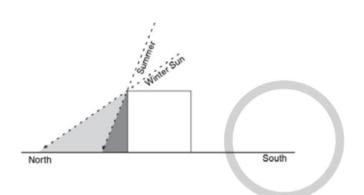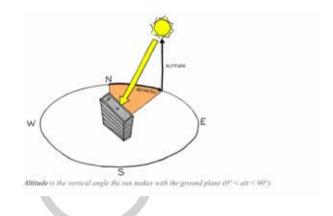
Figure 5-15 Schematic diagram of the seasonal variation in shade cast by a building in the northern hemisphere. Solar exposure in outdoor spaces near a building varies not only with weather conditions but also with time of day, day of year, and location of the space in relation to both the building and the sun.

Altitude is the vertical angle the sun makes with the ground plane (0° < alt < 90°).

les 24 heures Solaires

120 Site Analysis

Figure 5-14 Diagram of seasonal changes in the maximum daily sun angle for a mid-latitude location in the Northern Hemisphere. Source: Marsh, *Landscape Planning*, Third Ed., copyright © 1998, p. 290, Figure 15.3. Reprinted by permission of John

un soleil se lève

un soleil se lève à nouveau

Si la totalité des conditions nécessaires et suffisantes n'est pas acquise, il y a déséquilibre, insuffisance — malheur chaque jour et ...toute la vie !

Summer Solstice

Equinoxes

Winter Solstice

ZA

63°

40°

16°

Horizon

ZA=Zenith Angle

Environmental parameters affecting thermal comfort: : SOLAR ENERGY

SOLAR ENERGY= f (power, angle of incidence, sky conditions)= **World Location**

Environmental parameters affecting thermal comfort: SOLAR ENERGY
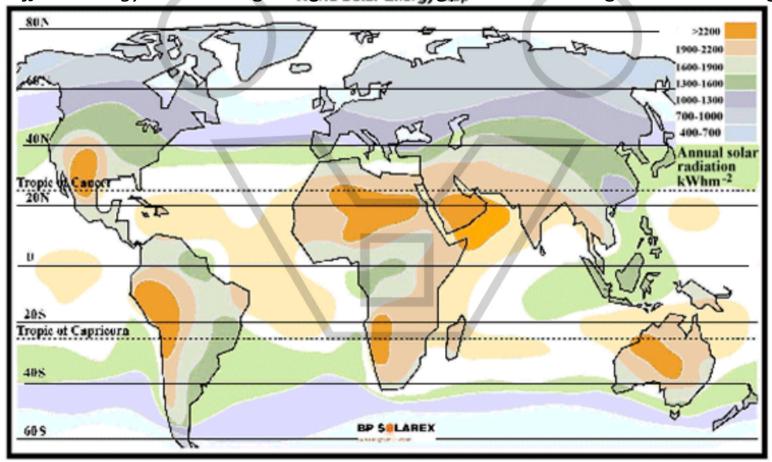
The influence of the site: GEOGRAPHICAL POSITION

Insolation is the sun's energy on a surface

Sun's energy depends on angle, sky conditions, volume and surfaces around.
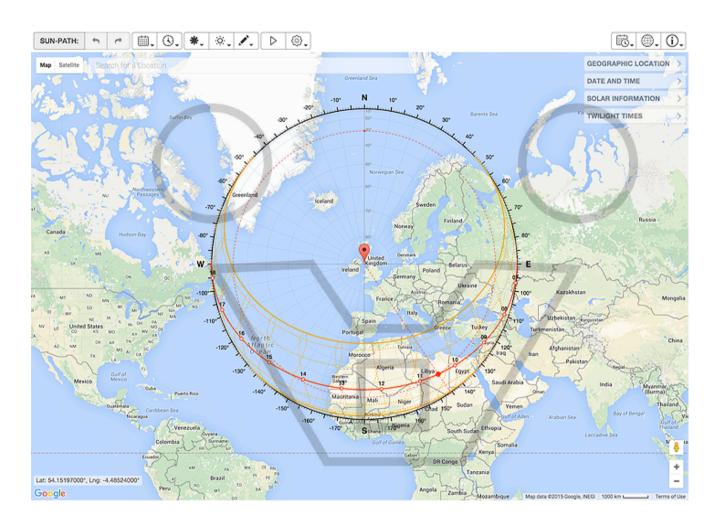
Weather files give the total amount of *direct energy* along a year measured perpendicularly t
the sun direction

And *diffuse energy* measured getting all the energy and subtracting the direct energy capted

World Solar Energy Map
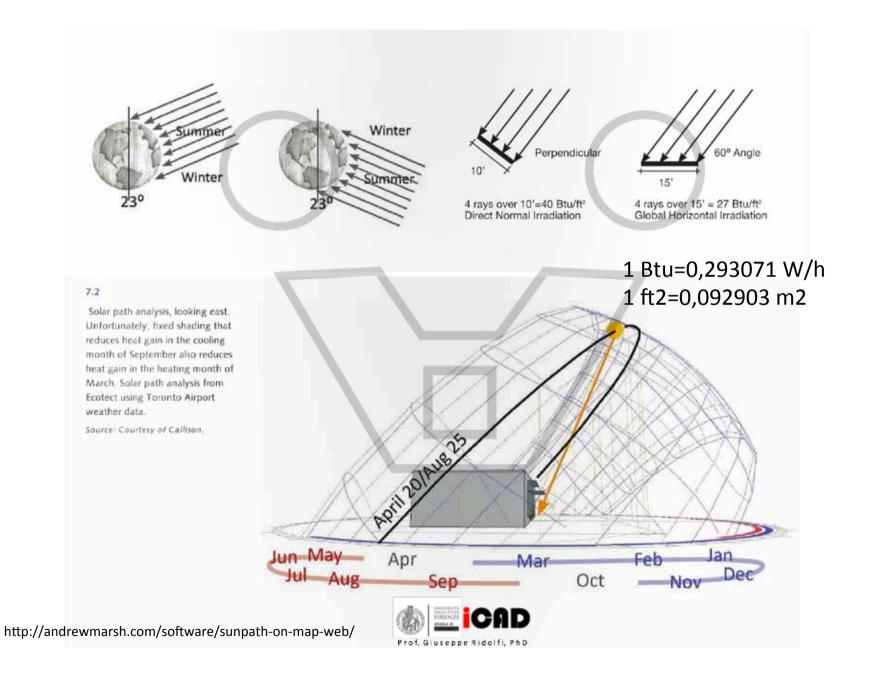
SOLAR GEOMETRY
http://andrewmarsh.com/software/sunpath-on-map-web/

The influence of the site: GEOGRAPHICAL POSITION

SOLAR GEOMETRY

http://andrewmarsh.com/apps/releases/sunpath2d.html

NAME	DATE (Sth.Hem.)	(Nth.Hem.)	DESCRIPTION
Summer Solstice	22 Dec.	22 Jun.	Sun at its highest noon altitude
Autumn Equinox	21 Mar.	21 Sep.	Sun rises due east, sets due west
Winter Solstice	21 Jun.	21 Dec.	Sun at its lowest noon altitude
Spring Equinox	21 Sep.	21 Mar.	Sun rises due east, sets due west

Prof. Giuseppe Ridolfi, PhD

The influence of the site: GEOGRAPHICAL POSITION

1 Btu=0,293071 W/h
1 ft2=0,092903 m2

7.2

Solar path analysis, looking east. Unfortunately, fixed shading that reduces heat gain in the cooling month of September also reduces heat gain in the heating month of March. Solar path analysis from Ecotect using Toronto Airport weather data.

Source: Courtesy of Callison.

Prof. Giuseppe Ridolfi, PhD

Environmental parameters affecting thermal comfort: SOLAR ENERGY
The influence of the site: GEOGRAPHICAL POSITION

Environmental parameters affecting thermal comfort: SOLAR ENERGY

The influence of the site: GEOMETRY

Confronto fra la radiazione solare giornaliera media incidente su superfici con differenti angoli di inclinazione β ed orientate a Sud (azimut γ=0). Località con latitudine φ=40°N (Nuoro) e cielo sereno

[Mj/d]

β = 30°
β = 60°
β = 30°
Orizzontale
Verticale

20
15
10
5
0

Gen | Feb | Mar | Apr | Mag | Giu | Lug | Ago | Set | Ott | Nov | Dic

The influence of the site: GEOGRAPHICAL POSITION

AVERAGE DAILY RADIATION

4: CLIMATE ANALYSIS
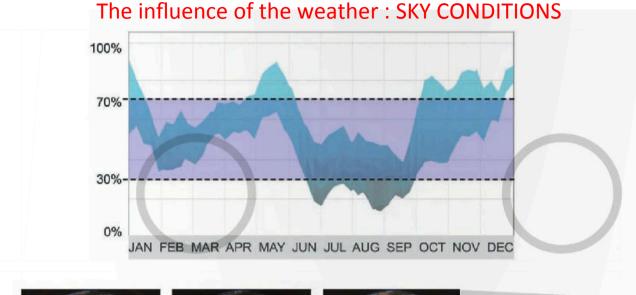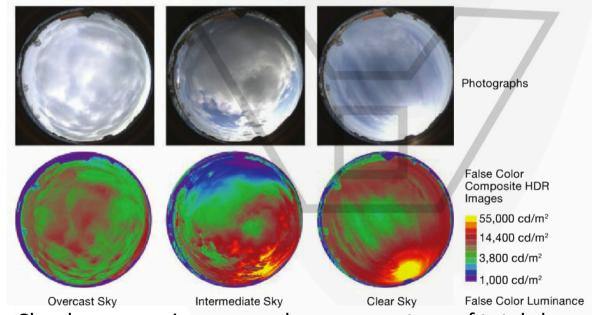
4.10 and 4.11

Solar roses from Central Park in New York City show the average daily amount of solar energy on each vertical segment of a cylinder. Since solar angles are symmetrical about the solstices, each season was centered on an equinox or solstice. The lower images show radiation on a horizontal surface for each hour and day of the year from the same weather file.

Source: Autodesk's Ecotect output. Courtesy of Callison.

Environmental parameters affecting thermal comfort: : SOLAR ENERGY

The influence of the weather : SKY CONDITIONS

8.2

Cloud cover in Allen, Texas, varies from intermediate and overcast in winter, to intermediate and clear in summer. The CIE defines clear skies as >70% cloud cover, overcast skies as <30% cloud cover, and other skies as intermediate.

Source: Modified output from Autodesk Ecotect Suite. Courtesy of Callison.

8.3

Actual sky conditions that correspond to overcast, intermediate, and clear skies are shown using high dynamic range (HDR) fish-eye photographs and false color images. While most daylight simulation uses synthetic, averaged sky conditions, actual sky conditions vary by the minute. HDR skies can be used in daylighting simulations, see Case Study 8.6.

Source: Inanici (2010). Images © Illuminating Engineering Society, www.ies.org.

Photographs

False Color Composite HDR Images

- 55,000 cd/m²
- 14,400 cd/m²
- 3,800 cd/m²
- 1,000 cd/m²

Overcast Sky   Intermediate Sky   Clear Sky   False Color Luminance

Cloud coverage is measured as a percentage of total sky

Environmental parameters affecting thermal comfort: : SOLAR ENERGY

The influence of the weather : SKY CONDITIONS

Radiazione solare	Condizioni atmosferiche							
	Cielo sereno	Nebbia	Nuvoloso	Disco solare giallo	Disco solare bianco	Sole appena percettibile	Nebbia fitta	Cielo coperto
globale	1000 W/m²	600 W/m²	500 W/m²	400 W/m²	300 W/m²	200 W/m²	100 W/m²	50 W/m²
diretta	90%	50%	70%	50%	40%	0%	0%	0%
diffusa	10%	50%	30%	50%	60%	100%	100%	100%

http://www.sunsim.it/
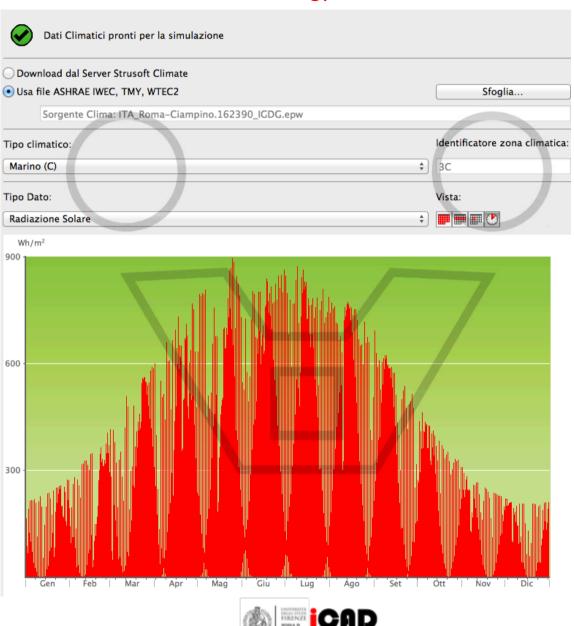
Environmental parameters affecting thermal comfort: SOLAR ENERGY
The influence of the site: Shading Mass

7.9

Fish-eye image showing annual solar path and adjacent buildings that shade a location within an urban context. Afternoon hours in the summer are mostly shaded, while the first two hours of each day are also shaded. The peak summer cooling date is highlighted, showing full shade after 4 p.m.

Source: Modified Autodesk Ecotect output. Courtesy of Callison.

Environmental parameters affecting thermal comfort: SOLAR ENERGY

Visualization of sun energy radiation

Environmental parameters affecting thermal comfort: : SOLAR ENERGY

Visualization of sun energy radiation

Detailed and Average

Environmental parameters affecting thermal comfort: SOLAR ENERGY
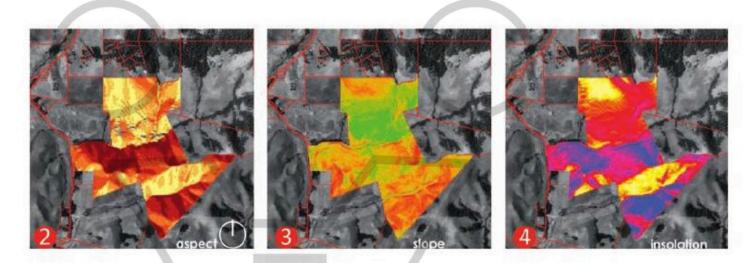
Visualization of sun energy radiation
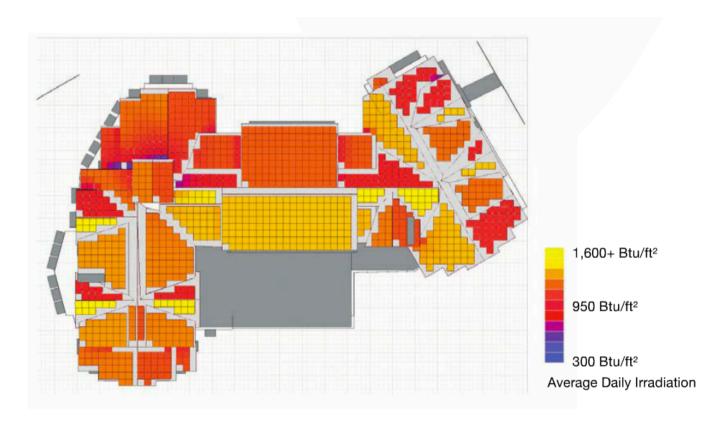
Terrain solar exposure and solar access to evaluate the best location

5.16

View Desirability, Slope
Desirability, Solar Desirability.

Irradiation analysis
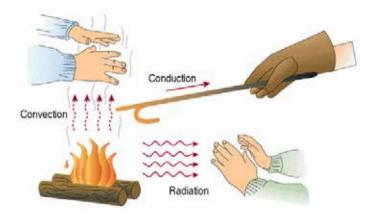
7.8
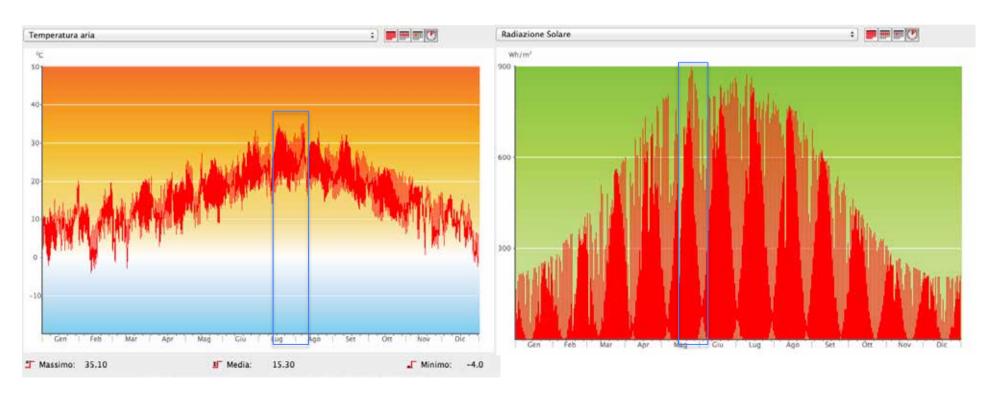
Roof plan with annual solar irradiation analysis to show ideal orientations and roof forms for renewable energy collection using Autodesk Ecotect.

Source: Courtesy of Callison.

1,600+ Btu/ft²

950 Btu/ft²

300 Btu/ft²

Average Daily Irradiation
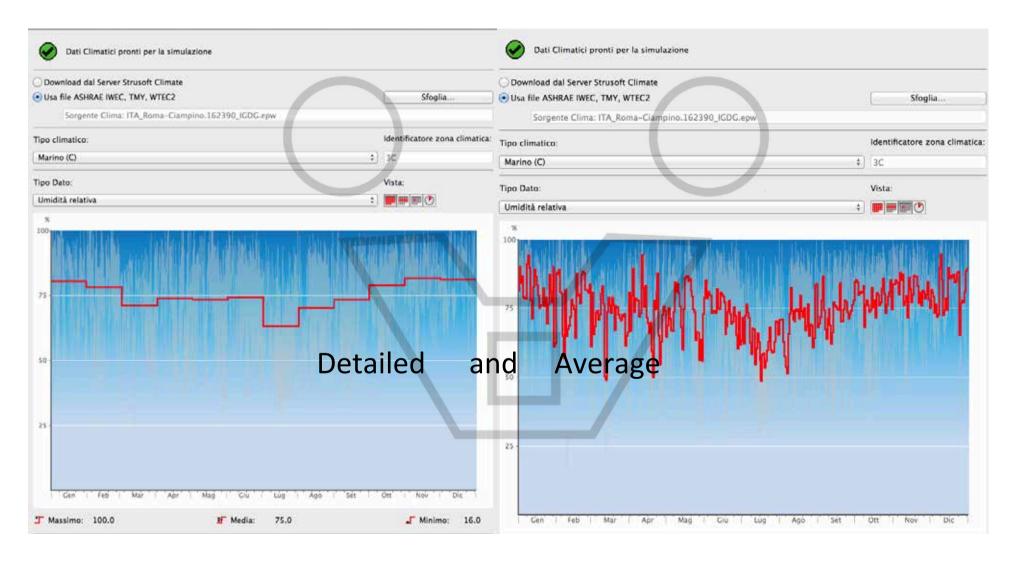
Environmental parameters affecting thermal comfort: AIR TEMPERATURE

Visualization of air temperature in relation with solar radiation

Environmental parameters affecting thermal comfort: HUMIDITY

Visualization of Relative Humidity

Detailed   and   Average

Environmental parameters affecting thermal comfort: HUMIDITY
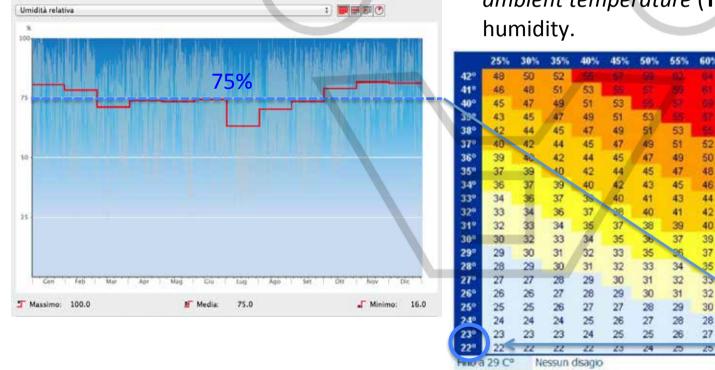
Apparent Temperature (AT)

The **AT** is defined as the temperature, at the reference humidity level, producing the same amount of discomfort as that experienced under the current ambient temperature and humidity.

Basically the **AT** is an adjustment to the *ambient temperature* (**T**) based on the level of humidity.
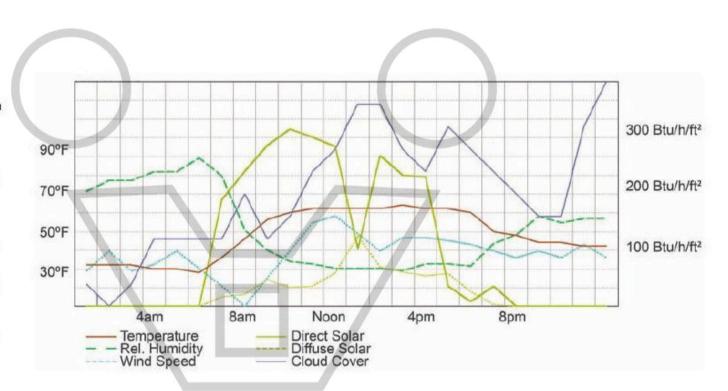
	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
42°	48	50	52	55	57	59	62	64	66	68	71	73	75	77	80	82
41°	46	48	51	53	55	57	59	61	64	66	68	70	72	74	76	79
40°	45	47	49	51	53	55	57	59	61	63	65	67	68	71	73	75
39°	43	45	47	49	51	53	55	57	59	61	63	65	66	68	70	72
38°	42	44	45	47	49	51	53	55	56	58	60	62	64	66	67	69
37°	40	42	44	45	47	49	51	52	54	56	58	59	61	63	65	66
36°	39	40	42	44	45	47	49	50	52	54	55	57	59	60	62	63
35°	37	39	40	42	44	45	47	48	50	51	53	54	56	58	59	61
34°	36	37	39	40	42	43	45	46	48	49	51	52	54	55	57	58
33°	34	36	37	38	40	41	43	44	46	47	48	50	51	53	54	55
32°	33	34	36	37	38	40	41	42	44	45	46	48	49	50	52	53
31°	32	33	34	35	37	38	39	40	42	43	44	45	47	48	49	50
30°	30	32	33	34	35	36	37	39	40	41	42	43	45	46	47	48
29°	29	30	31	32	33	35	36	37	38	39	40	41	42	43	45	46
28°	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
27°	27	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
26°	26	26	27	28	29	30	31	32	33	34	34	35	36	37	38	39
25°	25	25	26	27	27	28	29	30	31	32	33	34	34	35	36	37
24°	24	24	24	25	26	27	28	28	29	30	31	32	33	33	34	35
23°	23	23	23	24	25	25	26	27	28	28	29	30	31	32	32	33
22°	22	22	22	22	23	24	25	25	26	27	27	28	29	30	30	31

Fino a 29 C°	Nessun disagio
Da 30 a 34 C°	Sensazione di disagio
Da 35 a 39 C°	Intenso disagio. Prudenza: limitare le attività fisiche più pesanti
Da 40 a 45 C°	Forte sensazione di malessere. Pericolo: evitare gli sforzi
Da 46 a 53 C°	Pericolo grave: interrompere tutte le attività fisiche
Oltre 54 C°	Pericolo di morte: colpo di calore imminente

Relationship between Temperature and Humidity

4.5
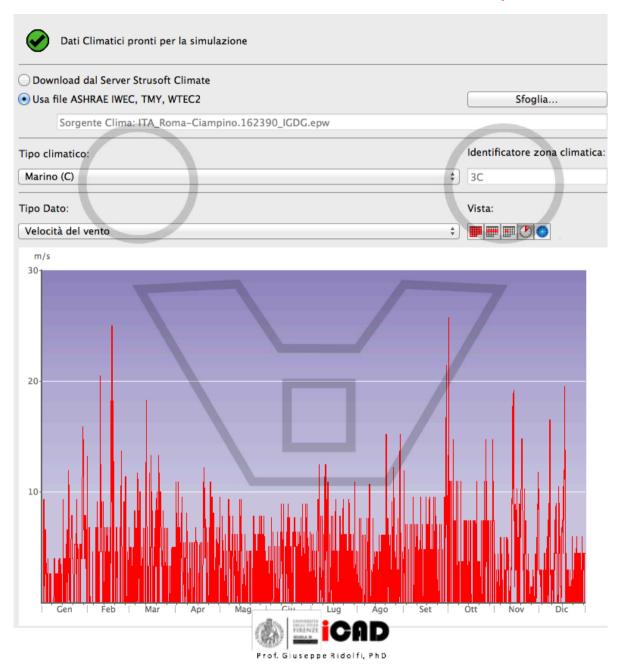
A 24-hour period set of data from a weather file shows the interaction of the dry bulb temperature, the relative humidity, the direct solar, diffuse solar, wind speed and cloud cover. Note the inverse relationship of temperature and humidity; direct and diffuse solar irradiation; and the inconsistent relationship between cloud cover and direct solar.

Source: Autodesk Ecotect Suite output of EnergyPlus weather data. Courtesy of Callison.

Environmental parameters affecting thermal comfort: WIND
Wind Velocity
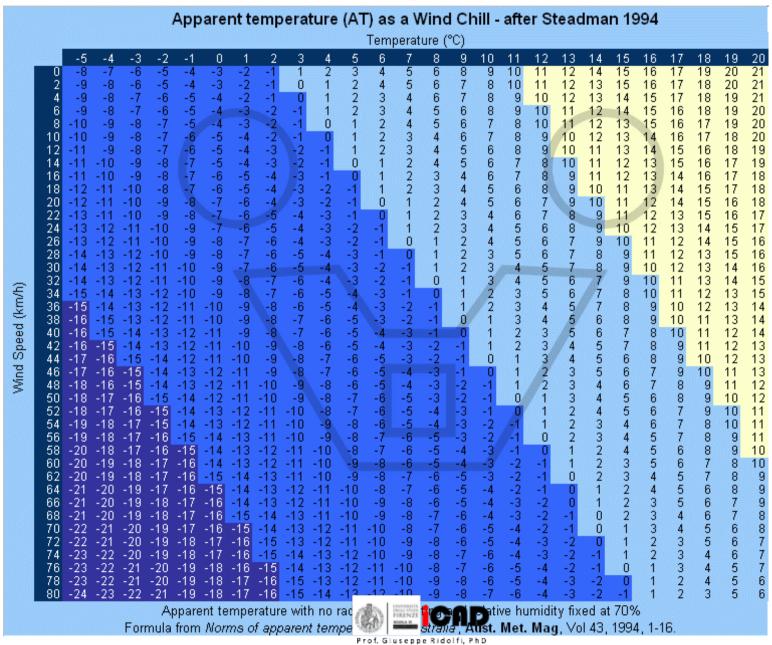
Environmental parameters affecting thermal comfort: HUMIDITY

Effect of Wind on Temperature

Apparent temperature (AT) as a Wind Chill - after Steadman 1994

HOW TO EVALUATE ENERGY PERFORMANCE

GREEN METRICS , CERTIFICATION & TARGETING

Prof. Giuseppe Ridolfi, PhD

Baseline solution or standardized metrics

Voluntary certifications

international sustainable building certification program

- <u>LEED</u> - Leadership in Energy and Environmental Design- U.S. Green Building Council (USGBC),
- <u>NZE</u> - Nearly Zero Energy > Net Zero Energy
- <u>LBC</u> - Living Building Challenge, 2006, International Living Future Institute.
- <u>ENERGY STAR,</u> U.S. Environmental Protection Agency in conjunction with the U.S. Department of Energy
- <u>NATIONAL GREEN BUILDING STANDARD,</u> National Association of Home Builders (NAHB)
- <u>GREENGUARD, Greenguard</u> 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

is a voulantary standard
based on EUI (often 4,75 kBtu/ft2) clodes to 2020

- Fabbisogno termico per riscaldamento ≤ 15 kWh/(m²a)
oppure: Carico termico specifico ≤ 10 W/m²
- Fabbisogno frigorifero per raffrescamento ≤ 15 kWh/(m²a)
- Tenuta all'aria n_{50} ≤ 0,6 h^{-1}
- Fabbisogno di energia primaria ≤ 120 kWh/(m²a)
- Basso surriscaldamento estivo (n. gg. < 10% con T_i > 25 °C)

Mentre **è consigliato** ma non obbligatorio soddisfare questi
altri parametri:
- Progettazione senza ponti termici < 0,01 W/mK
- Serramenti a taglio termico U_w ≤ 0,8 W/m²K
- 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

Prof. Giuseppe Ridolfi, PhD

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)

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
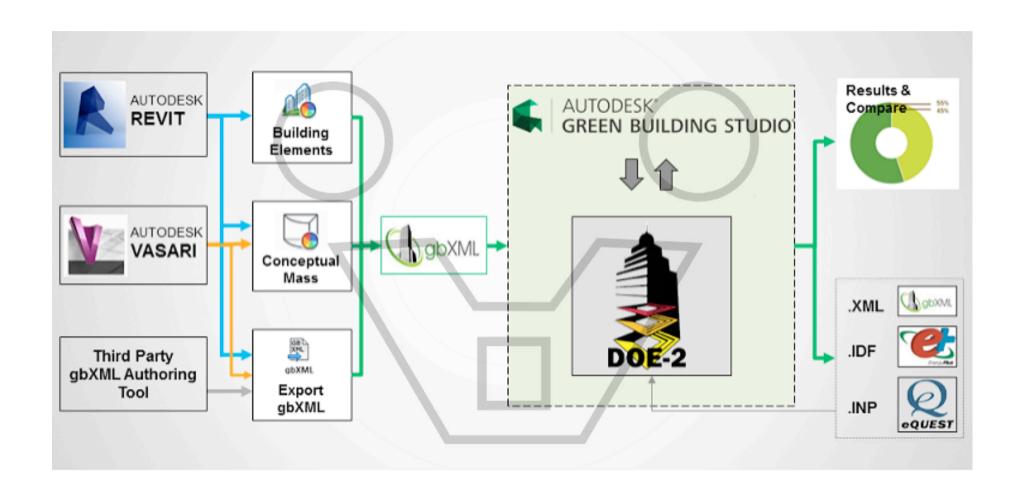
Other parameters used in energy modeling

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
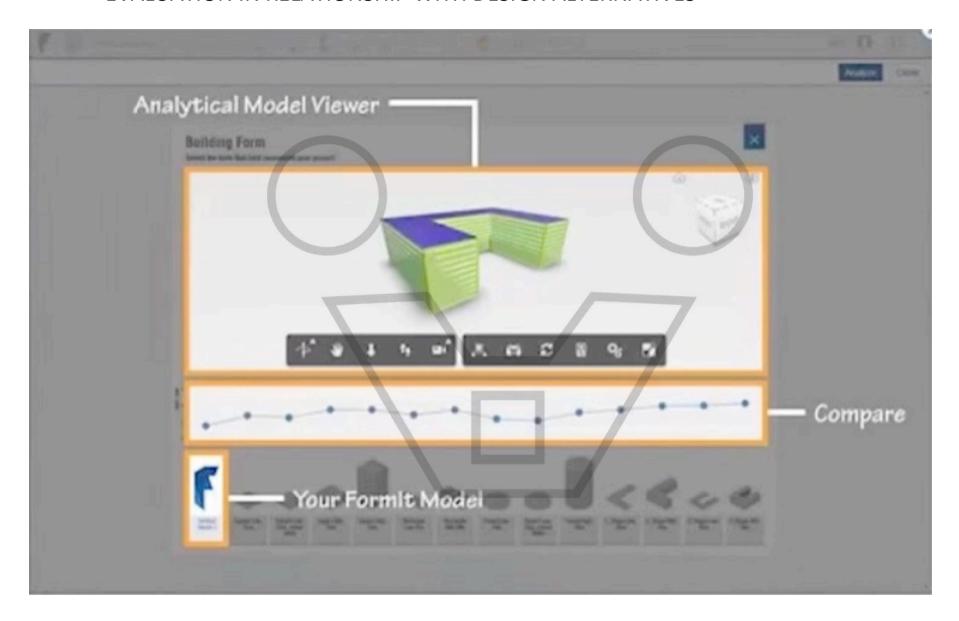
Infiltration or air leakage is caused by air entering or leaving the building due to unintentional gaps in the building envelope. The outside air infiltrated into the inner space would cool or heat interior spaces through convection and make the envelope insulation redundant. The air leakage from inside 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.
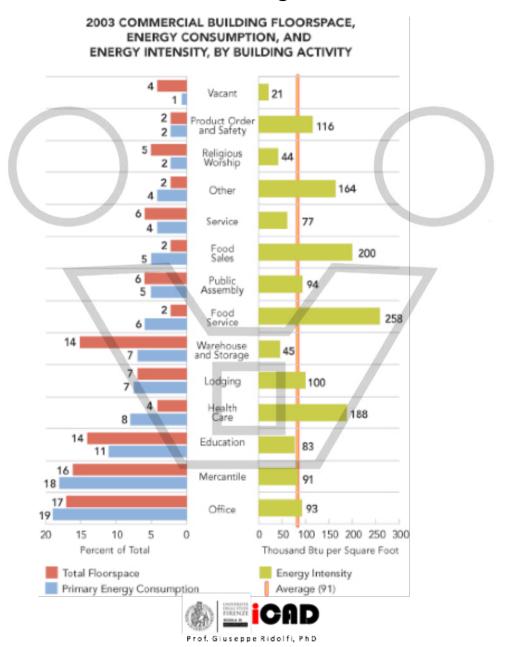
EVALUATION IN RELATIONSHIP WITH DESIGN ALTERNATIVES
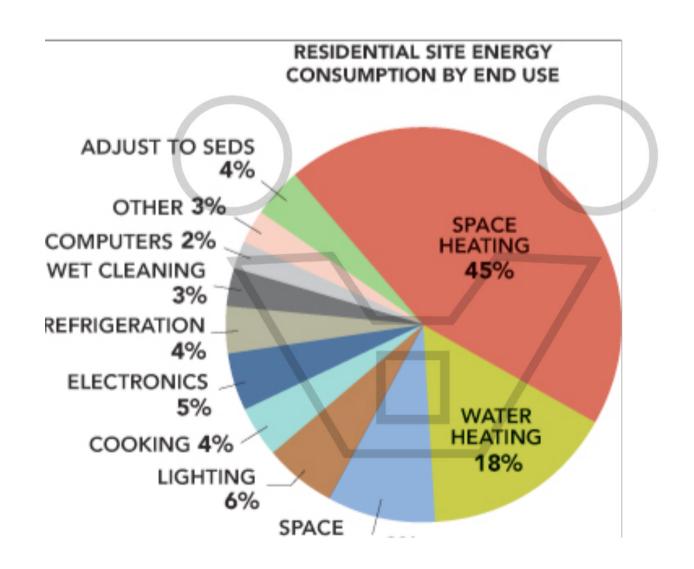
EVALUATION IN RELATIONSHIP WITH
BASELINE SOLUTION based on current average benchmark

2003 COMMERCIAL BUILDING FLOORSPACE, ENERGY CONSUMPTION, AND ENERGY INTENSITY, BY BUILDING ACTIVITY

EVALUATION IN RELATIONSHIP WITH BASELINE SOLUTION
based on current average benchmark

RESIDENTIAL SITE ENERGY CONSUMPTION BY END USE

ADJUST TO SEDS 4%
OTHER 3%
COMPUTERS 2%
WET CLEANING 3%
REFRIGERATION 4%
ELECTRONICS 5%
COOKING 4%
LIGHTING 6%
SPACE
SPACE HEATING 45%
WATER HEATING 18%

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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

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.

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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/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"

iCAD

Commercial Space / Building Type	Site EUI			Commercial Space / Building Type	Site EUI kWh/m², yr		
	med	70%	90%		med	70%	90%
ATLANTIC				**MANITOBA**			
Wholesale Trade	436.1	130.8	43.6	Wholesale Trade	433.4	130.0	43.3
Retail Trade	525.0	157.5	52.5	Retail Trade	527.8	158.3	52.8
Transportation & Warehousing	319.5	95.8	31.9	Transportation & Warehousing	394.5	118.3	39.4
Information & Cultural Industries	558.4	167.5	55.8	Information & Cultural Industries	536.9	161.7	53.9
Offices	405.6	121.7	40.6	Offices	422.3	126.7	42.2
Educational Services	444.5	133.3	44.4	Educational Services	486.2	145.8	48.6
Healthcare & Social Assistance	738.9	221.7	73.9	Healthcare & Social Assistance	780.6	234.2	78.1
Arts, Entertainment & Recreation	497.3	149.2	49.7	Arts, Entertainment & Recreation	458.4	137.5	45.8
Accommodation & Food Service	719.5	215.9	72.0	Accommodation & Food Service	794.5	238.4	79.5
Other Services	391.7	117.5	39.2	Other Services	463.9	139.2	46.4
QUEBEC				**SASKATCHEWAN**			
Wholesale Trade	527.8	158.3	52.8	Wholesale Trade	566.7	170.0	56.7
Retail Trade	563.9	169.2	56.4	Retail Trade	725.1	217.5	72.5
Transportation & Warehousing	452.8	135.8	45.3	Transportation & Warehousing	497.3	149.2	49.7
Information & Cultural Industries	780.6	234.2	76.1	Information & Cultural Industries	711.2	213.4	71.1
Offices	452.8	135.8	45.3	Offices	563.9	169.2	56.4
Educational Services	561.2	168.3	56.1	Educational Services	600.0	180.0	60.0
Healthcare & Social Assistance	905.6	271.7	90.6	Healthcare & Social Assistance	788.2	235.9	78.6
Arts, Entertainment & Recreation	661.2	198.3	66.1	Arts, Entertainment & Recreation	583.4	175.0	58.3
Accommodation & Food Service	894.5	268.4	89.5	Accommodation & Food Service	827.8	248.4	82.8
Other Services	505.6	151.7	50.6	Other Services	563.9	169.2	56.4
ONTARIO				**ALBERTA**			
Wholesale Trade	463.9	139.2	46.4	Wholesale Trade	413.9	124.2	41.4
Retail Trade	469.5	140.8	46.9	Retail Trade	500.0	150.0	50.0
Transportation & Warehousing	394.5	118.3	39.4	Transportation & Warehousing	369.5	110.8	36.9
Information & Cultural Industries	444.5	133.3	44.4	Information & Cultural Industries	508.4	152.5	50.8
Offices	397.3	119.2	39.7	Offices	380.6	114.2	38.1
Educational Services	452.8	135.8	45.3	Educational Services	425.0	127.5	42.5
Healthcare & Social Assistance	697.3	209.2	69.7	Healthcare & Social Assistance	616.7	185.0	61.7
Arts, Entertainment & Recreation	502.8	150.8	50.3	Arts, Entertainment & Recreation	463.9	139.2	46.4
Accommodation & Food Service	666.7	200.0	66.7	Accommodation & Food Service	725.1	217.5	72.5
Other Services	436.1	130.8	43.6	Other Services	391.7	117.5	39.2
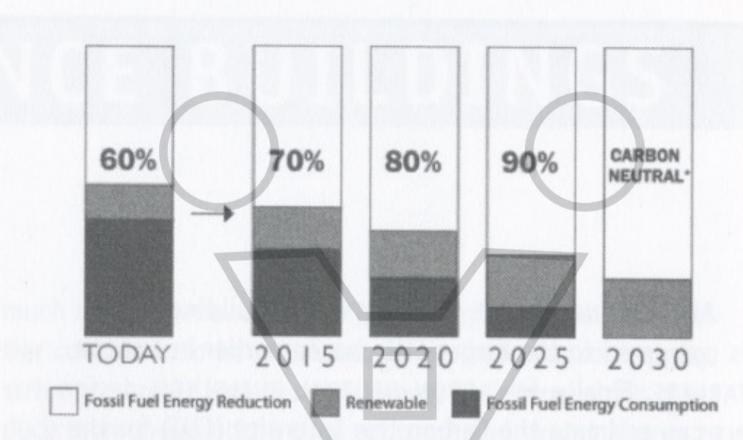
Energy Use Intensity (EUI) Targets, Canadian Commercial Buildings, Provincial Averages, kWh/m²/yr

Derived from Natural Resources Canada, Office of Energy Efficiency, Comp[...] Use Database. Multiply kWh x [...]

60% **70%** **80%** **90%** CARBON NEUTRAL*

TODAY   2015   2020   2025   2030

☐ Fossil Fuel Energy Reduction   ▨ Renewable   ▨ Fossil Fuel Energy Consumption

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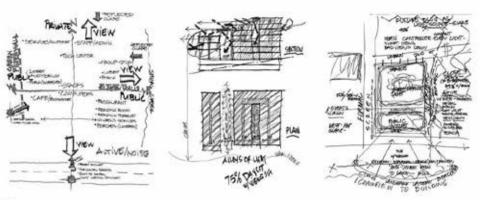
The Architecture 2030 Challenge allows up to 20% of the overall energy reduction to come from off-site renewable energy. The carbon-neutral target uses no fossil fuel/GHG-emitting energy to operate.

5.2

For the kick-off eco-charette 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 ambient 35fc task	side/ top	N or S	—
private office	8am–6pm	Y	Y	Y	Y	N	20fc ambient 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	at reception desk		N	15fc ambient	side/ top	N or S	ground floor
training space	8am–5pm	N	Y	Y	Y	Y	20fc	side		interior, with views

Prof. Giuseppe Ridolfi, PhD

Results for Estimated Energy Use

Energy	Design	Target	Median Building
Energy Performance Rating (1-100)	N/A	99	50
Energy Reduction (%)	N/A	80	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			
CO2-eq Emissions (metric tons/year)	N/A	745	1,861
CO2-eq Emissions Reduction (%)	N/A	80%	0%

Facility Information   Edit

81658
United States

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

Estimated Design Energy			Edit
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	$ 0.003/kBtu

* The Median Building is equivalent to an EPA Energy Performance Rating of 50.

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.

In any case the optimized solution is a compromise between different aspects
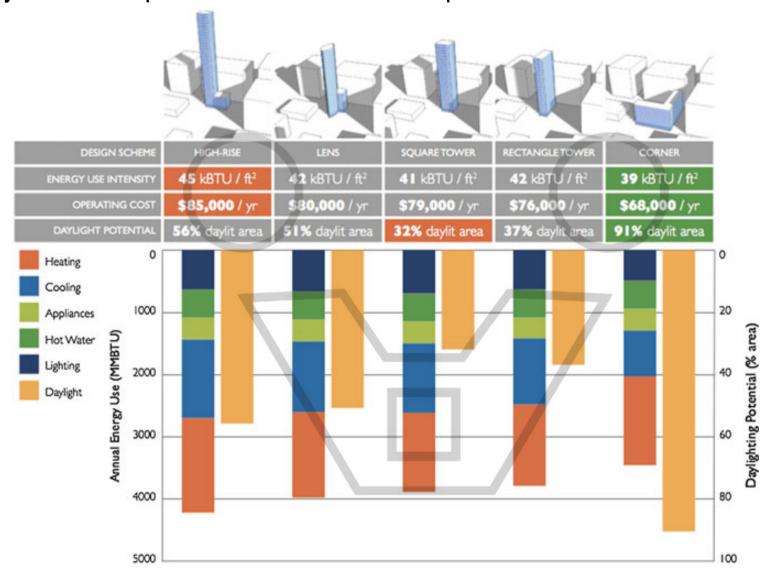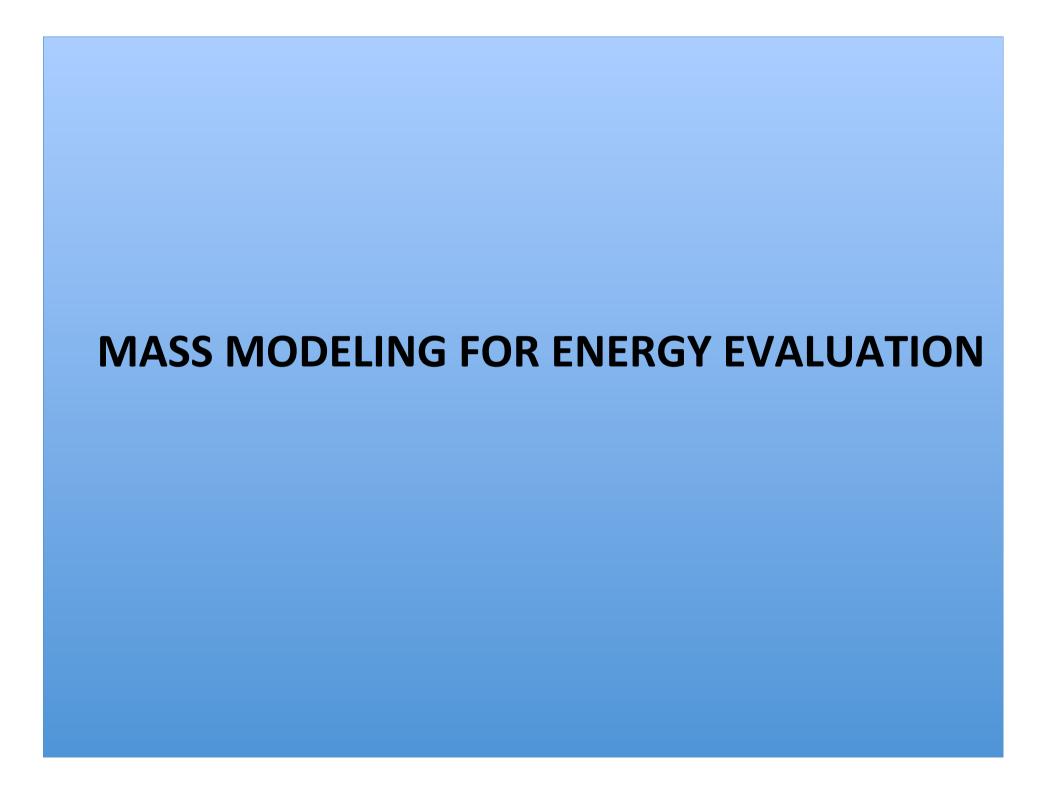
Fig. 4.4 Massing options and implication on building performance (Sefaira 2013)

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
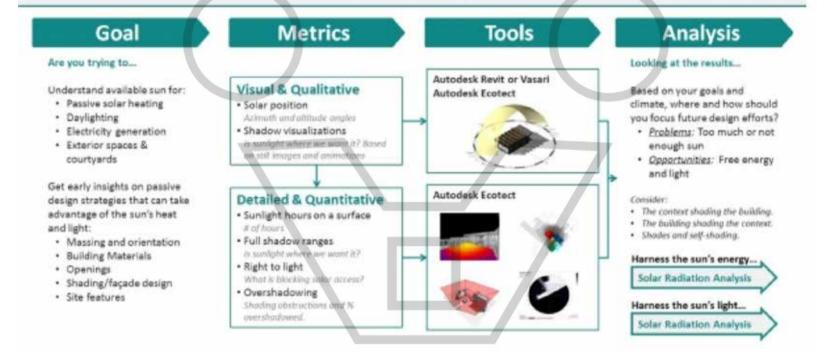
"Massing" is the architectural term used when determining the overall layout (e.g. compact or spread-out), shape (e.g. square, rectangle, oval), size (e.g. height, length, width) and form factor (more solid or porous with cut-outs) of the building. Massing choices depend on the project specifics such 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 orien- tation 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

Goal

Are you trying to...

Understand available sun for:
- Passive solar heating
- Daylighting
- Electricity generation
- Exterior spaces & courtyards

Get early insights on passive design strategies that can take advantage of the sun's heat and light:
- Massing and orientation
- Building Materials
- Openings
- Shading/façade design
- Site features

Metrics

Visual & Qualitative
- Solar position
  Azimuth and altitude angles
- Shadow visualizations
  Is sunlight where we want it? Based on still images and animations

Detailed & Quantitative
- Sunlight hours on a surface
  # of hours
- Full shadow ranges
  Is sunlight where we want it?
- Right to light
  What is blocking solar access?
- Overshadowing
  Shading obstructions and % overshadowed.

Tools

Autodesk Revit or Vasari
Autodesk Ecotect

Autodesk Ecotect

Analysis

Looking at the results...

Based on your goals and climate, where and how should you focus future design efforts?
- *Problems*: Too much or not enough sun
- *Opportunities*: Free energy and light

Consider:
- *The context shading the building.*
- *The building shading the context.*
- *Shades and self-shading.*

Harness the sun's energy...
Solar Radiation Analysis

Harness the sun's light...
Solar Radiation Analysis

Autodesk Sustainability Workshop

Autodesk

Prof. Giuseppe Ridolfi, PhD

Level 3 – Space & Zone Thermal Properties

ENERGY CONCEPTUAL MASS MODELING: A NEW WAY TO DESIGN

Level 3 – Overall Energy Model Geometry Accuracy

Energy Model Components	Physical	Energy	Difference
Spaces - Floor area (ft²)	5,719	5,725	0.1%
Spaces - Volume (ft³)	73,564	71,920	-2.2%
Surfaces - Roofs (ft²)	1,291	1,212	-6.1%
Surfaces - Exterior walls (ft²)	8,144	7,858	-3.5%
Surfaces - Interior walls (ft²)	5,582	5,376	-3.7%
Surfaces - Interior floors (ft²)	4,521	4,818	6.6%
Surfaces - Underground walls (ft²)	2,375	2,324	-2.1%
Surfaces - Underground slabs (ft²)	2,244	2,182	-2.8%
Surfaces - Doors (ft²)	368	358	-2.7%
Surfaces - Fixed windows (ft²)	1,867	1,889	1.2%
Surfaces - Operable windows (ft²)	309	301	-2.6%
Average Difference			**-1.6%**

BIM w/ Known Physical Measures

Energy Model

FormIt primitives representing 'conceptual mass forms'

FormIt primitives representing 'design detail'

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

Building Construction

Construction Types

<Building>

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·ft²·°F))
Exterior Walls	☑	8 in lightweight concrete block (U=0.1428 BTU/(h·ft²·°F))
Interior Walls	☑	Frame partition with 3/4 in gypsum board (U=0.2595 BTU/(h·ft²·°F))
Ceilings	☑	8 in lightweight concrete ceiling (U=0.2397 BTU/(h·ft²·°F))
Floors	☑	Passive floor, no insulation, tile or vinyl (U=0.5210 BTU/(h·ft²·°F))
Slabs	☑	Un-insulated solid (U=0.1243 BTU/(h·ft²·°F))
Doors	☑	Metal (U=0.6520 BTU/(h·ft²·°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·ft²·°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

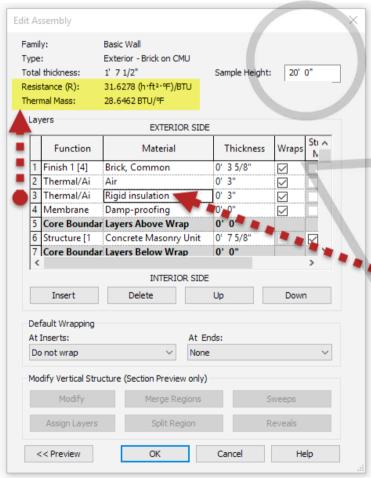| Mass Model	Constructions
Mass Exterior Wall	Lightweight Construction – Typical Mild Climate Insulation
Mass Interior Wall	Lightweight Construction – No Insulation
Mass Exterior Wall - Underground	High Mass Construction – Typical Mild Climate Insulation
Mass Roof	Typical Insulation - Cool Roof
Mass 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

Prof. Giuseppe Ridolfi, PhD

Architectural & Energy Analytical Model elements…

Concept → → → Detail

Conceptual Massing elements →
With and w/o Mass Floors
% Glazing, Perimeter/Core Zoning etc.

Architectural Building elements →
Walls, Roofs, Floors, Windows,
Curtain Panels, Ceilings etc.

Rooms / Spaces & Zones
Occupancy, Lighting, Equipment,
Outdoor air, Set-Points etc.

Energy Analytical Model elements
(Automatically created from elements above / No editing)

Analytical Spaces
Properties:
- Floor Area
- Volume
- Name (Room/Space)

Analytical Surfaces
Properties:
- Surface Type
- Area
- Orientation & Tilt

gbXML (Spaces, Surfaces etc.)

Energy Analysis with Revit 2016...

Energy Model

Analysis Mode	Use Conceptual Masses and Building Elements

Use Building Elements
Use Conceptual Masses
Use Conceptual Masses and Building Elements

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

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

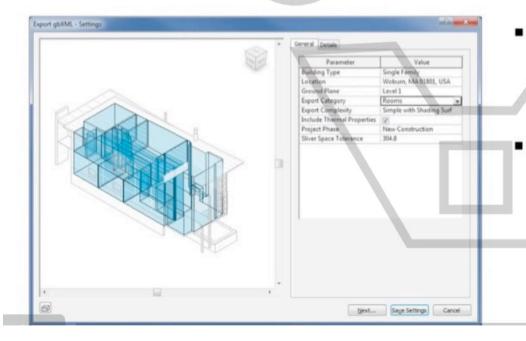3D View   3D Energy Model View

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
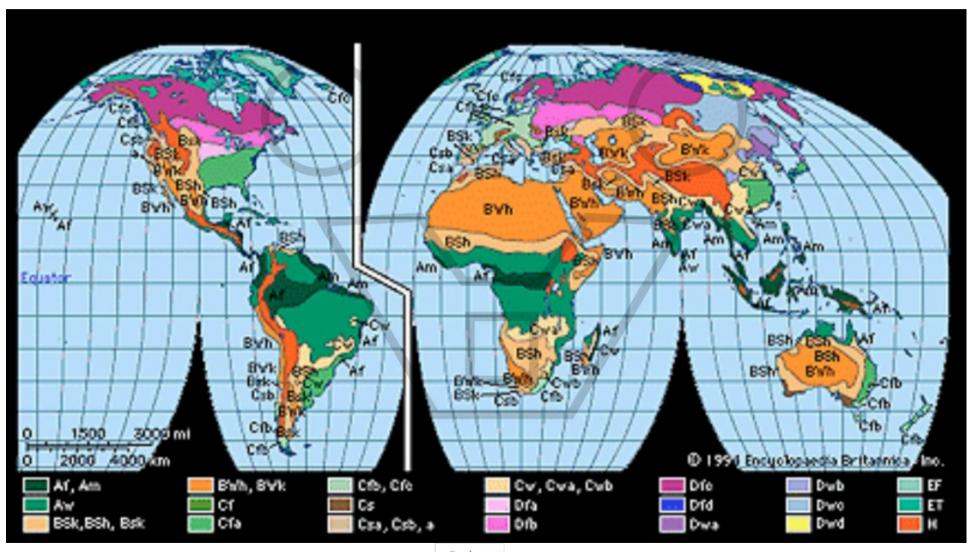
- Interoperability is the key to successfully using BIM software tools

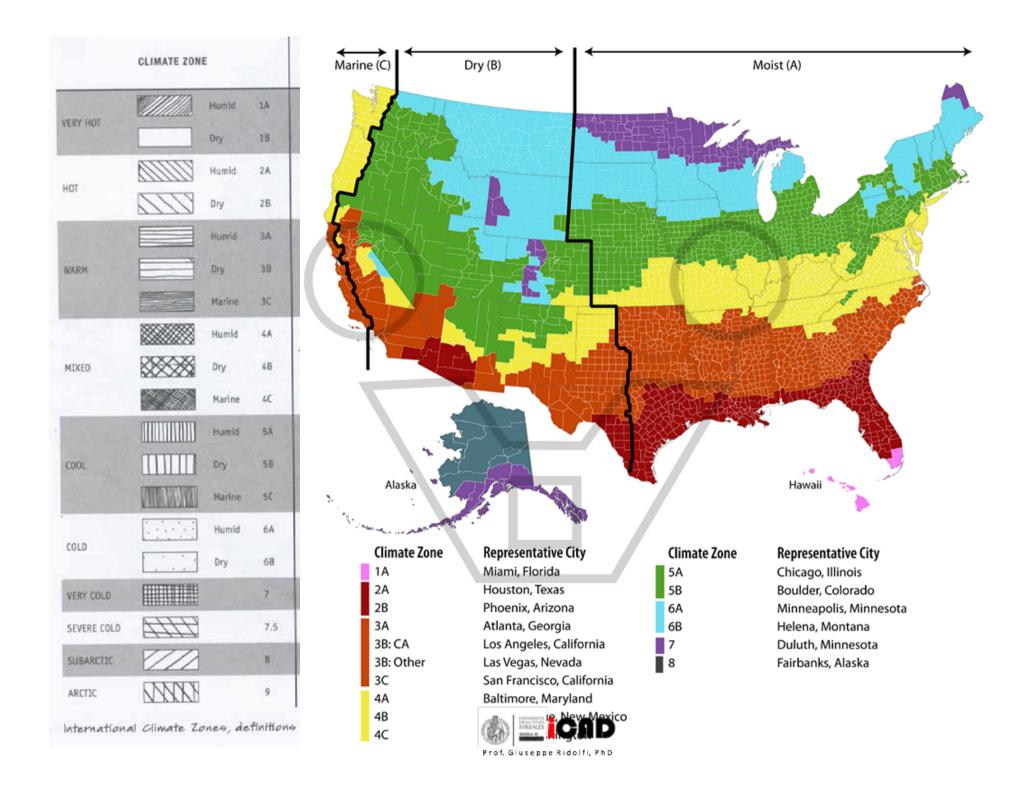- It minimizes the human involvement and translation errors

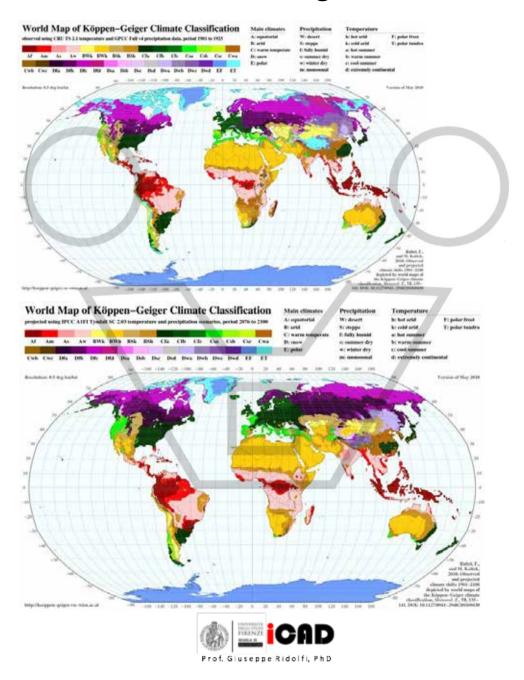# 12 STEPS PASSIVE STRATEGIES
IN MASS MODELING

Prof. Giuseppe Ridolfi, PhD

1- Find your climate zone

CLIMATE ZONE

VERY HOT		Humid	1A
		Dry	1B
HOT		Humid	2A
		Dry	2B
WARM		Humid	3A
		Dry	3B
		Marine	3C
MIXED		Humid	4A
		Dry	4B
		Marine	4C
COOL		Humid	5A
		Dry	5B
		Marine	5C
COLD		Humid	6A
		Dry	6B
VERY COLD			7
SEVERE COLD			7.5
SUBARCTIC			8
ARCTIC			9

International Climate Zones, definitions

Marine (C)   Dry (B)   Moist (A)

Alaska

Hawaii

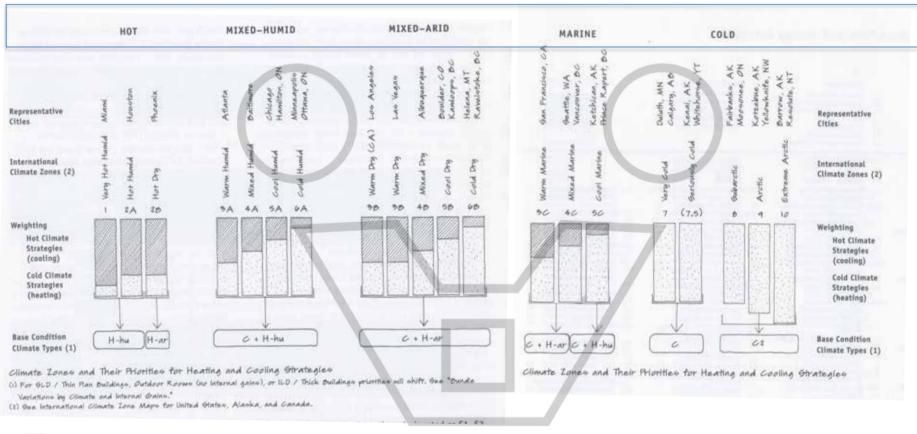| Climate Zone	Representative City	Climate Zone	Representative City
1A	Miami, Florida	5A	Chicago, Illinois
2A	Houston, Texas	5B	Boulder, Colorado
2B	Phoenix, Arizona	6A	Minneapolis, Minnesota
3A	Atlanta, Georgia	6B	Helena, Montana
3B: CA	Los Angeles, California	7	Duluth, Minnesota
3B: Other	Las Vegas, Nevada	8	Fairbanks, Alaska
3C	San Francisco, California		
4A	Baltimore, Maryland		
4B	le, New Mexico		
4C	ngton		

Prof. Giuseppe Ridolfi, PhD

2- Tune-Up your climate zone considering the climate evolution and site

3. Select the main energy behaviour according with climate zone

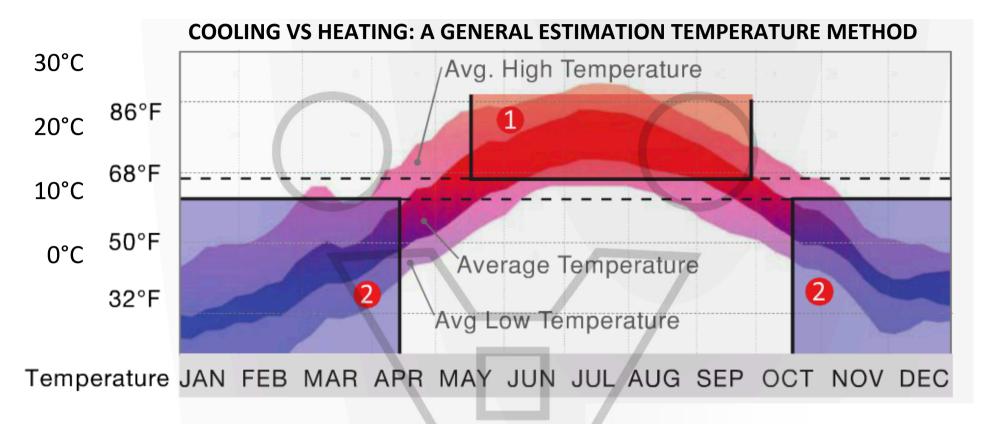To be cooled

To be heated

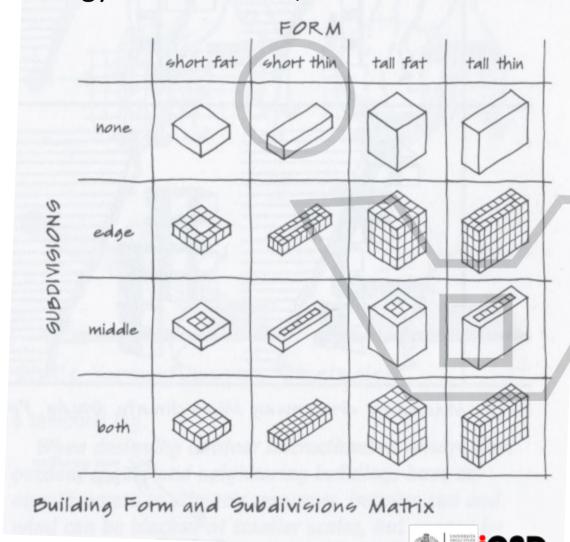# 4. Confirm the main energy behaviour with conceptual energy analysis

COOLING VS HEATING: A GENERAL ESTIMATION TEMPERATURE METHOD

7.3 Temperature Method. Annual temperature profile, with estimated heating and cooling seasons highlighted.

Source: Ecotect outputs of annual weather data from Central Park in New York City.

iCAD

Prof. Giuseppe Ridolfi, PhD

5. Select the mass types according to functional destination, architectural image, energy consideration,···

Building Form and Subdivisions Matrix

Prof. Giuseppe Ridolfi, PhD

Short Fat/Thick *(internal load dominant)* are the current type for commercial buildings, manufacturing,…

Short Thin/Skin *(skin dominant)* are the current type for housing schools,..

Tall Fat/Thick *((internal load dominant)* are the current type for hospitals, offices,…

Tall Thin/Skin *(skin dominant)* are the current type for housing, offices, schools,…

Compact or Thick buildings have less dissipation and works better in cold climate, but have a limited possibilities for passive design

Skin dominant buildings allows a better ventilation and daylight, but have an higher dissipation. They works fine for passive design

Tall buildings have less roof solar radiation, better for cooling strategies

Compact or **Thick** buildings have less dissipation and works better in cold climate, but have a limited possibilities for passive design

Skin dominant buildings allows a better ventilation and daylight, but have an higher dissipation. They works fine for passive design

6. Define the main energy strategies according with mass types

CLIMATE	PERCEIVED CLIMATIC CONDITION	ILD/THICK BUILDING	SLD/THIN BUILDING	OUTDOOR ROOMS
COLD	Heating Dominated	C + H-hu C + H-ar	C	C2
MIXED	Combined Heating & Cooling	H–hu H–ar	C + H–hu C + H–ar	C
HOT HUMID	Cooling Dominated: Humid	H2–hu	H–hu	C + H–hu
HOT ARID	Cooling Dominated: Arid	H2–ar	H–ar	C + H–ar
		HIGH INTERNAL GAINS	LOW INTERNAL GAINS	NO INTERNAL GAINS

ILD= Internal-Load-Dominated
SLD=Skin-Load Dominated
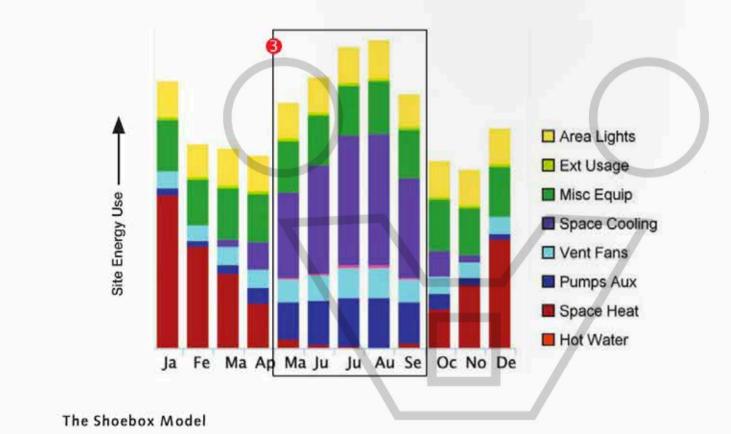C=Cold Bundle
H=Hot Bundle
ar=arid
hu=ventilated dominated
H2=very hot, heavily cooling dominated
C2=heavily heating dominated

7. Tuneup the energy strategy according to more detailed analysis

COOLING vs HEATING: a detailed estimation using Shoebox model

7.4

Shoebox Model Method.
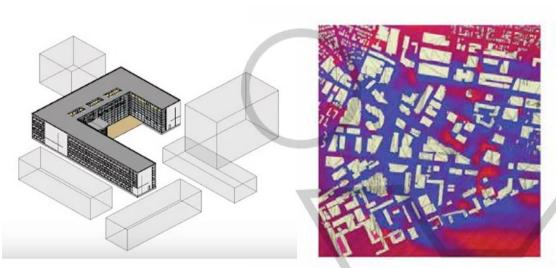Monthly energy use profile for an office floor plate in New York City. The simulation was performed in Green Building Studio using a shoebox model.

The Shoebox Model

A simple, automated shoebox model can generate a more accurate illustration of months requiring shading design. For this analysis, a thermal zone with glazing was uploaded from Autodesk Ecotect to the Green Building Studio to run an EnergyPlus simulation. Months where cooling energy is high (3) are chosen for shading. This example seems to require more cooling than the temperature method example because the shoebox model uses an office typology, where people, equipment, and lighting add heat during the day.

8. Model the context

5.10

Completed wind speed studies were used to mass new structures to block undesirable winter winds through public plazas. This study was completed as part of the Cambridge Master Plan in Boston, using Autodesk Vasari 3D for a Computational Fluid Dynamics simulation, with false colors representing wind speed. Wind is simulated to come from the upper left.

Source: Courtesy of CBT Architects and Planners.
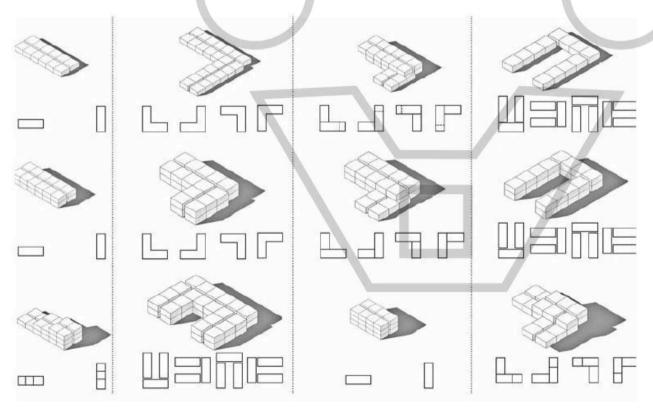
Rapporto superficie/volume

Distribuzione urbana densa vs compatta
Alti edifici vs bassi
Edifici compatti vs bassi
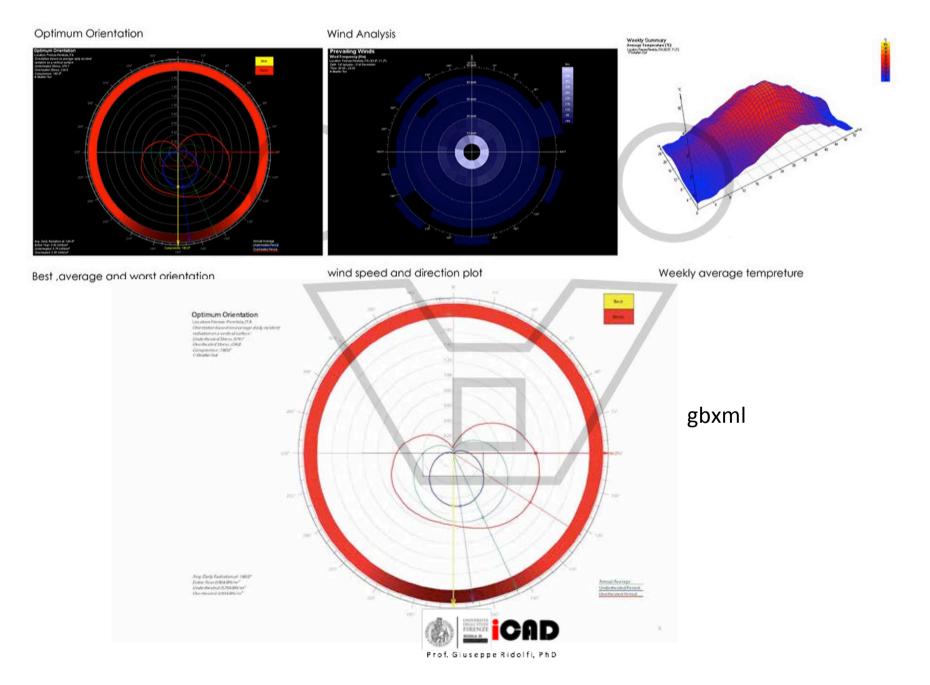
9. Model mass alternatives

Massing

An early step in site planning involves massing the program into geometrical blocks driven by typology, such as linear, double-loaded residential towers and hotels, which tend to be bar buildings between 60' and 75' wide. Most other typologies have standard widths or depths. A shoebox model of one or more typical widths can be used to study skin-to-core depth, orientation, glazing percentage, or other aspects.

5.11
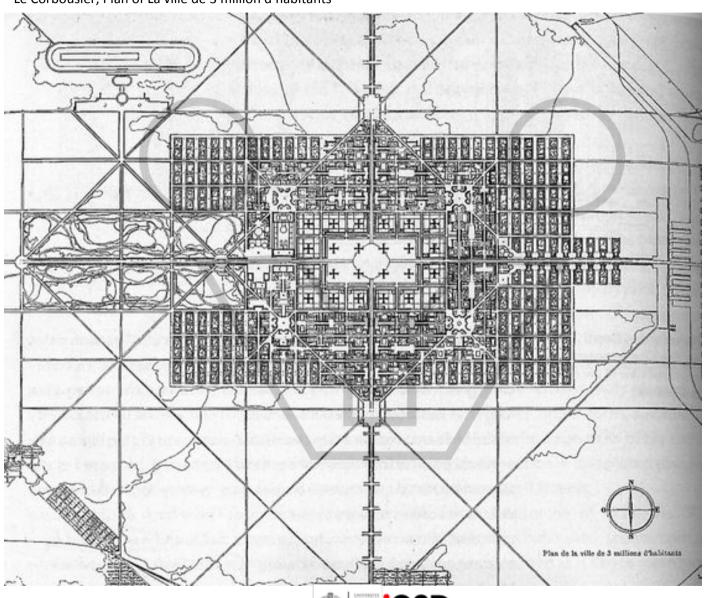
HMC Architects in-house energy simulations specialists, ArchLab, used eQuest to analyze various single- and double-loaded classroom layouts for overall energy use. This study was done using common room layouts and energy data from existing buildings, and serves as a reference for many other projects as well. The team learned that self-shading has a larger impact on energy use than orientation. Over 50 configurations were compared in each of the four orientations, with the team settling on a design with a U-shaped courtyard.

iCAD

Prof. Giuseppe Ridolfi, PhD

10. Define the best mass orientation

Optimum Orientation

Best ,average and worst orientation

Wind Analysis

wind speed and direction plot

Weekly Summary

Weekly average tempreture

gbxml

Prof. Giuseppe Ridolfi, PhD

When Modern Movement used the North-South orientation (+19°)
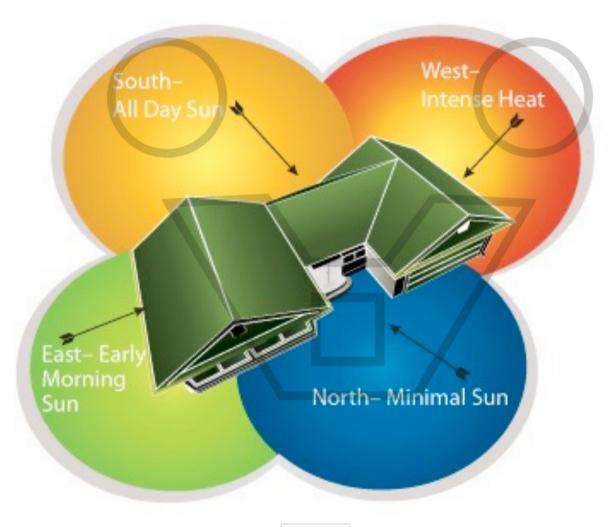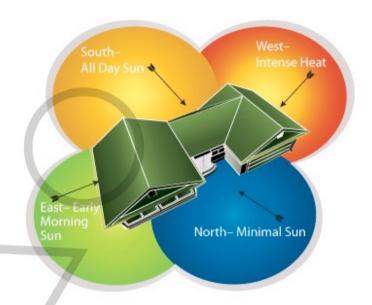
Le Corbousier, Plan of La ville de 3 million d'habitants

Plan de la ville de 3 millions d'habitants

10. Define the best mass orientation

New orientation for Temperate Climate

10. Define the best mass orientation

Orientamento	Periodo estivo	Periodo invernale
Finestre a sud-est	Molto soleggiate - Raggi quasi orizzontali	Molto soleggiate - Raggi quasi orizzontali
Finestre a sud-ovest	Molto soleggiate - Raggi quasi orizzontali	Molto soleggiate - Raggi quasi orizzontali
Finestre a est		Raggi orizzontali
Finestre a ovest		Raggi orizzontali
Finestre a nord	Poco soleggiate	
Finestre a sud	Raggi quasi verticali	Raggi orizzontali
Finestre a nord e nord-ovest	Raggi perpendicolari	Assenza di raggi solari
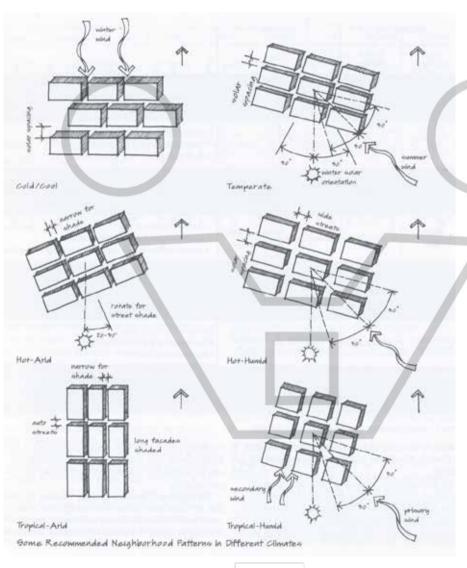
TEMPERATE: exposed facade to South-East-(West)

COLD: exposed facade to West and South with big windows an low sill

ARID: small high windows exposed to East and North to in order to avoid ground radiation

HOT-HUMID: Windows exposed to North-South in order to take advantage of the big pressure difference for ventilation.

10. Define the best mass orientation

Some Recommended Neighborhood Patterns in Different Climates
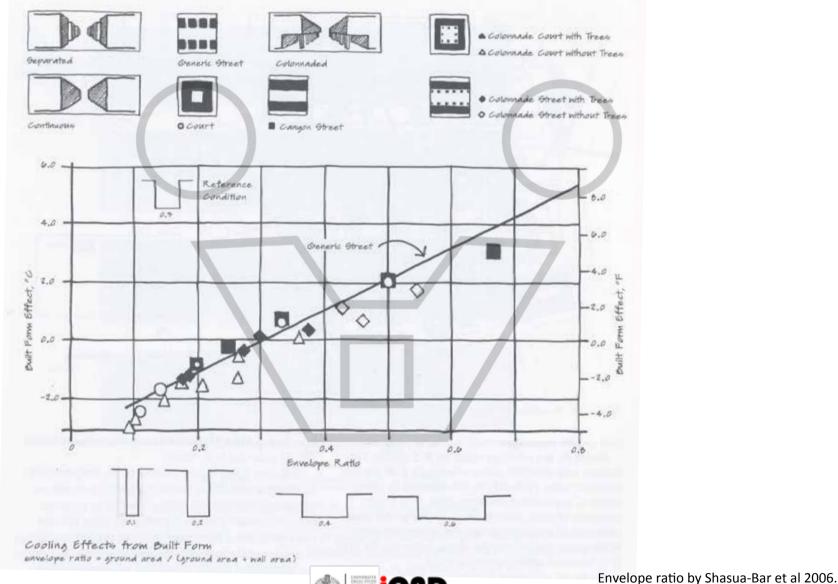
- More orientation flexibility in temperate, hot humid and tropical-humid climate
- Consider to obtain *breezy street* for hot climate,
- Evaluate the effect of dense or desperse urban fabric

10. Define the best mass orientation

Los Angeles

11. Define the neighborhood pattern and model it

Ratio of the ground area between building to the total surface area of the ground and walls

Envelope ratio by Shasua-Bar et al 2006.

11. Define the neighborhood pattern and model it

Canyon Street Forms with Colonnades

VI – V2 = 0.1   VI – V2 = 0.17   VI – V2 = 0.25

Envelope Ratio Difference, VI–V2

VI = Envelope Ratio without colonnades
V2 = Envelope Ratio with colonnades

trees effect

colonnade effect

Trees Effect and Colonnade Effect, °C

Trees Effect and Colonnade Effect, °F

Envelope Ratio

Cooling Effects From Trees and Colonnades
envelope ratio = ground area / (ground area + wall area)

iCAD

Prof. Giuseppe Ridolfi, PhD

11. Define the neighborhood pattern and model it

Units/Acre	Unit Area ft² (m²)		Yard Area ft² (m²)	Setback ft (m)	Solar Access	Type	Building Spacing ft (m)	Building Width ft (m)
21	1500	(139)	1175 (109)	15 (4.6)	100%	Townhouse	62 (19)	20 (6)
22	1500	(139)	875 (81)	15 (4.6)	100%	Townhouse	42 (13)	30 (9)
23	1500	(139)	750 (70)	0 (0)	100%	Townhouse	42 (13)	30 (9)
28	1500	(139)	437 (41)	0 (0)	75%	Townhouse	20 (6)	30 (9)
32	2-1500 (139) 1-750 (70)		600 (56)	15 (4.6)	100%	Stacked Townhouse	42 (13)	30 (9)
38	2-1500 (139) 2-750 (70)		562 (52)	15 (4.6)	100%	Stacked Townhouse	62 (19)	30 (9)
42	2-1500 (139) 2-1200 (112) 2-750 (70)		250 (23)	15 (4.6)	100%	Apartment	30 (9)	80 (24)

Studies of Housing Form and Density for Solar Access

11. Define the neighborhood pattern and model it

Building Height vs. Density for Solar Access

11. Define the neighborhood pattern and model it

Expansion of the Comfort Zone in Outdoor Spaces by Designing with Climate
Left: hourly conditions; Right: conditions after manipulating available hourly sun and wind. Top row: Madison, WI; Bottom: Houston, TX

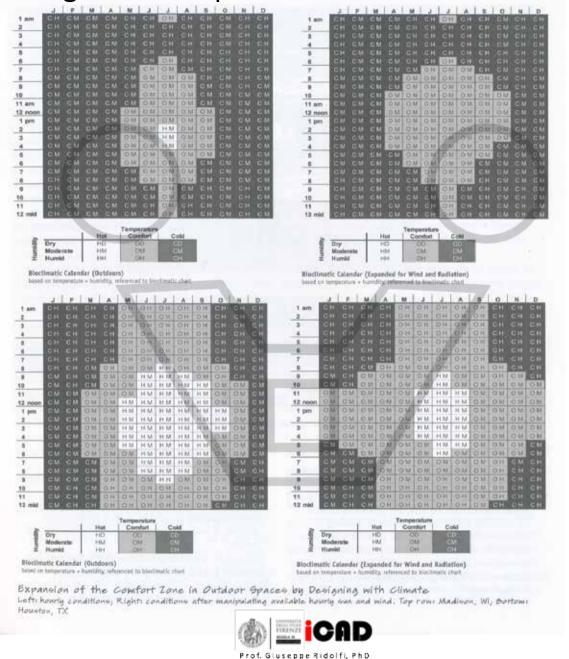# 12. Update the building model: spazial zone and thermal block

Plan and Section Organizations for Solar Heating of Thick Buildings

12. Update the building model: building hight

Solar Collection Surface Area & Building Height

All latitudes, assumes 25'w × 30'd × 12'h (7.6 m × 9 m × 3.7 m) unit, 75% of total solar wall and roof available for collection
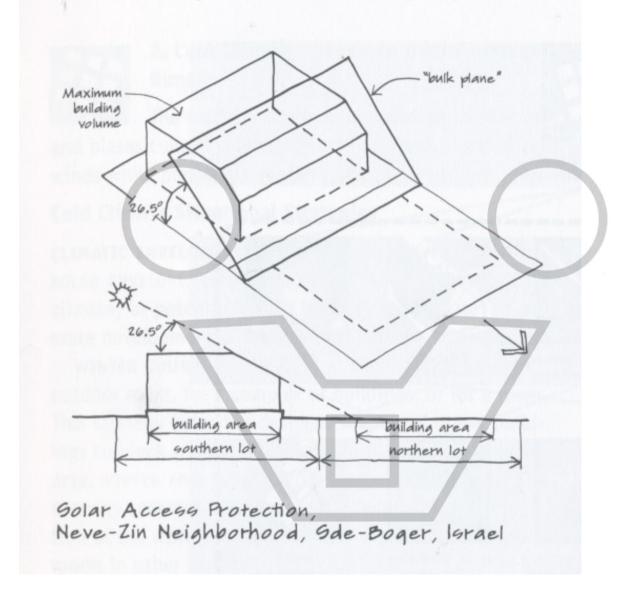
Current Scheme
Design Case

Light Wells
Centralized Core

Increased Floor Height
13'-6" Floor-to-Floor

5% DF

0% DF
Daylight Factor

Miller Hull studied the effects of increasing floor-to-floor height on daylighting for the 6-story, Net Zero Energy targetted Bullitt Center. An early study showed that increasing the floor-to-floor height from 11'4" to 13'6" allowed successful daylighting to be achieved on 65% of the floor plate instead of only 23%.

Source: Courtesy of Miller Hull. Ecotect output of Radiance daylighting analysis.

12. Update the building model: building hight

Solar Access Protection,
Neve-Zin Neighborhood, Sde-Boger, Israel

12. Update the building model: exterior shading elements

Level 3 – Exterior Shading

E.g. Overhanging Roof

E.g. Parapet Walls

E.g. Surrounding Obstructions

16 Autodesk

gbXML   AUTODESK

12. Update the building model: exterior shading elements

House in Tucson, Arizona, Judith Chafee
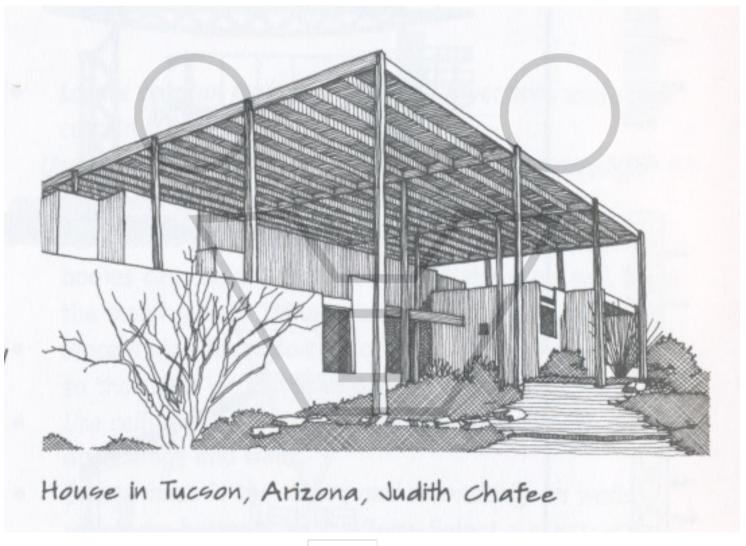
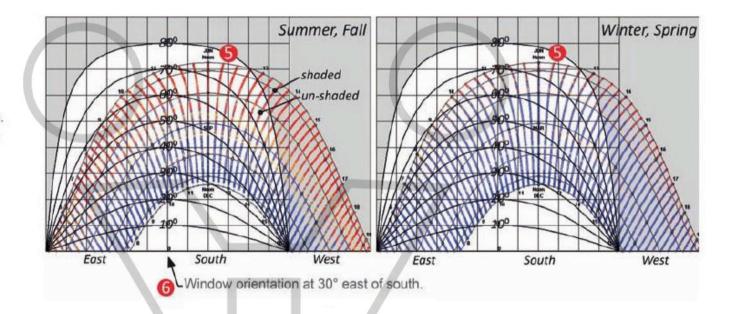# 12. Update the building model: exterior shading elements
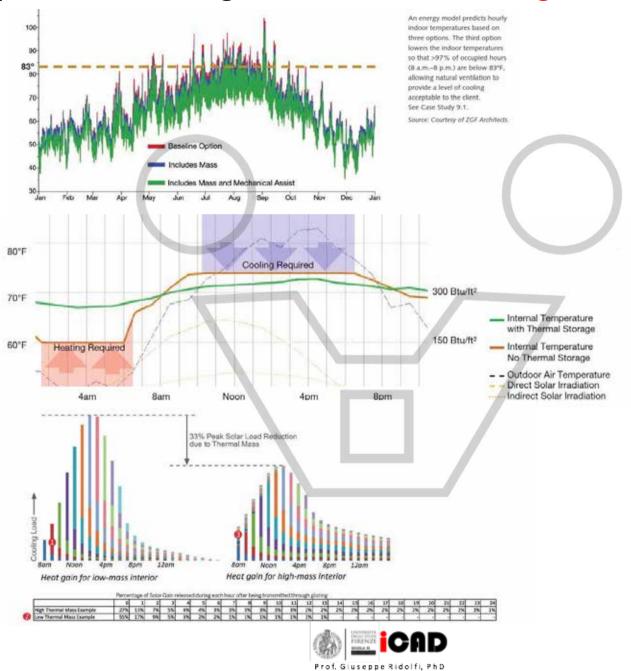
SHADING VOLUMES FROM THE CONTEXT

7.5

Climate Consultant software allows a quick interactive estimation of shading effectiveness at various orientations and shading depths.

Source: Courtesy of UCLA Energy Design Tools Group, http://www.energy-design-tools.aud.ucla.edu/.

Window orientation at 30° east of south.

12. Update the building model: exterior shading elements

An energy model predicts hourly indoor temperatures based on three options. The third option lowers the indoor temperatures so that >97% of occupied hours (8 a.m.–8 p.m.) are below 83°F, allowing natural ventilation to provide a level of cooling acceptable to the client. See Case Study 9.1.

Source: Courtesy of ZGF Architects.

LINKS

Climate Analysis
(https://sustainabilityworkshop.autodesk.com/buildings/climate-analysis)

Solar Position
(https://sustainabilityworkshop.autodesk.com/buildings/solar-position)
The Solar Envelope
(http://www-bcf.usc.edu/~rknowles/sol_env/sol_env.html#anchor471853)
Reading Sun Path Diagrams [video]
(https://sustainabilityworkshop.autodesk.com/buildings/reading-sun-path-diagrams)
Sun and Shadow Studies in BIM
(https://sustainabilityworkshop.autodesk.com/buildings/sun-and-shadow-studies-bim)
Sun and Shadow Studies in BIM –Workflow [video]
(https://www.youtube.com/watch?time_continue=317&v=_LrjmknwPyg)

The difference between source and site energy
(https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager/understand-metrics/difference)

Revit Tutorials: Conceptual Massing
(https://www.youtube.com/watch?v=00Uo8gIc1YU)
Revit Tutorials: Design Options
(https://www.youtube.com/watch?v=b1zNYwjnVPA)
Revit Design Options 1 of 3 [video]
(https://www.youtube.com/watch?v=cGelwjOAvPI)

Energy Analysis Workflows in Revit
(http://help.autodesk.com/view/BUILDING_PERFORMANCE_ANALYSIS/ENU/?guid=GUID-E85A114E-BA0D-4811-B1A5-4EE26462708A)
Revit Energy Analysis Webinar [video] (https://www.youtube.com/watch?v=nFdW913mgLI)
Building Performance Analysis in Revit 2016 R2 with Autodesk Insight 360 (http://www.aecbytes.com/tipsandtricks/2015/issue76-revit.html)

examples
Italian Nursery School: Conceptual Design Analysis
(https://sustainabilityworkshop.autodesk.com/project-gallery/italian-nursery-school-conceptual-design-analysis)
Sustaining Modernity: An Analysis of The Gropius House
(https://sustainabilityworkshop.autodesk.com/project-gallery/sustaining-modernity-analysis-gropius-house)