



Analysis Methods and Tools (I)



Ir Dr. Sam C. M. Hui

Department of Mechanical Engineering

The University of Hong Kong

E-mail: cmhui@hku.hk

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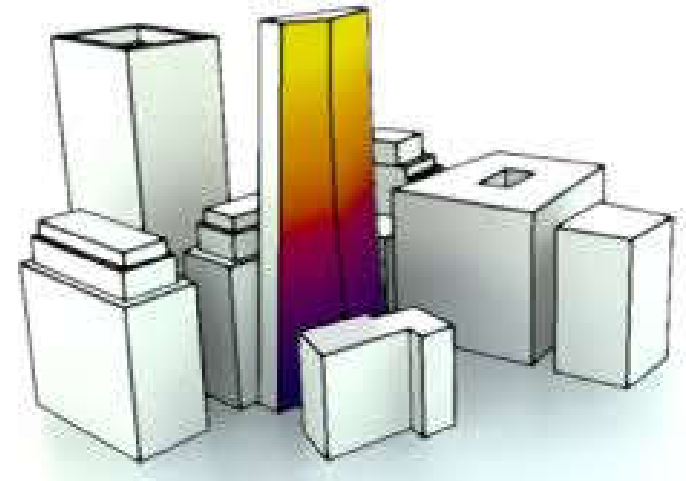


- Project phases and analysis
- Building design tools
- Building performance analysis
- Climate analysis examples

Project phases and analysis



- Sustainable Building Projects
 - Require evaluation of building performance
- Typical analyses for sustainable buildings:
 - Climate analysis
 - Solar & daylighting analysis
 - Building energy analysis
 - Air flow & ventilation analysis
 - Life cycle analysis
 - Carbon analysis



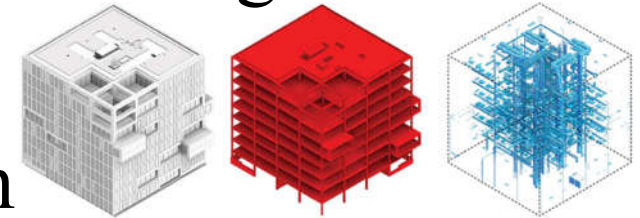
Project phases and analysis



- Building Information Modeling (BIM)

- An approach to design that uses intelligent 3D computer models to create, modify, share, and coordinate information throughout the design process

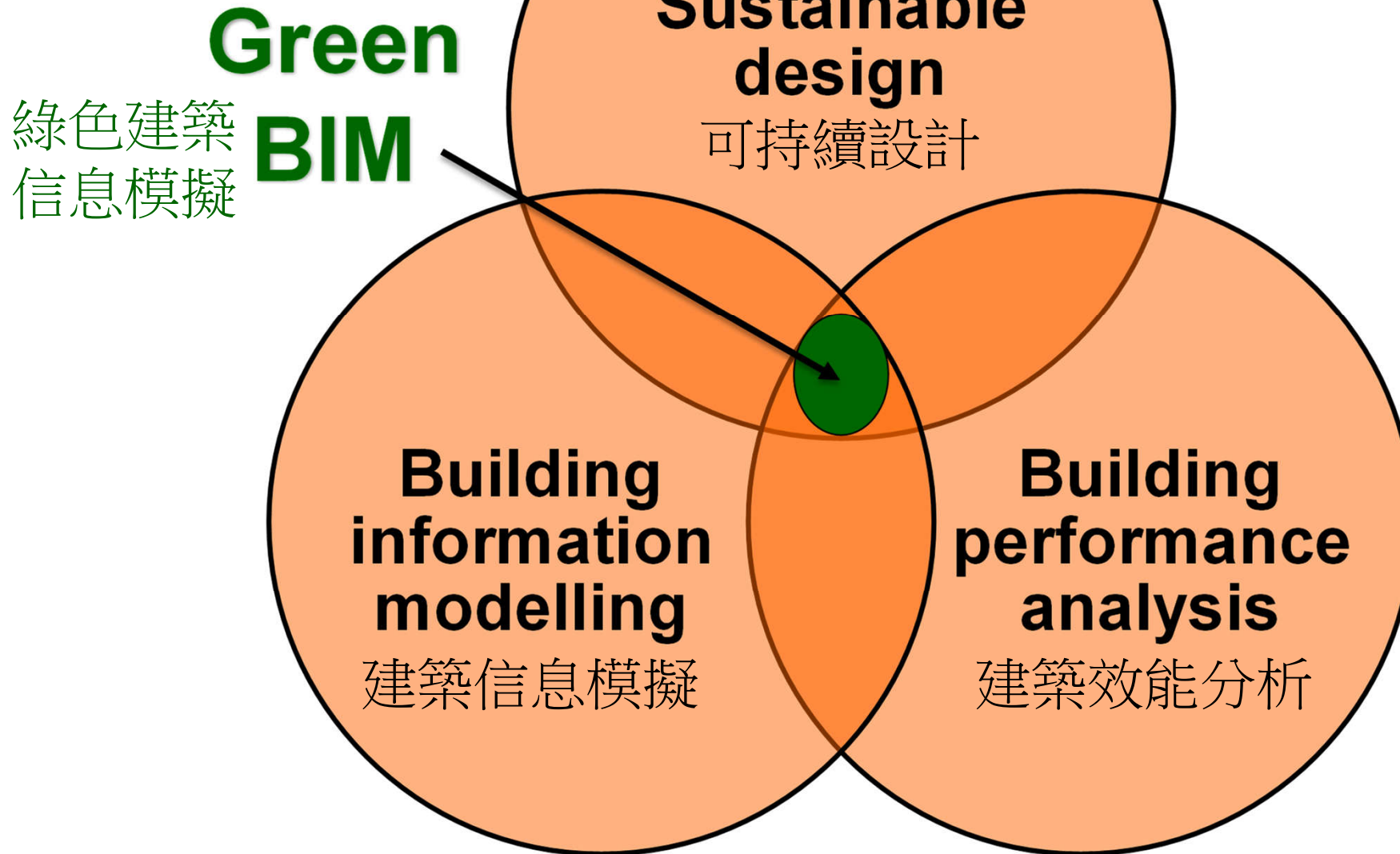
- BIM is useful for sustainable design



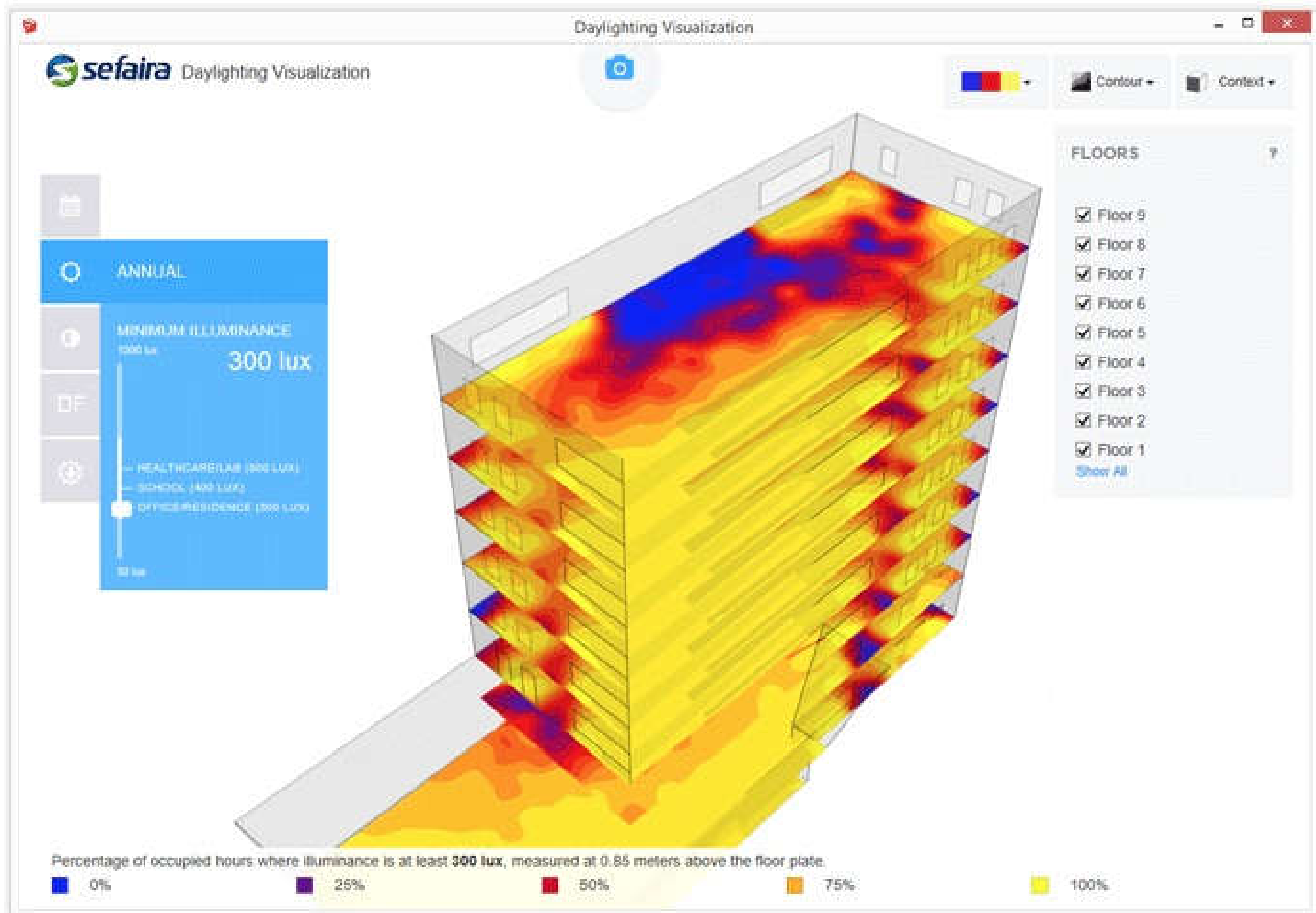
- It can help people iteratively test, analyze, and improve the building design
- It can be used for building performance analysis (BPA)

Green BIM

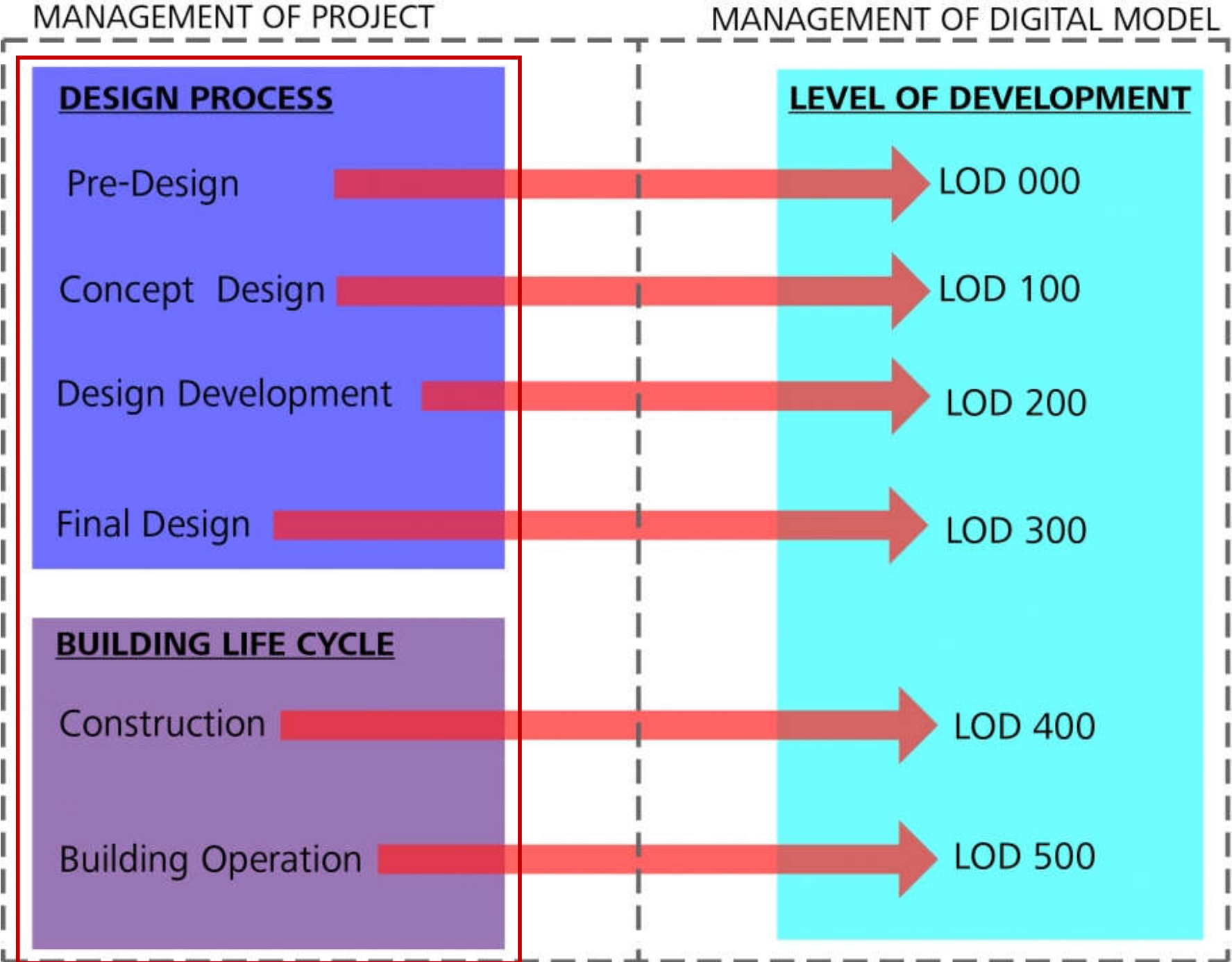
Basic concepts of Green BIM



BIM-supported daylight visualization and analysis



Design process of buildings and level of development (LOD)



(Source: <https://knowledge.autodesk.com/community/collection/building-performance-analysis-0>)

Pre-Design

Objectives:

Identify the requirements of the project, existing conditions, and unearth any essential information that will inform the design process.

Sustainable Design Inquires:

- What information will support building performance analysis (BPA) practices?
- What specific climate considerations should be brought to light?
- What passive sustainable design strategies should be considered in the building design?
- What environmental resources can the building design utilize?
- What are the energy/performance goals for the project?

Building Performance Analysis (BPA) Actions:

- Decide what **climate data** is most appropriate for the geographic location.
- Conduct a **site analysis** that minimally includes investigation of solar radiation, wind patterns, presence and condition of existing structures, inventorying existing vegetation, and documenting any acoustic challenges that exist.
- Analyze **climate charts** and determine if building is likely to be heating or cooling dominated.
- Research what **sustainable design strategies** would be applicable to both the geographic location, and climate zone of the project.
- Establish **measurement matrices** that are to be used throughout the duration of the project to confirm sustainable design goals are being accounted for (such as LEED).

Conceptual Design

Objectives:

Decide on the direction of the design by experimenting, iterating, and obtaining integrated design input from all parties.

Sustainable Design Inquires:

- What is the most efficient building form?
- How is the building positioned on the building site?
- How is the floor plan organized?
- How do passive sustainable design strategies integrate with the building?

Building Performance Analysis (BPA) Actions:

- Run **conceptual energy analysis** using and modifying massing forms and determine how the Energy Use Intensity (EUI) can be reduced by changes in building form, and orientation. Doing so can help determine the most energy efficient building form.
- Conduct **basic shade/shadow analysis** of the massing model to determine what areas of the building could potentially support daylighting, and consequently inform interior space planning. This also informs the positioning of the building on the site.
- Do **solar radiation studies** of the mass model to maximize opportunities for solar collection (e.g. for solar photovoltaics and solar thermal systems).
- Study how the **orientation of the massing model** interacts with wind on the site. Orientation of the building can optimize opportunities for passive cooling and ventilation.

Design Development

Objectives:

Verify and edit performative attributes of proposed design, while refining material, mechanical, and structural systems with specificity.

Sustainable Design Inquires:

- How should the floor plan be modified to improve the quality of day lighting?
- How can HVAC equipment be designed most efficiently?
- How can structural system be designed most efficiently?
- Do passive sustainable design strategies provide the expected performance?
- What materials are being used to construct the building?

Building Performance Analysis (BPA) Actions:

- Run **whole building energy analysis** of building model, and identify how changes in wall construction can reduce energy demands. This also presents a good opportunity to test the performance of HVAC systems that were initially selected in Concept Design.
- Complete **simulations** that determine the general geometry of performative features to determine if shades, light shelves, and solar chimneys are working as predicted.
- Run **interior daylighting analysis** of spaces, and confirm proper light levels are being achieved.
- After maximizing the efficiency of the building envelope, run **cooling/heating load simulation** so that HVAC equipment can be sized for efficiency.
- Perform **structural analysis** of model so that structural systems can be optimized.

Final Design and Documentation

Objectives:

Provide detailed direction, and specification, to construct the most comprehensive iteration of the building. Assure that the constructed manifestation of the design will be as sustainable as feasibly possible.

Sustainable Design Inquires:

- Are sustainable design goals achieved?
- Are building owner's expectations of costs and performance achieved?
- What is the expected performance of the building?

Building Performance Analysis (BPA) Actions:

- Perform **detailed whole building energy analysis** of the final design to document expected performance, and measure against baselines. And compare final design against the measurement matrices that were defined in Pre-Design.
- Perform **greenhouse gas emissions analysis** to document expected environmental impact.
- Audit final building materials** for costs and green qualities (recycled content, close proximity to construction site, low VOCs).

Construction

Objectives:

Bring the building design into physical reality, by practicing sustainable construction methods and utilizing quality control methods.

Sustainable Design Inquires:

- How can waste be reduced in the construction process?
- How can fabrication methods reduce waste?
- How can construction be done in a sustainable manner?

Building Performance Analysis (BPA) Actions:

- Analyze building quantities** to assure that exact material quantities are delivered to the project site. Doing so will avoid excess material that gets turned into waste.
- Analyze best **fabrication methods** with digital automation. This step reduces waste material in the production of building assemblies.
- Run **construction scheduling simulations** that identify how to reduce equipment operations on the project site. Less use of construction equipment reduces both energy consumption and air pollution.

Operations and Maintenance

Objectives:

The building becomes occupied and has all equipment operating.

Sustainable Design Inquires:

- Are environmental control systems operating correctly?
- Is building able to maintain sustainable design goals when occupied?
- Is maintenance being done that assures environmental control systems can continue to perform at their optimum?

Building Performance Analysis (BPA) Actions:

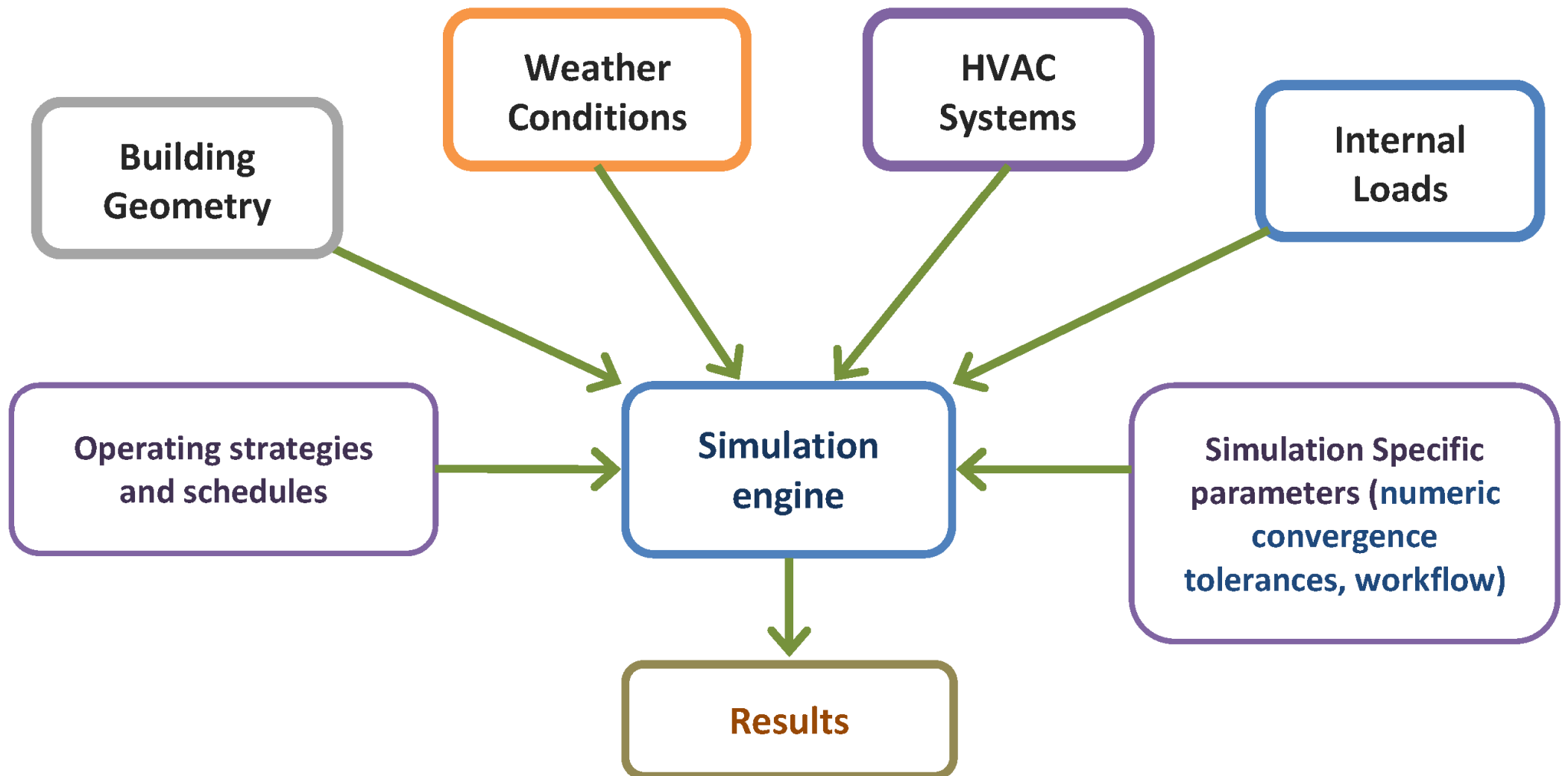
- Perform initial and ongoing **commissioning** of environmental systems to assure they are working as anticipated. Poorly performing environmental systems can result in compromised occupant comfort, and unnecessary energy consumption.
- Add ongoing utility cost/demand data to energy model, and compare/identify differences between **designed and actual performance**.
- Administer occupancy survey to verify **occupant satisfaction**, and make recommendations to facilities management for improving occupant satisfaction.

Project phases and analysis



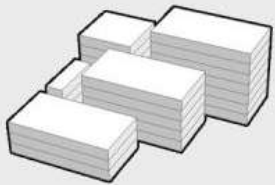
- Thermal analysis
 - Cooling & heating load calculations
 - HVAC plant and control systems
 - Dynamic thermal simulations
 - Wall/window make-ups & condensation analysis
 - Energy analysis
 - CO₂ emission calculations
 - Natural ventilation & mixed mode systems
- [Model – Simulate – Results – Analysis]

General input data of thermal simulation engines

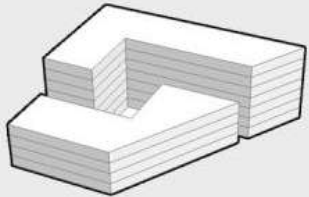


Design option comparison for schematic design studies

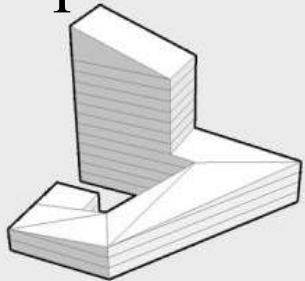
Option 1



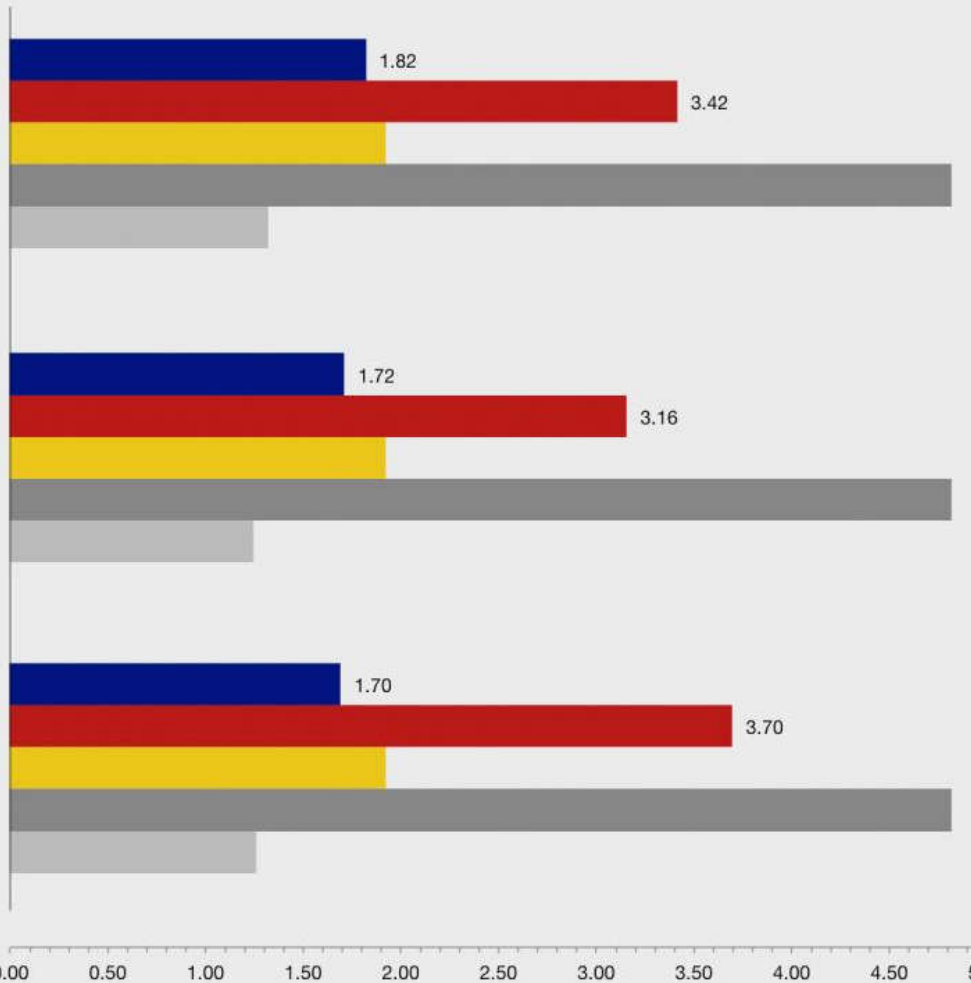
Option 2



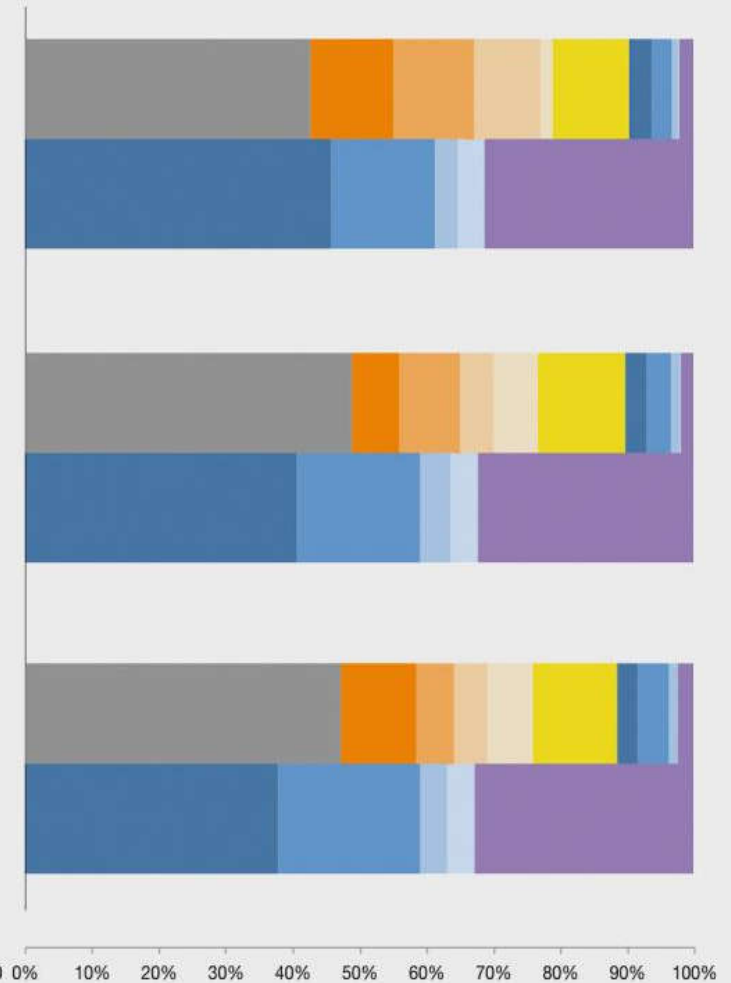
Option 3



ENERGY USE (kWh / ft² / yr)



HEAT GAINS & LOSSES (%)



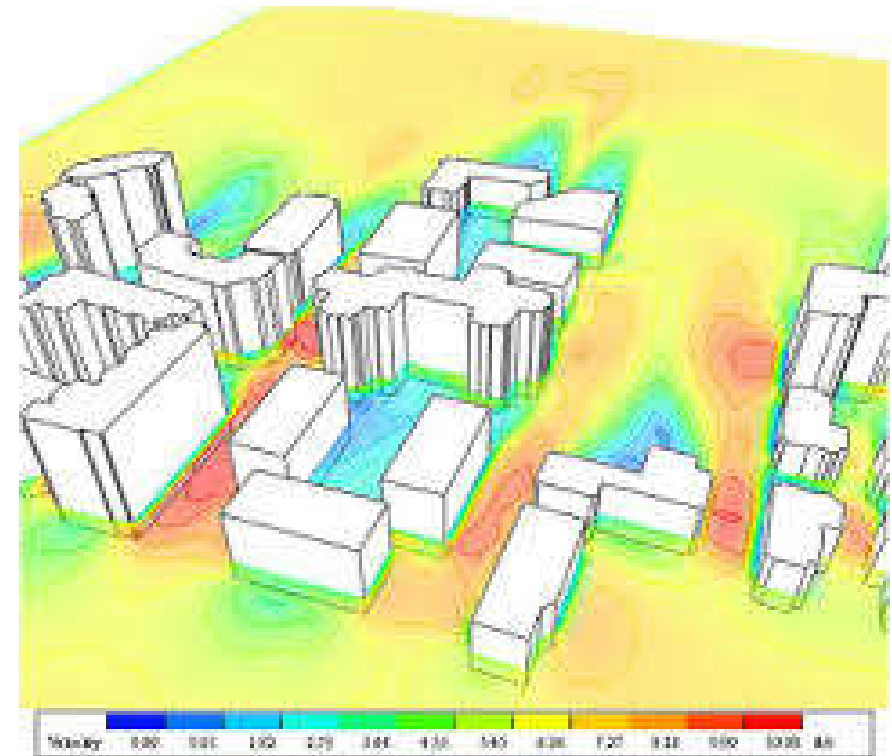
- Cooling
- Heating
- Lighting
- Equipment
- Fans & Pumps

- Equipment & People
- South Solar
- East Solar
- North Solar
- West Solar
- Lighting
- Glazing Conductor
- Wall Conduction
- Roof Conduction
- Floor Conduction
- Infiltration

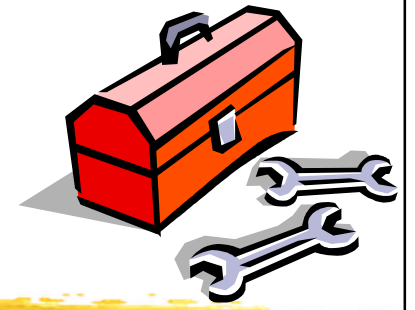
Project phases and analysis



- Computational fluid dynamics (CFD)
 - Predict complex air flow inside & around buildings
 - Visualization of results
 - Comfort analysis
 - Ventilation airflow analysis
 - Wind pattern studies



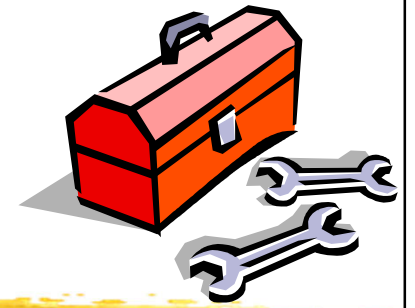
Building design tools



- Examples of design and analysis tools
 - Autodesk Insight for Revit
 - Autodesk Green Building Studio
 - IES Virtual Environment
 - Sefaira



Building design tools



- Autodesk Revit



(<https://www.autodesk.com/products/revit/overview>)

- Building Information Modeling (BIM) software
- To support design, analysis, collaboration, documentation and visualization
- Insight: Building Performance Analysis (BPA)
 - <https://www.autodesk.com/products/insight/overview>
 - Integrated with Revit
 - Autodesk Insight Overview (1:43)

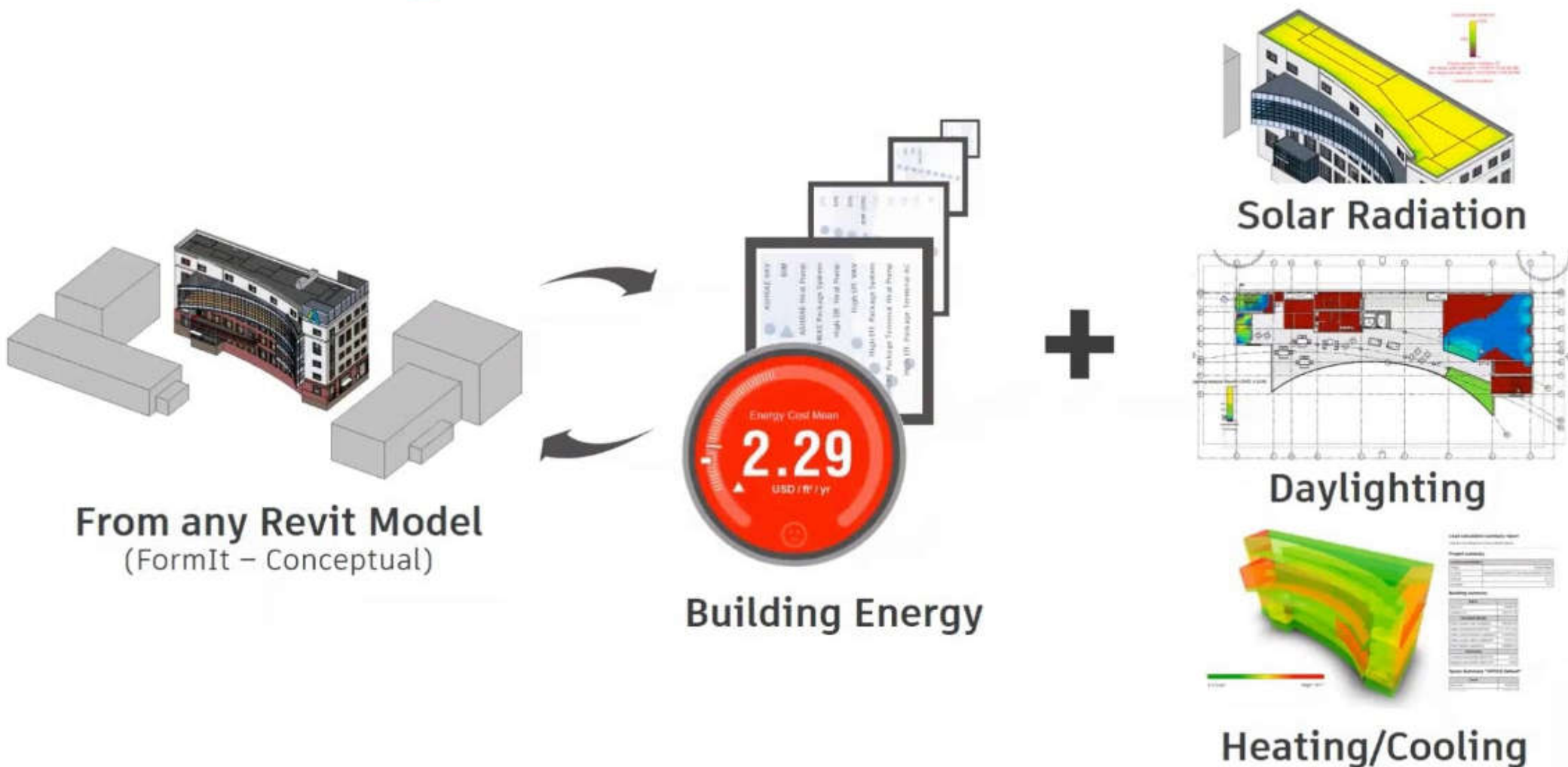


<https://youtu.be/QZchfkbSwG8>

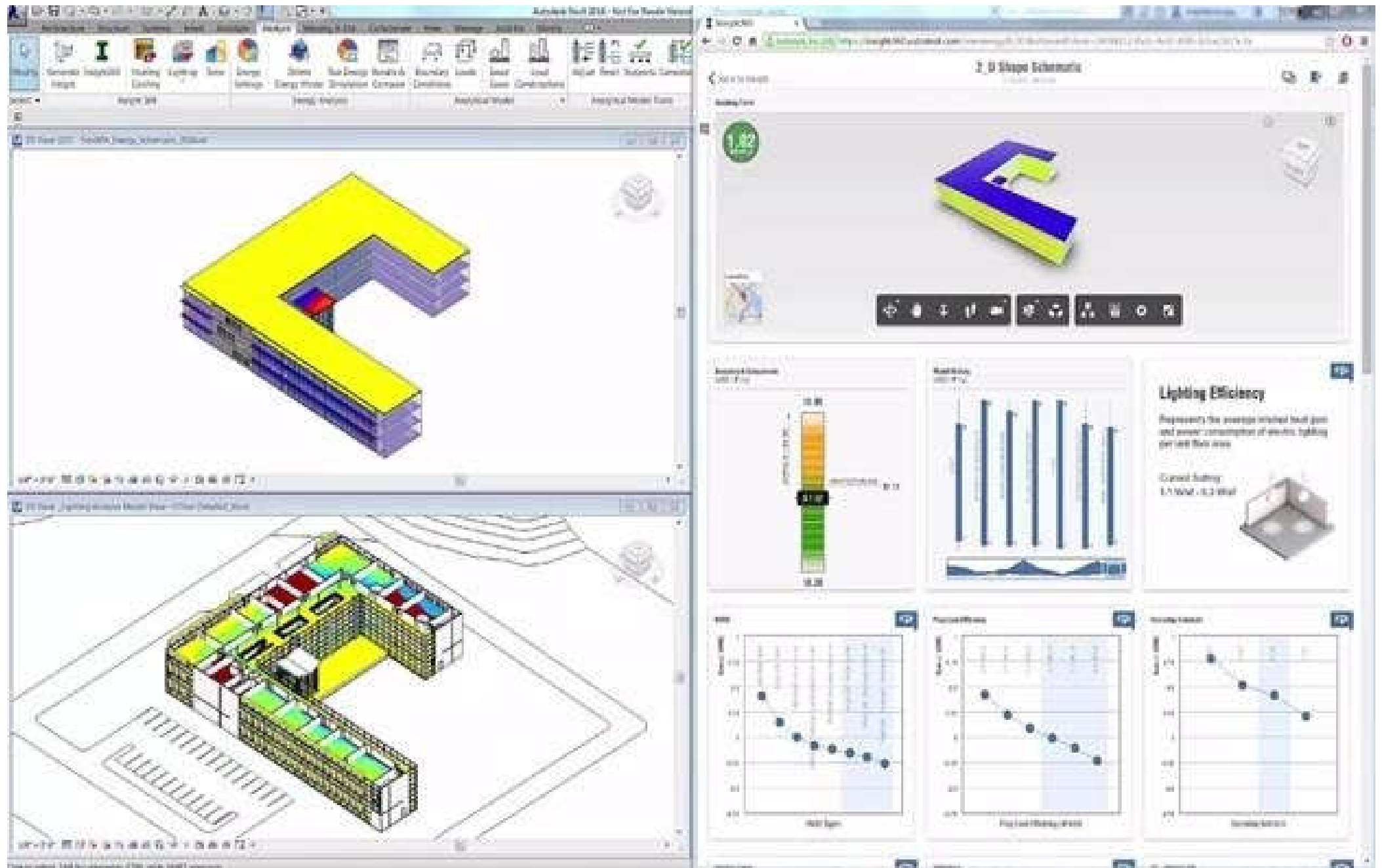


Autodesk Revit and Insight for Building Performance Analysis

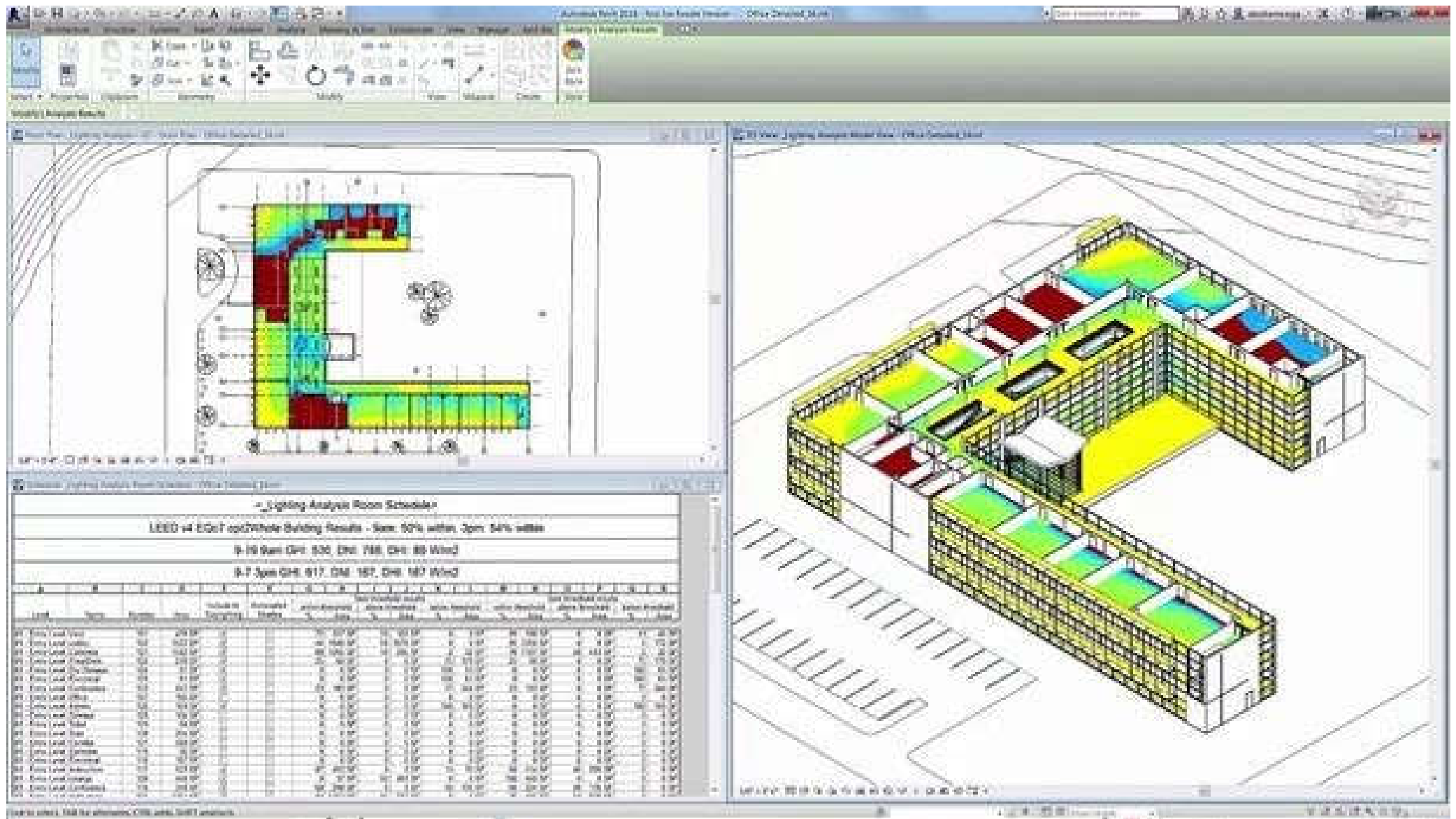
What is Insight?



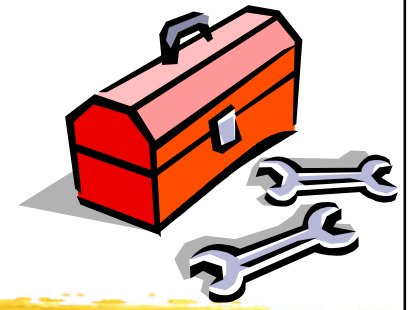
Whole building energy analysis using Insight for Revit



Daylighting analysis using Insight for Revit



Building design tools



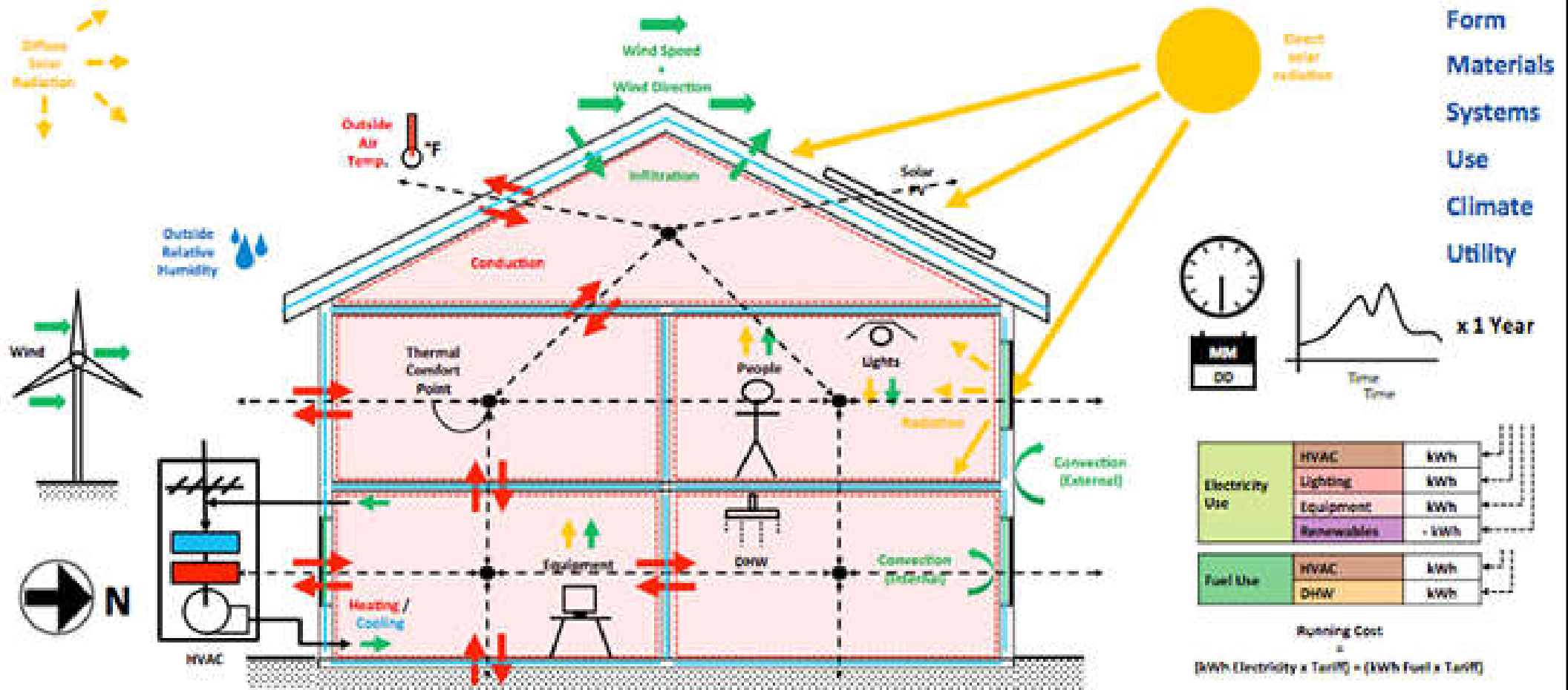
- Autodesk Green Building Studio (GBS)

- <https://gbs.autodesk.com/GBS/>



- A web-/cloud-based service for use in evaluating the environmental impact of building design and design alternatives. It can assess:
 - Energy and carbon results (e.g. EnergyPlus, eQUEST)
 - Water usage data
 - Photovoltaic potential
 - Daylighting results, natural ventilation potential
 - The results are often reported in monetary terms

Dynamic whole building energy analysis using Green Building Studio

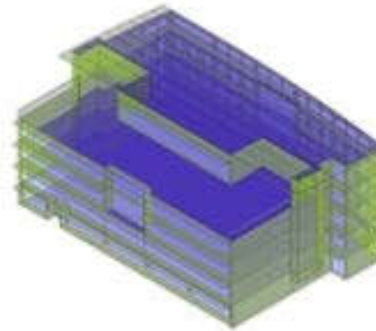




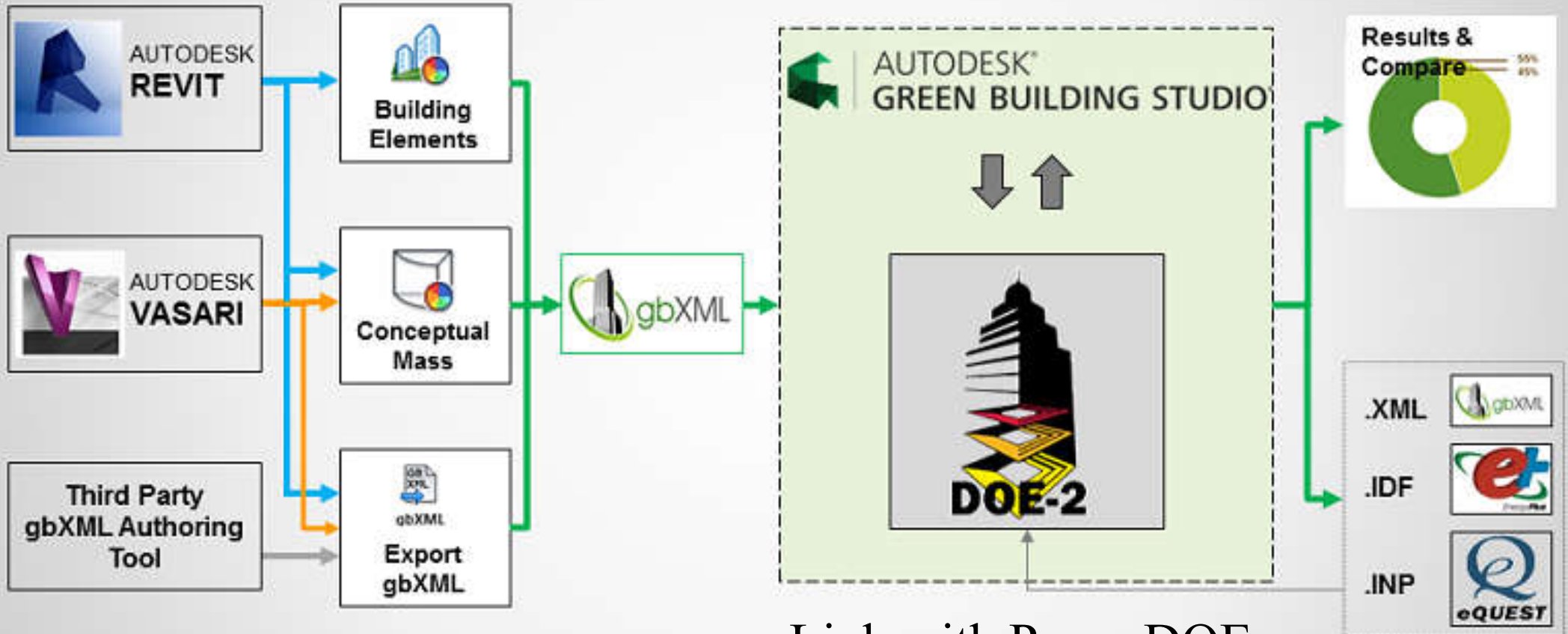
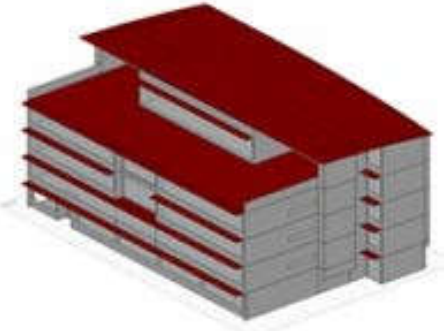
Revit Architecture



gbXML

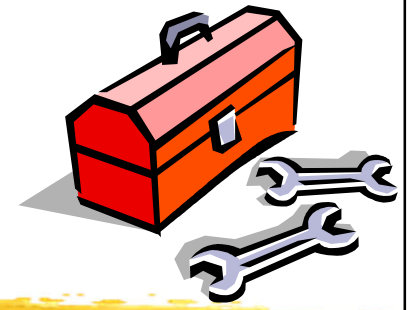


Ecotect Analysis



Link with PowerDOE,
eQUEST or EnergyPlus

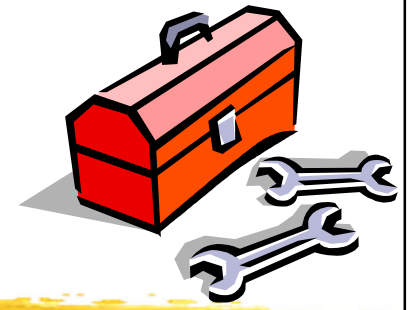
Building design tools



- gbXML (green building extensible markup language) [<http://www.gbxml.org/>]
 - Open schema designed to transfer essential information contained within a 3D building information model BIM (such as walls, windows, and room areas)
 - Allows for a consistent way to share information for engineering analysis tools



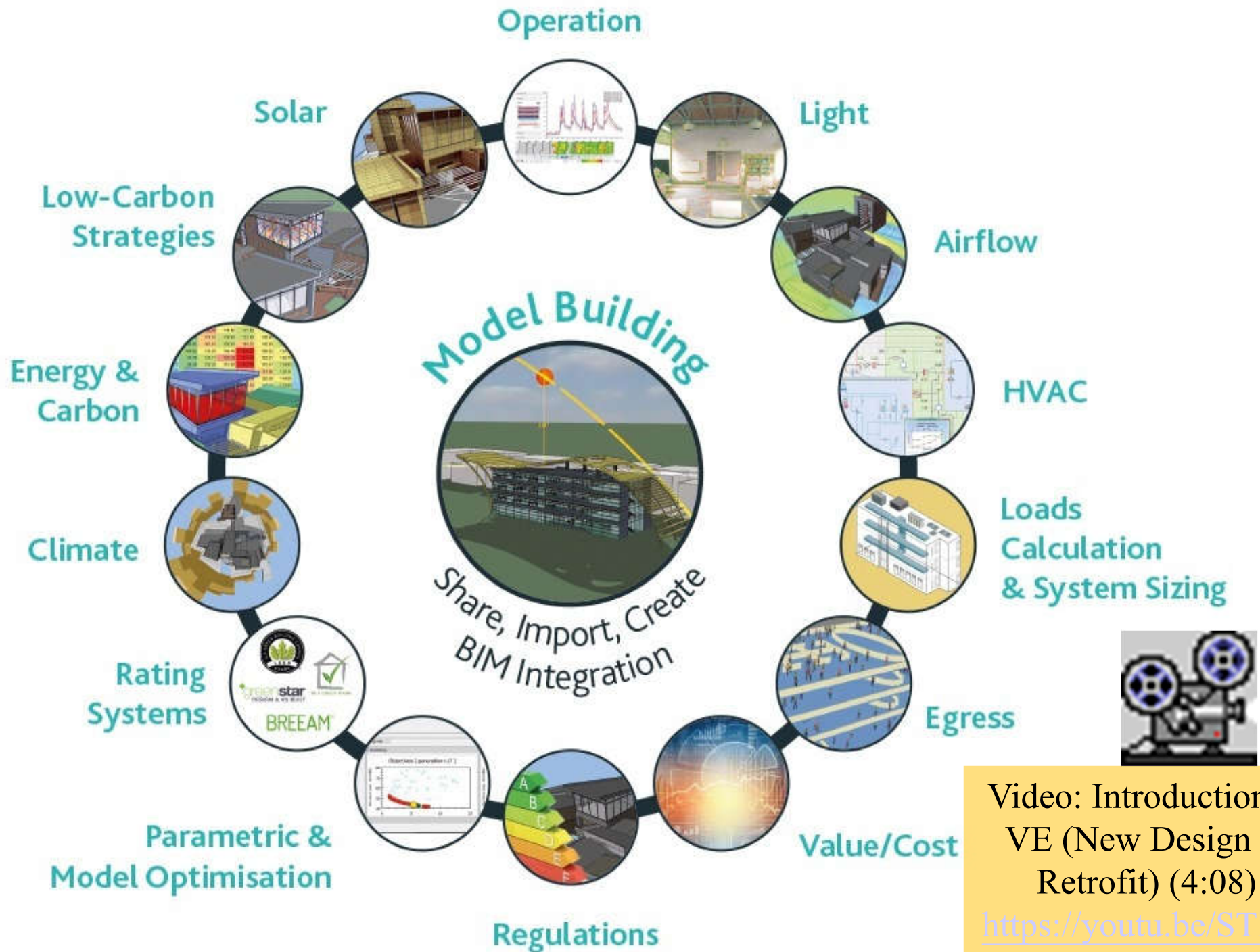
Building design tools



- IES Virtual Environment VE (www.iesve.com)
 - IES = Integrated Environmental Solutions
 - Applications:
 - Energy Modelling & Compliance
 - Whole building energy simulation; LEED, UK, North America & global compliance
 - Building & Systems Design
 - Solar shading, daylight simulation & lighting design, HVAC sizing & optimization, airflow, climate analysis & weather, renewable energy design & optimization, life cycle analysis
 - 3D Modelling & BIM Interoperability

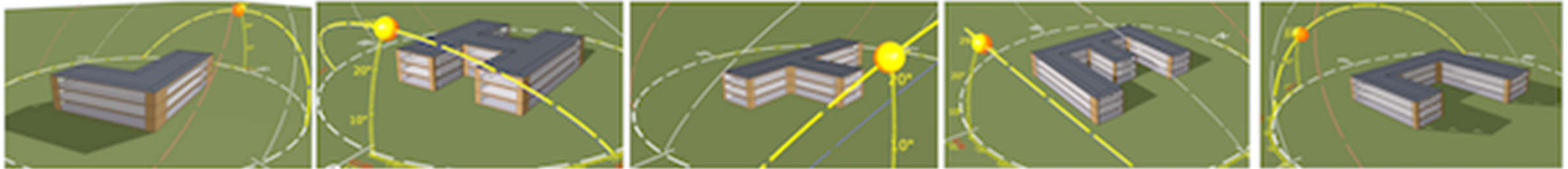


IES Virtual Environment (VE): integrated analysis

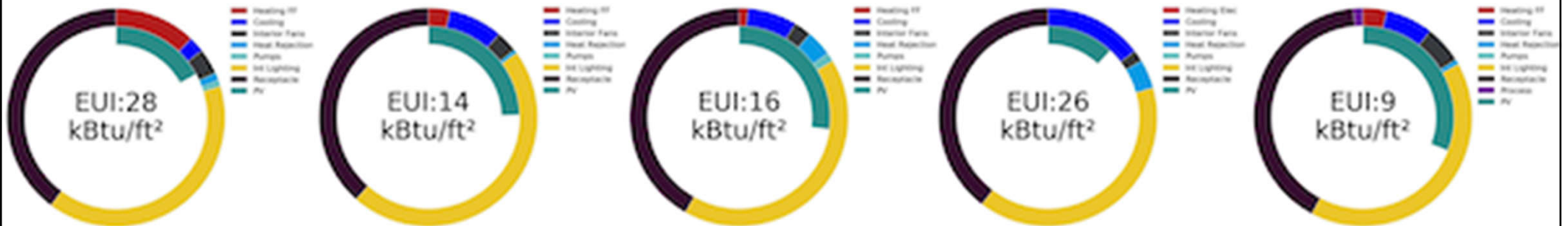


IESVE 2019 schematic geometry wizard for building performance analysis (massing, building energy use & daylighting)

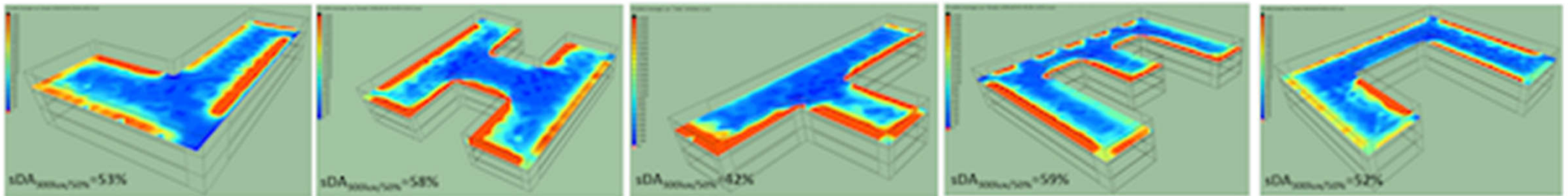
Schematic-Design Massing Options



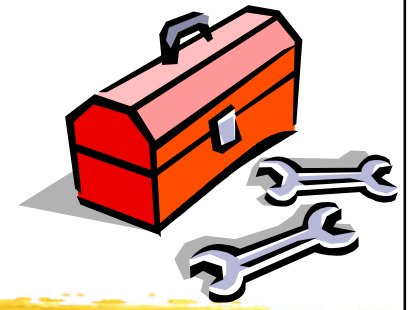
Building Energy Use Intensity (EUI) kBtu/ft²/year



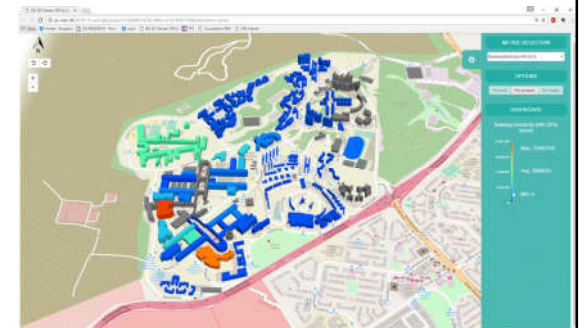
Spatial Daylight Autonomy



Building design tools



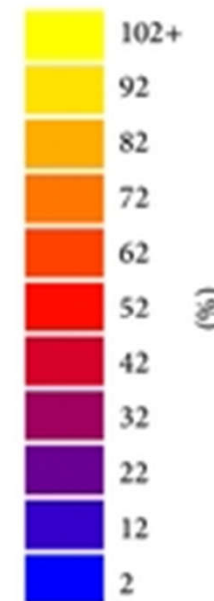
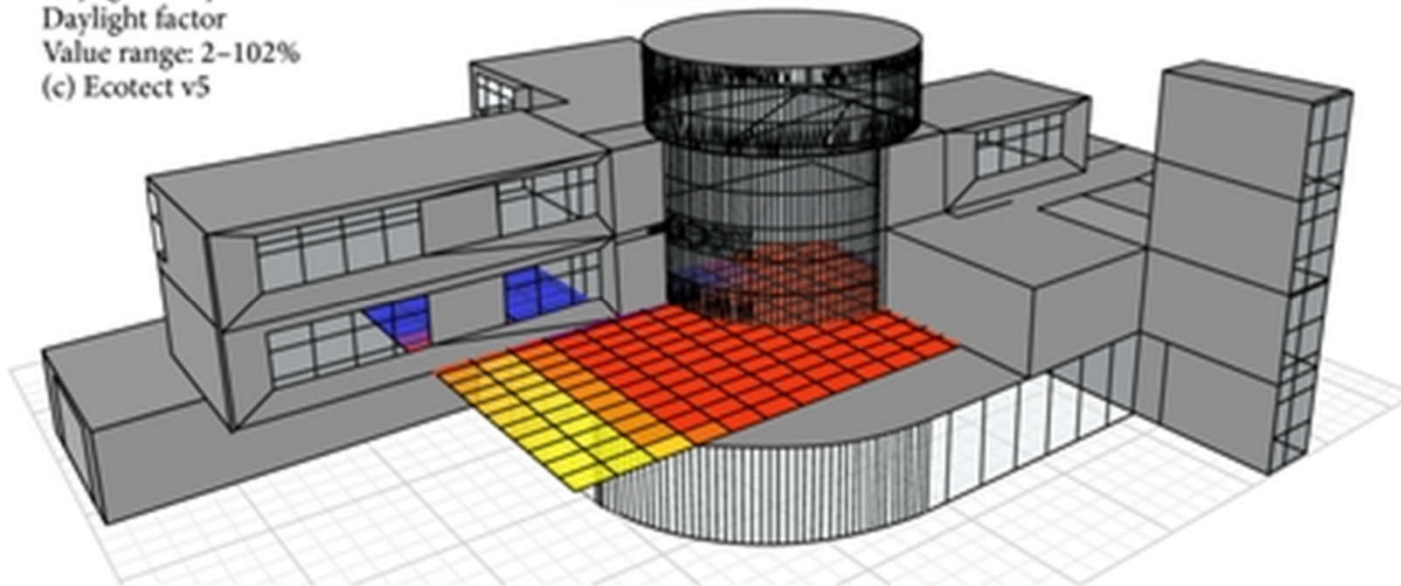
- IES VE case studies (in Singapore)
 - NTU EcoCampus <https://www.iesve.com/icl/case-studies/2835/NTU-EcoCampus>
 - 3D masterplanning and visualization
 - BCA Academy Campus <https://www.iesve.com/icl/case-studies/2836/BCA-Academy-Campus>
 - Energy modelling and performance optimisation



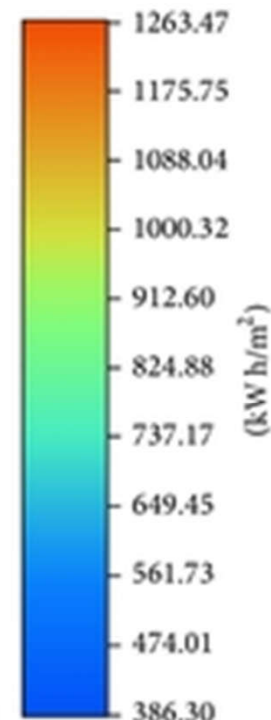
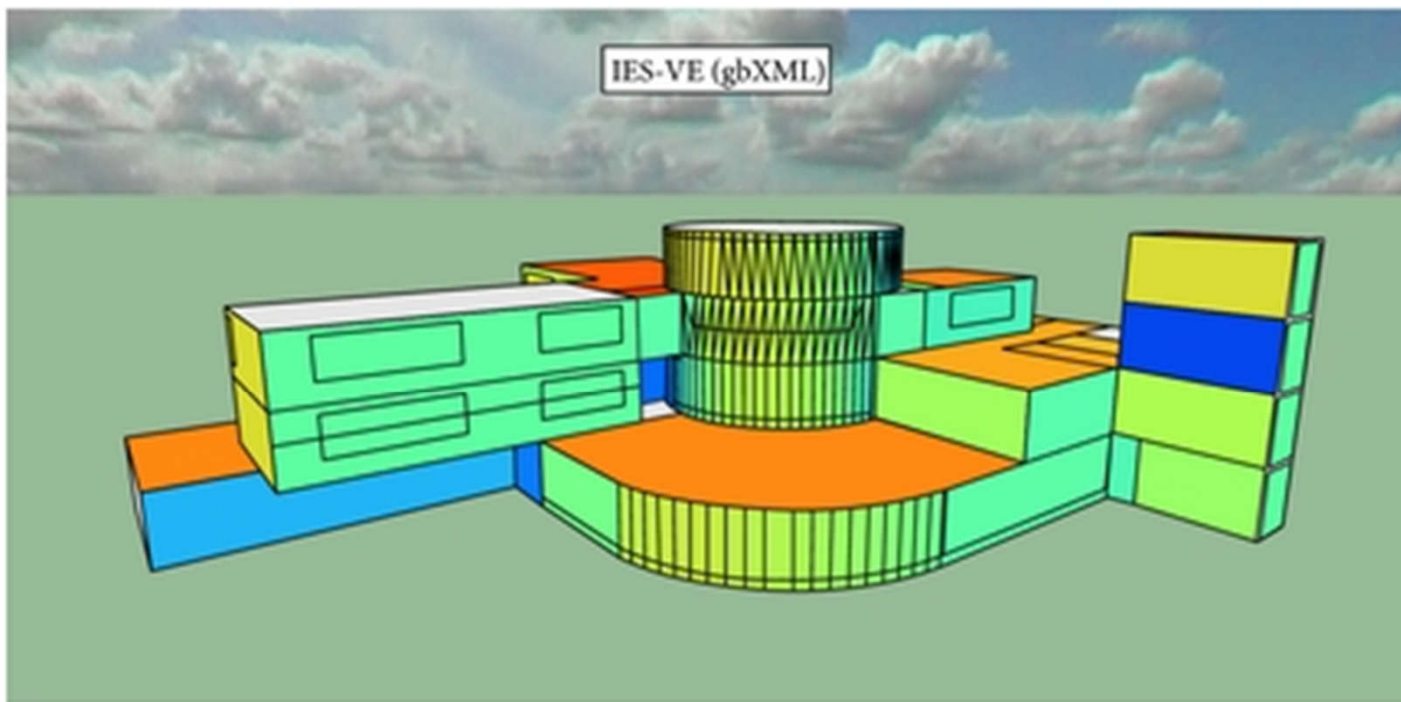
Snapshot of the sample daylighting simulation in Ecotect and IES-VE

Daylight analysis
Daylight factor
Value range: 2-102%
(c) Ecotect v5

Ecotect (gbXML)

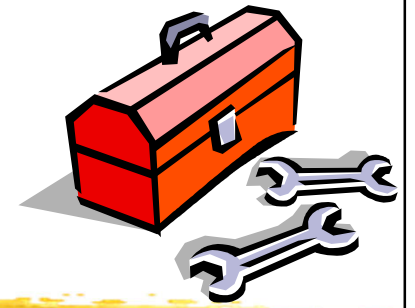


IES-VE (gbXML)



0.1/Jan-00:00 to 31/Dec-23:00

Building design tools

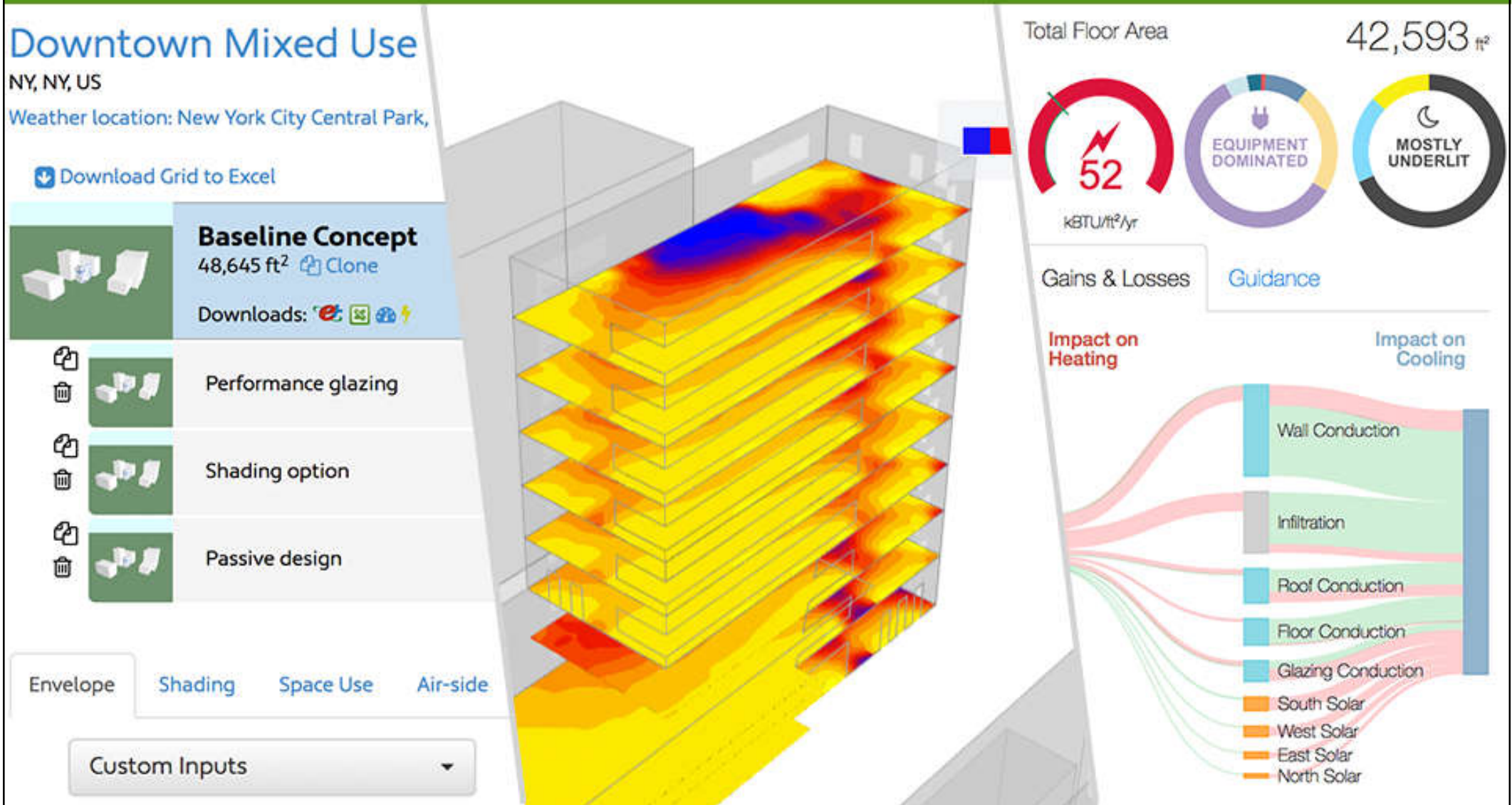


- Sefaira <https://sefaira.com/>



- Early stage analysis
 - Compare massings, layout and envelope options
 - Study natural ventilation & HVAC systems
- Use EnergyPlus and Radiance
- Applications:
 - Energy (use, cost, CO₂, renewables)
 - Daylighting (daylight factor, direct sunlight)
 - Thermal comfort
 - HVAC sizing (heating & cooling loads)

Sefaira building performance analysis



(Source: <https://sefaira.com/interested-in-a-demo-of-sefaira-architecture/>)

Sefaira daylighting analysis and visualization

sefaira for SketchUp

Upload to Sefaira

Close Daylighting Visualization

Entity Palette

Analysis Update

Office in New York, NY, USA

PROPERTIES

Total Floor Area **58,280** ft²

29 kWh/ft²/yr

COOLING DOMINATED

MOSTLY WELL LIT

History Element Performance

Energy Use Overlit

Design Changes → Current Design

Daylighting Visualization

Gradient Context

FLOORS 2.79 FT WORKPLANE HEIGHT

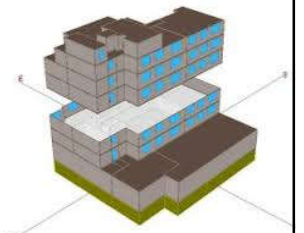
- Floor 9
- Floor 8
- Floor 7
- Floor 6
- Floor 5
- Floor 4
- Floor 3
- Floor 2
- Floor 1

Show All

Percentage of occupied hours where illuminance is at least **300 lux**, measured at 2.79 feet above the floor plate.

0% 25% 50% 75% 100%

(Source: <https://sefaira.com/resources/june-product-update-2016/>)



Building performance analysis

- Building Performance Analysis (BPA)
 - Building performance studies to assess how the building is performing, what is driving that performance, and what you can do to influence it
 - Typical tasks:
 - Climate & weather analysis
 - Building load & energy modelling
 - Solar analysis & strategies
 - Daylighting/lighting analysis & strategies
 - Wind & airflow analysis

BIM

Building
Information
Modeling

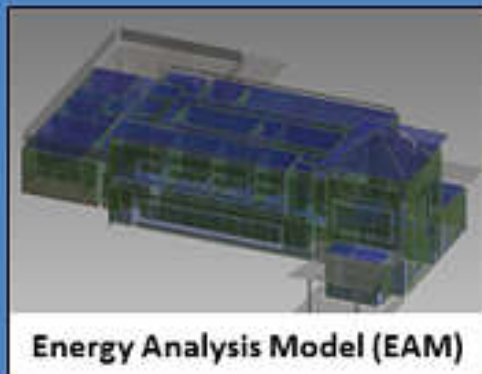


- Visualization
- Structural analysis
- Cost
- Documentation
- Fabrication/Construction
- Etc...

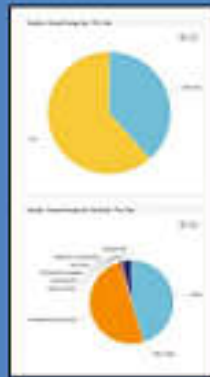
Building Performance Analysis (BPA)

Whole Building Energy Analysis

- Conceptual Models
- Detailed Models

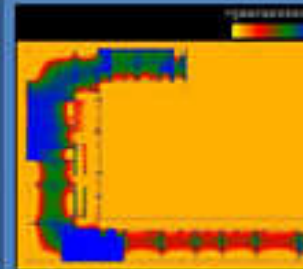


Energy Analysis Model (EAM)



+

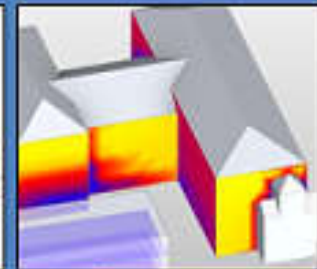
Other Performance Studies



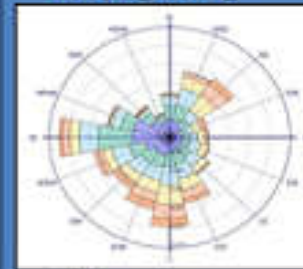
Lighting &
Daylighting



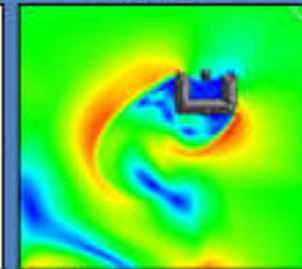
Sun &
Shadows



Solar
Radiation



Climate
Analysis



Airflow &
Ventilation



Lifecycle
Analysis

Building performance analysis workflows

First, know what you're trying to accomplish, and how you'll measure success.

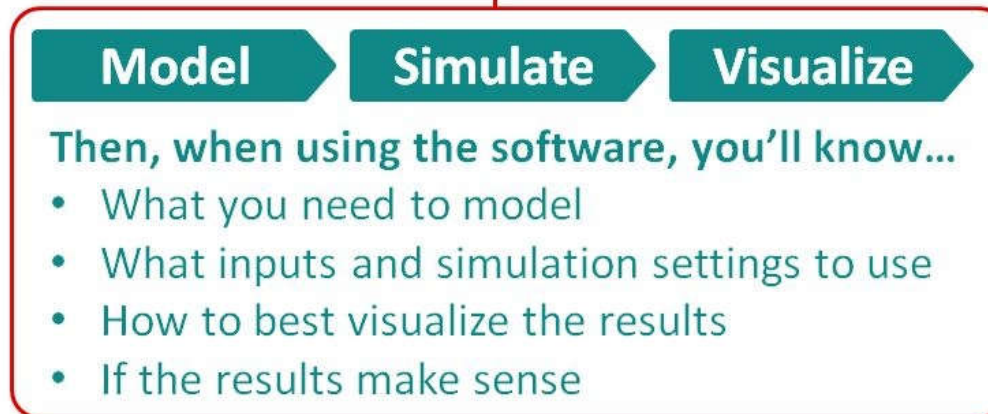


This will help you understand what tools to use, and what to look for in your analysis.

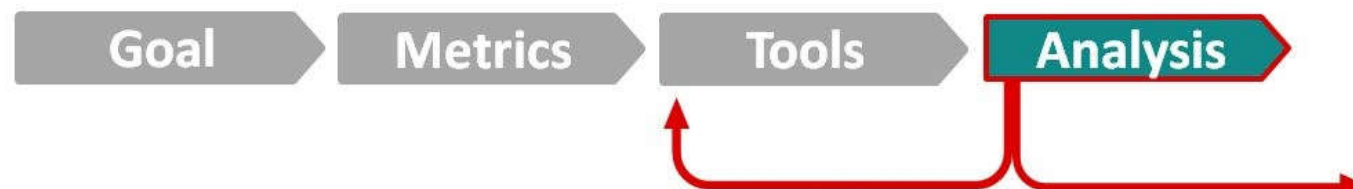
Level 1:



Level 2:



Finally, you will know how to interpret your analysis results so that you can make better decisions.

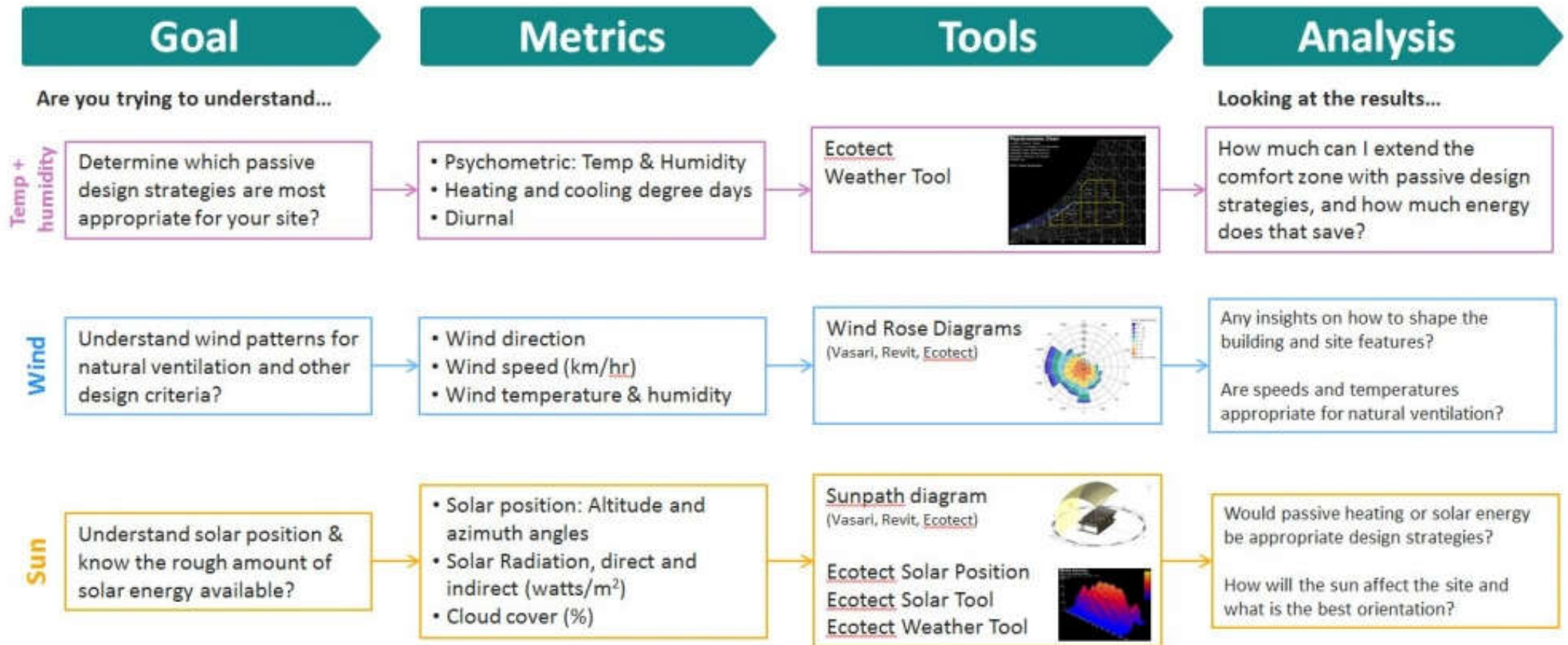


You might iterate ... or do other analyses

Climate analysis

Workflow: Goals, Metrics, and Analysis Tools

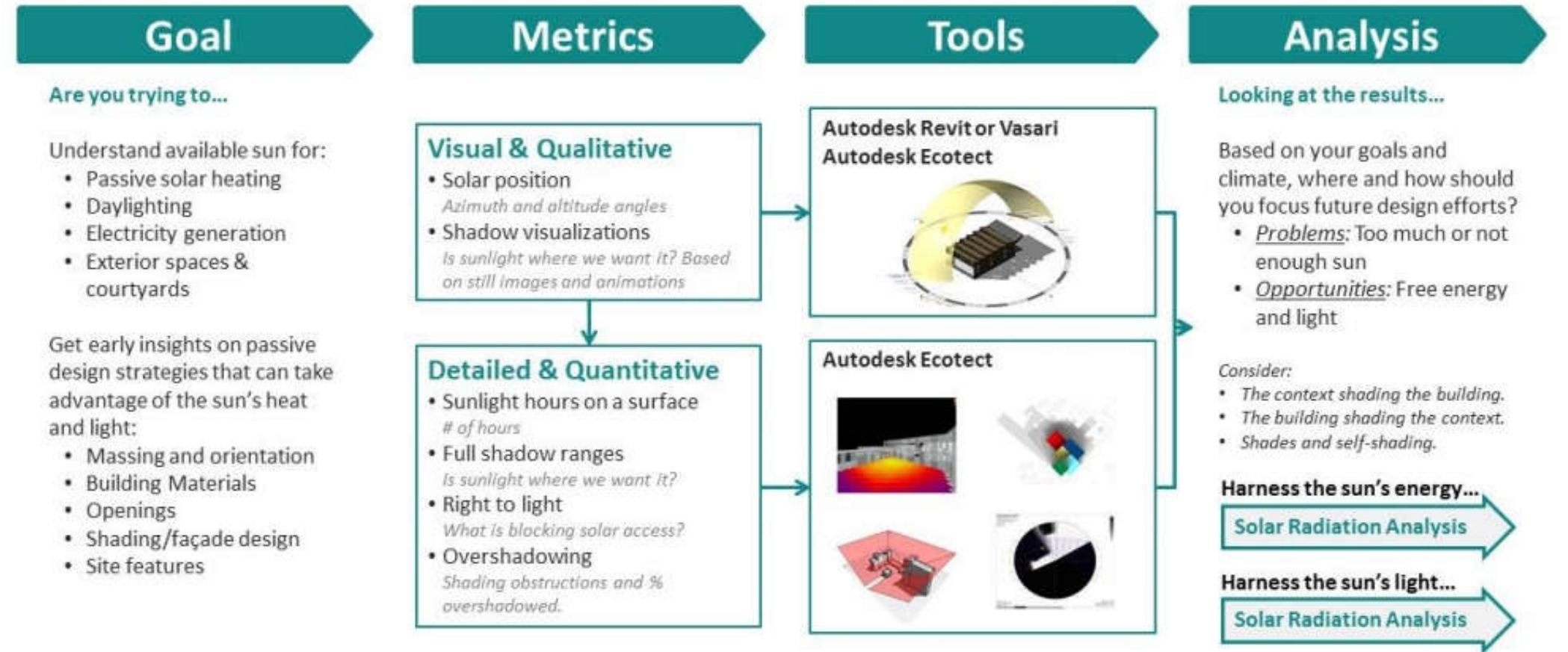
Climate Analysis for High Performance Building Design



Sun and shadow studies

Workflow Part 1: Goals, Metrics, and Analysis Tools

Sun and Shadow Studies for High Performance Building Design



Sun and shadow studies (cont'd)

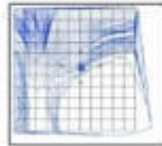
Workflow Part 2: Modeling, Simulation, and Visualization Settings

Autodesk Vasari - Sun and Shadow Studies for High Performance Building Design

Model

Model Site & Context

Surrounding buildings, site features, and topography.
Import underlay image



Set Location

Dictates latitude, longitude, and climate.



Building Geometry

If it exists
Mass model



Simulate

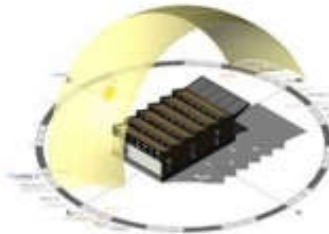
Sun Settings

Based on analysis goals

- Times of day
- Seasons
- Extremes (solstices)
- Single day or range



Visualize Shadows & Sun Path



Visualize

Still Images

A specific time and date
Export as image or screen clipping



Animations

A range of times or days
Export as movie file



Sun and shadow studies (cont'd)

Workflow Part 3: Modeling, Simulation, and Visualization Settings

Autodesk Ecotect - Sun and Shadow Studies for High Performance Building Design

Model

Model Site & Context

Surrounding buildings, site features, and topography. Import underlay image



Set Location

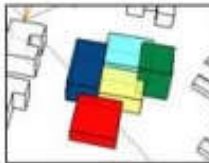
Dictates latitude, longitude, and climate.



Building Geometry

If it exists

Mass model - .xml
Detailed model - .fbx to .dxf



Simulate

Sun Settings

Based on analysis goals

Visualize Shadows (also in Vasari)

Sunlight Hours

Hours of sunlight falling on a surface

Shadow Range

Full daily profile of the shadow path

Right to Light/ Solar Envelope

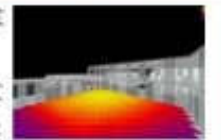
Access to daylight based on context

Overshadowing

What is shading the building when

Visualize

- Visualized on a grid or object
- Ensure comparable scale
- Study key surfaces like direct gain windows, or courtyards



- Ensure same time range
- Locate features like pools or landscaping



- Planes cut through model
- What blocks your access?
- Blocking others' access?
- Vertical sky component



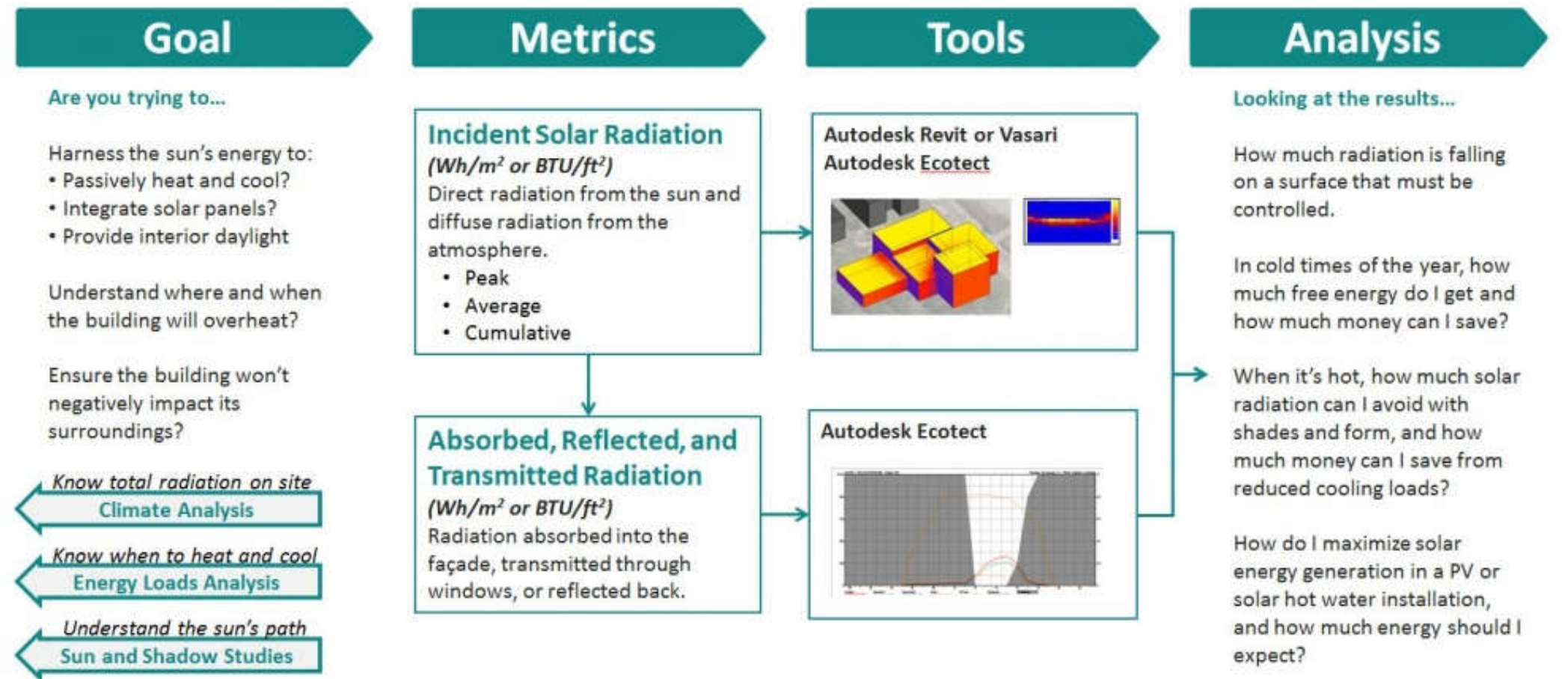
- Study points or surfaces
- What is the solar window?
- Percentage of a surface in sun or shade



Solar loads/solar radiation analysis

Workflow Part 1: Goals, Metrics, and Analysis Tools

Solar Radiation Analysis for High Performance Building Design



Analysis of exterior airflow for buildings and building sites

Workflow Part 1: Goals, Metrics, and Analysis Tools

Exterior Airflow for Buildings and Building Sites: Vasari Wind Tunnel Tool

Goal

Are you trying to...

- Create comfortable outside areas and courtyards by strategically locating walls, trees, and landscaping?
- Design your building and site to reduce unwanted airflow acceleration on walkways?
- Get a basic understanding of where to place openings to get the most out of cross ventilation?
- Roughly estimate air pressure distribution on structures?

Metrics

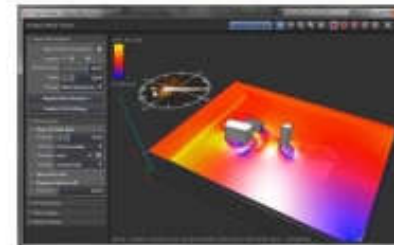
Rough qualitative comparison between design options of:

- Wind patterns (false color)
- Wind speeds (m/s)
- Pressures (Pa)



Tools

Vasari Wind Tunnel Tool



(Autodesk Simulation CFD should be used for more advanced and rigorous analysis.)

Analysis

Looking at the results:

- Are there areas that are getting too much or not enough airflow based on the design objectives?
- What is the ratio of the initial air velocity and the maximum air velocity on my site? Are there areas where the wind is being channeled and accelerated?
- In areas I want to shelter, what is the best relative airspeed reduction I can achieve?

Analysis of exterior airflow for buildings and building sites (cont'd)

Workflow Part 2: Modeling, Simulation, and Visualization Settings

Vasari Wind Tunnel Tool for Exterior Airflow for Buildings and Building Sites

Model

Model Site Context

Surrounding buildings and topography (as masses)



Create Conceptual Mass Model

Exterior form, orientation on the site



Choose a Weather Station

Dictates wind data and rose diagram.



Simulate

Set Analysis Grid

- Make boundary conditions large enough.

Wind Speed & Direction

- Use wind rose diagram data for guidance.
- Consider time of year & day
- Be careful of the scale & units

2D vs. 3D Analysis

- 3D analysis is recommended for more accurate results, but takes longer.

Run the simulation until it stabilizes.

- When the image is moving, it's not showing the wind. It's calculating.



Visualize

(Screen captures are the only way to export data)

False-color 2D Slices Horizontal and Vertical

- Qualitative differences in flow patterns.
- Clear visualizations of areas of interest (i.e. head height, wake of a building)
- Adjust color scales to probe and compare results



3D Volumetric Traces

- More dynamic way of visualizing 3D flow.

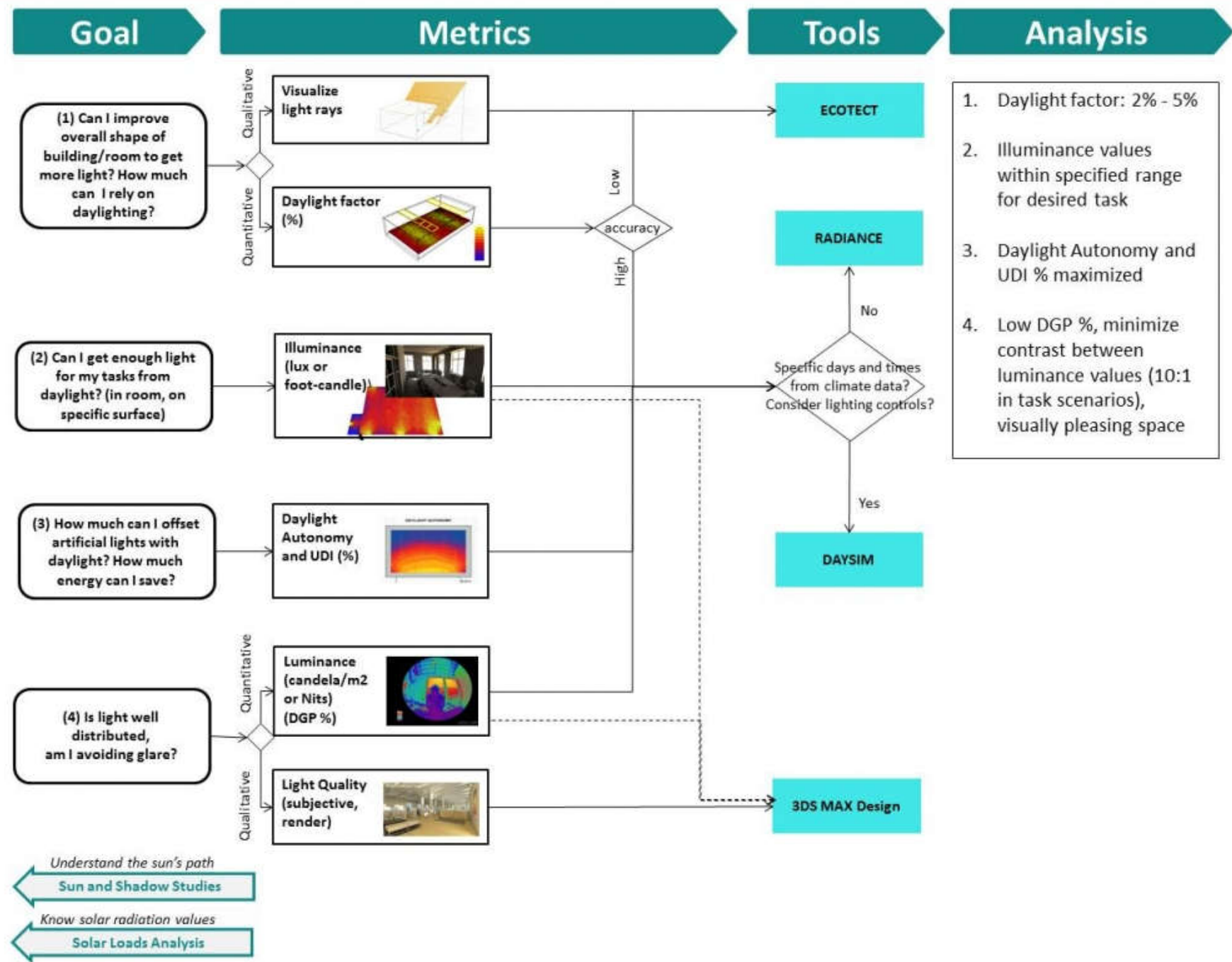


Point cloud & ISO Surf.

- Interrogate the model to better understand patterns of specific speeds and pressures.

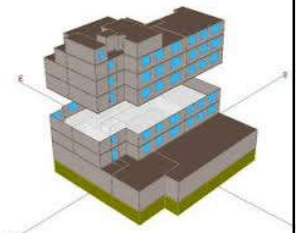


Daylight Analysis for High Performance Building Design

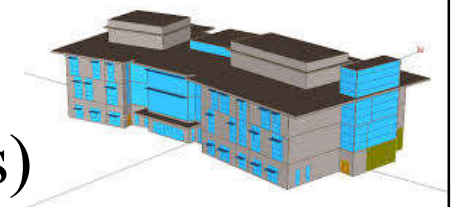


(Source: Autodesk)

Building performance analysis



- Whole building energy analysis
 - Simulate expected energy use in the building
 - Track the effectiveness of individual passive design strategies and energy efficiency measures
 - The sophistication and precision of the tools and analysis will increase as one moves along
 - Conceptual energy analysis (early design stage)
 - Detailed energy analysis
 - Energy retrofit analysis (for existing buildings)

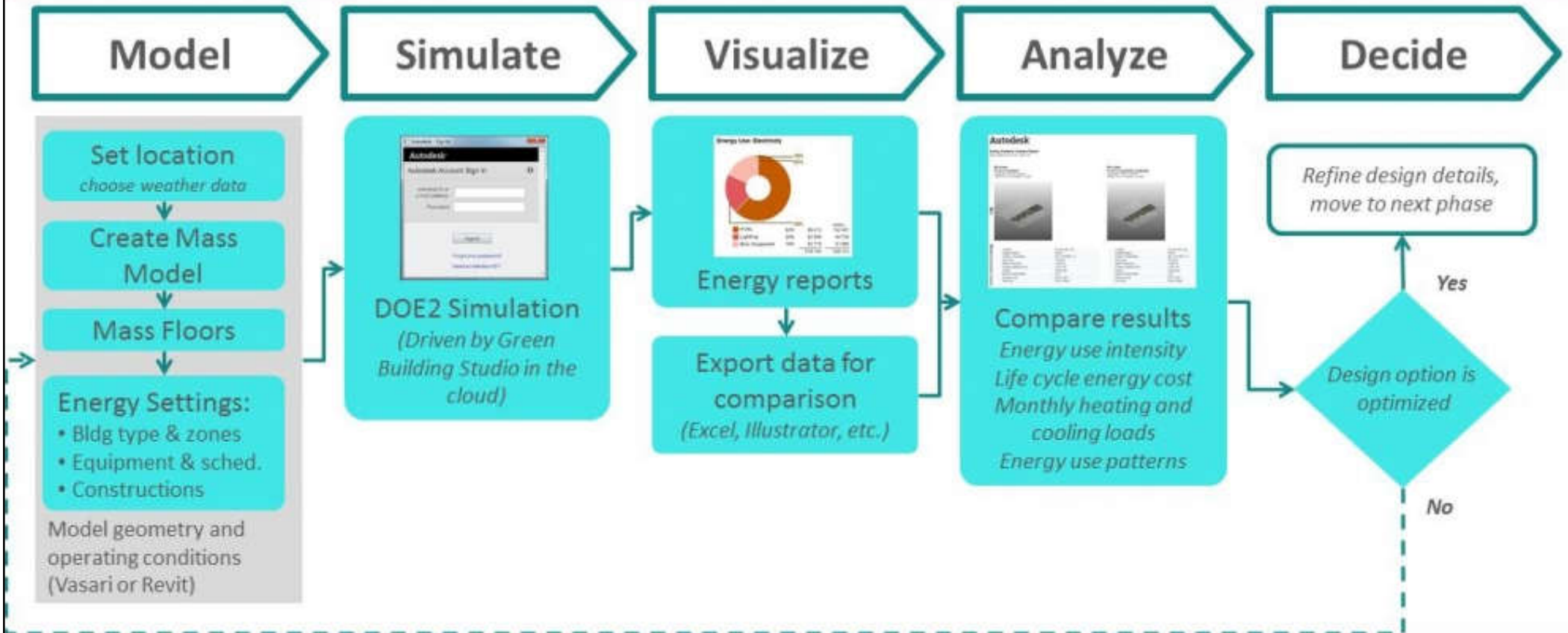


Whole building conceptual energy analysis

Whole Building Conceptual Energy Analysis

Goal: Optimize building form, orientation, layout, and constructions based on total energy use.

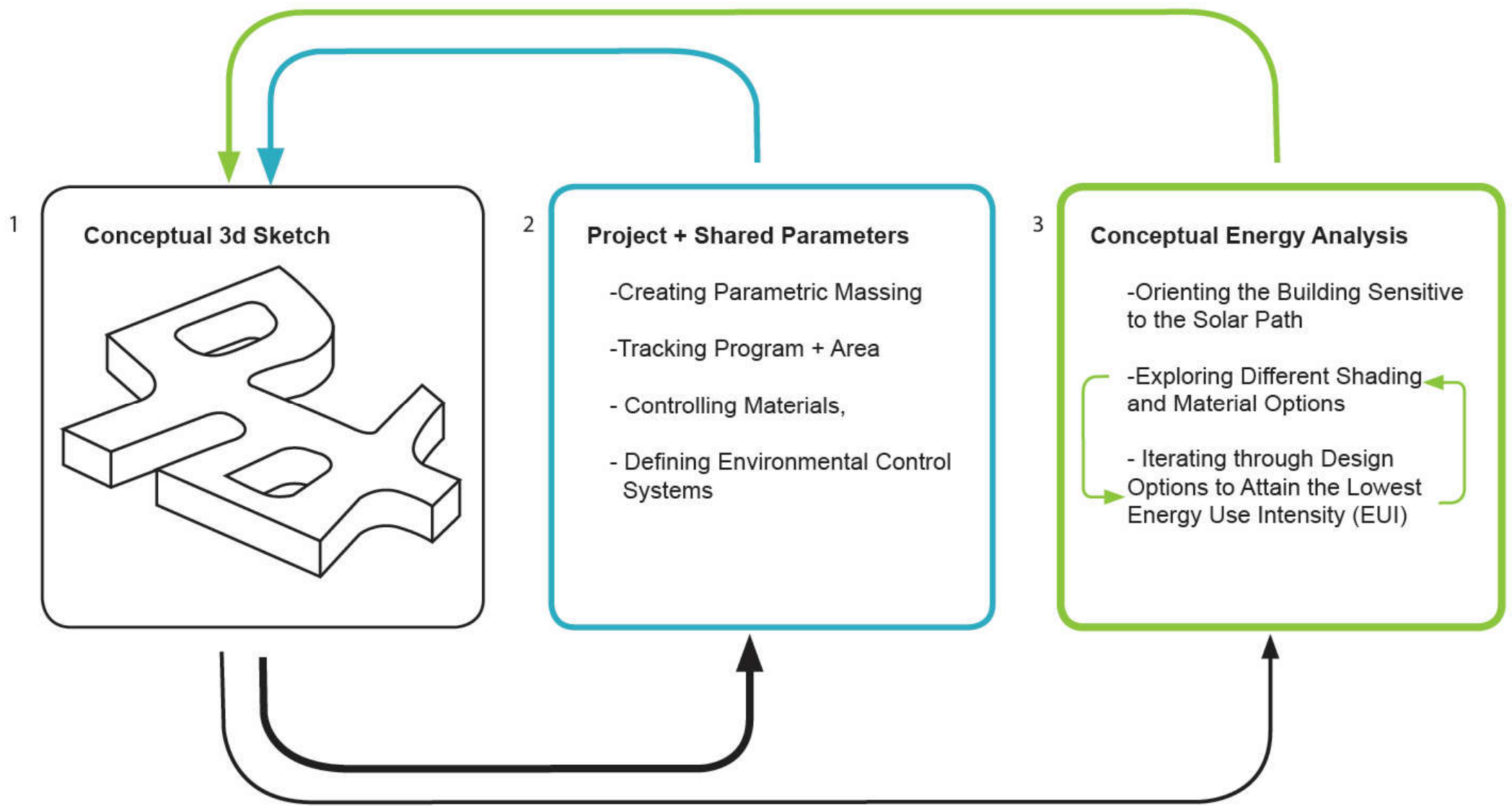
Vasari or Revit



Autodesk Sustainability Workshop

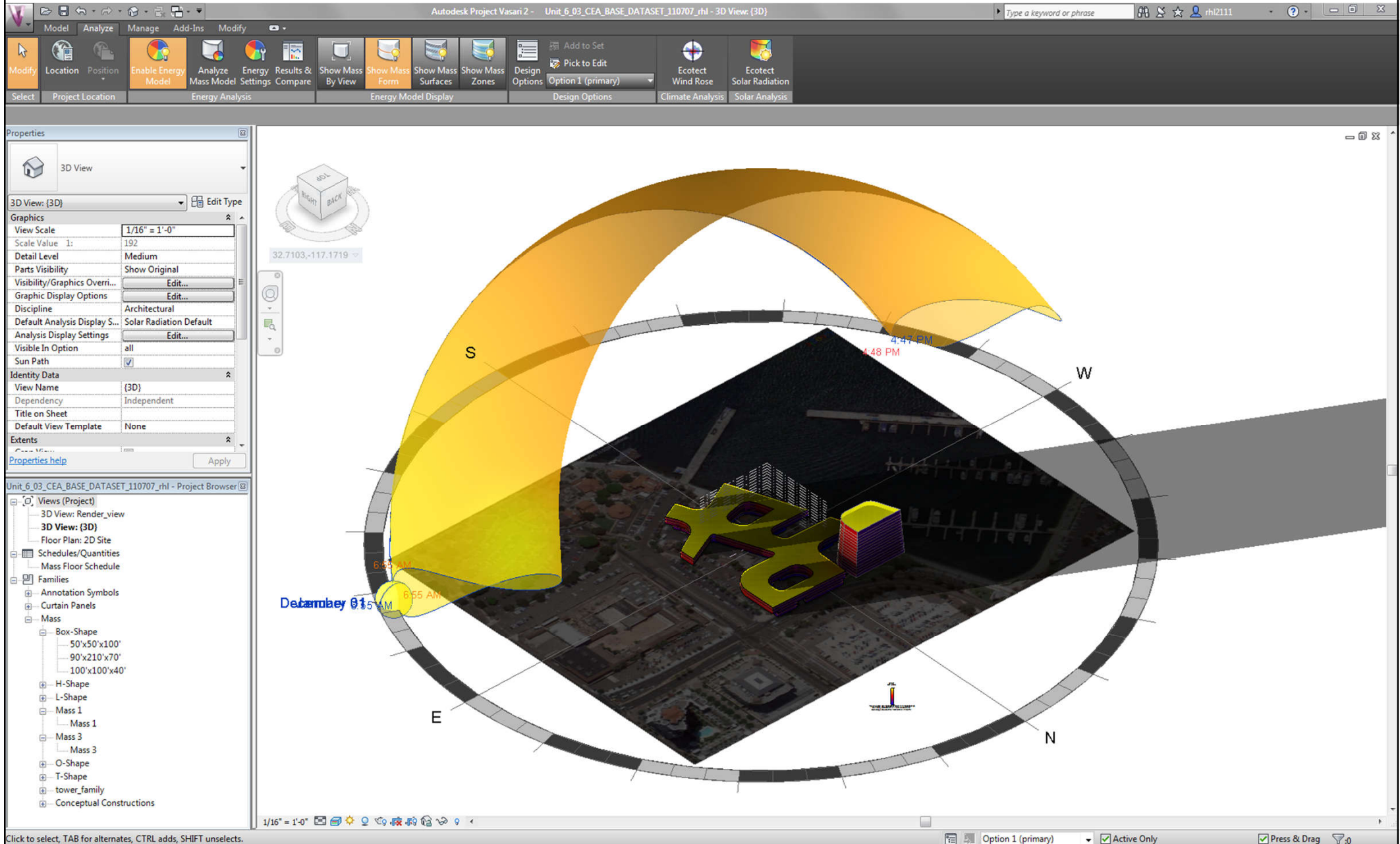
Autodesk

Performance based conceptual design and energy analysis



Do you know why conceptual energy analysis is important?

Conceptual energy analysis: study how the sun affects the design



(Source: Autodesk)

Solar study and solar response for different design options

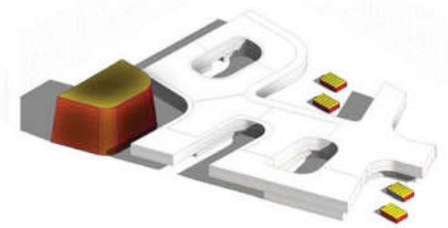
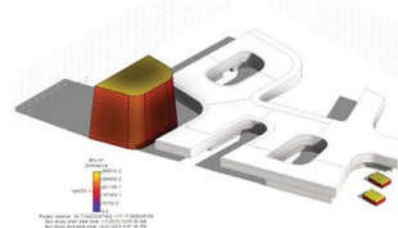
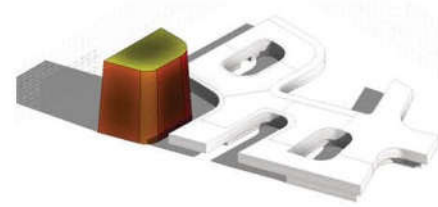
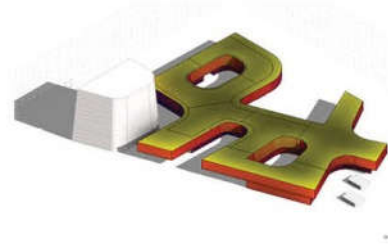
Main Building Solar Study

Tower Option A Solar Study

Tower Option B Solar Study

Tower Option C Solar Study

3.2



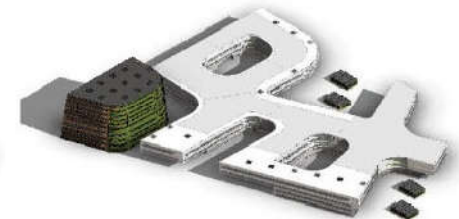
Main Building Solar Response

Tower Option A Solar Response

Tower Option B Solar Response

Tower Option C Solar Response

3.3

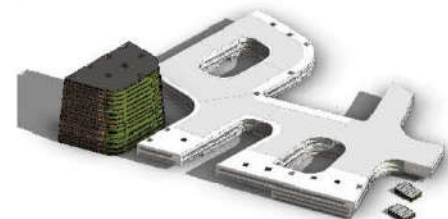


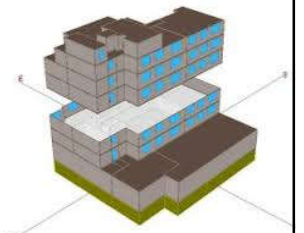
CEA of A Solar Response

CEA of B Solar Response

CEA of C Solar Response

3.4



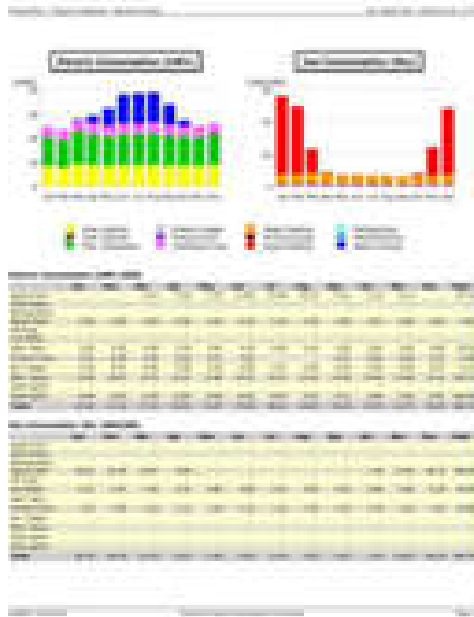
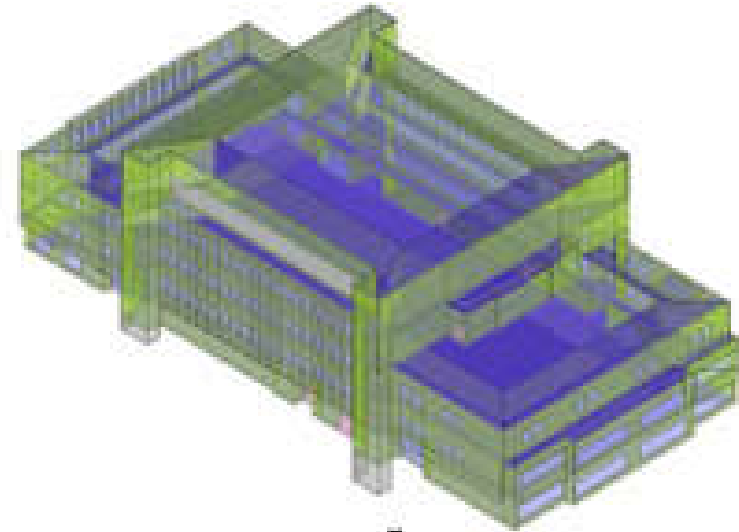
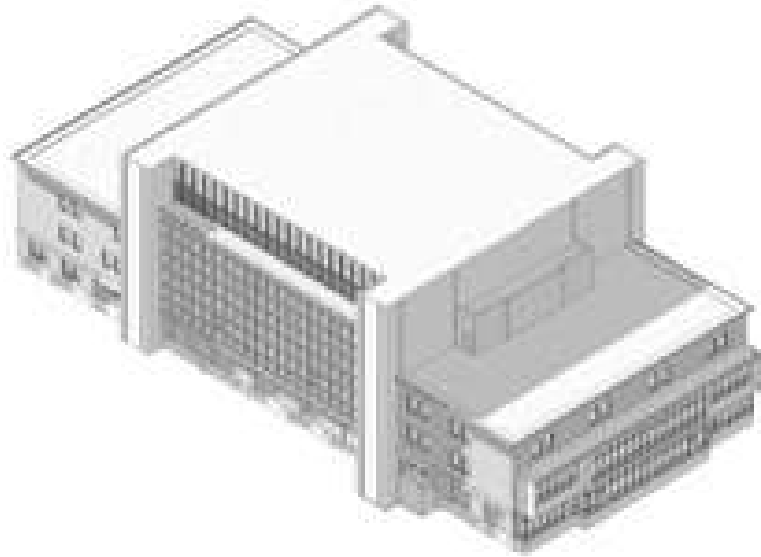


Building performance analysis

- Workflow of building energy analysis
 - Model geometry analysis (architectural elements)
 - Data input (energy model)
 - Dynamic energy calculation
 - Result sheet
- Early design phase:
 - Quick evaluation for different design solutions
- Detailed design phase:
 - Standard-compliance analysis

Architectural building elements

Energy analytical model



Energy analysis results

Energy model viewed in eQUEST

Shading & Peak Load Reduction

Glare & Visual Comfort

Electric Lighting Design & Integration

Computational Fluid Dynamics (CFD)

Life Cycle Cost Analysis (LCCA)

Two Dimensional Heat Flow Modeling

Hygrothermal Modeling

Fenestration Design & Analysis

Assembly Detailing & Specification

EnergyPlus Software

Iterative Whole Building Energy Simulation

Cooling Load Reduction Analysis

HVAC System Optimization

Energy Consumption Optimization

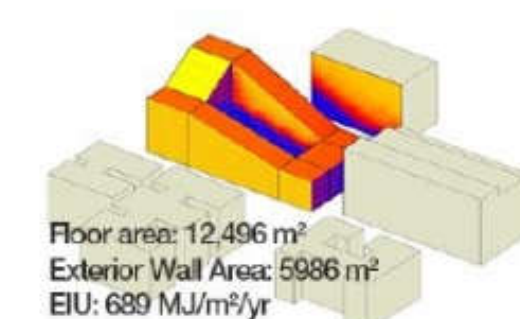
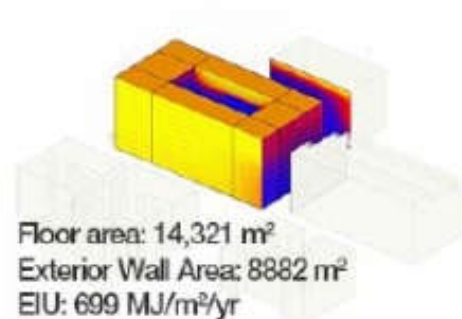
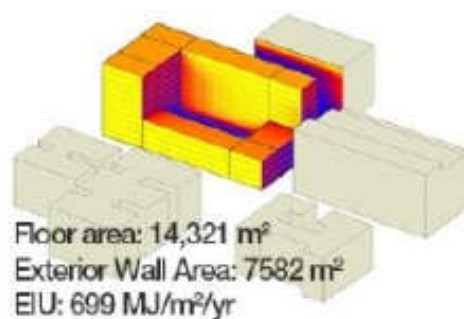
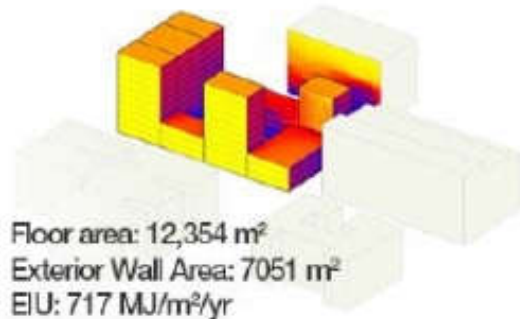
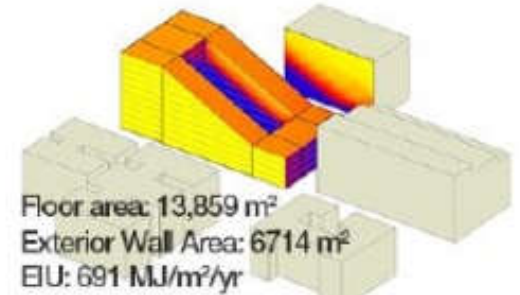
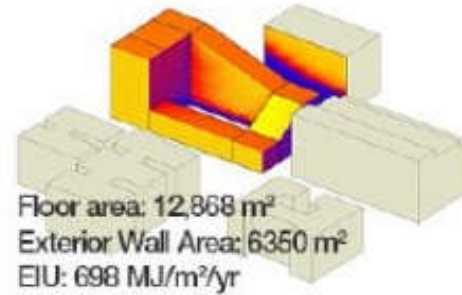
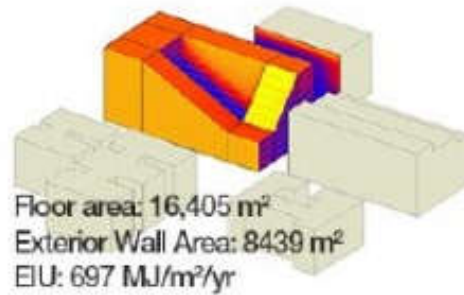
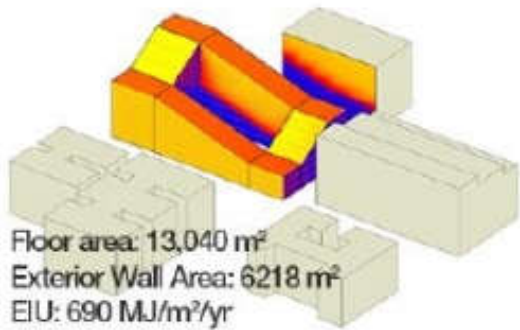
Thermal Comfort Analysis

Passive Systems Integration



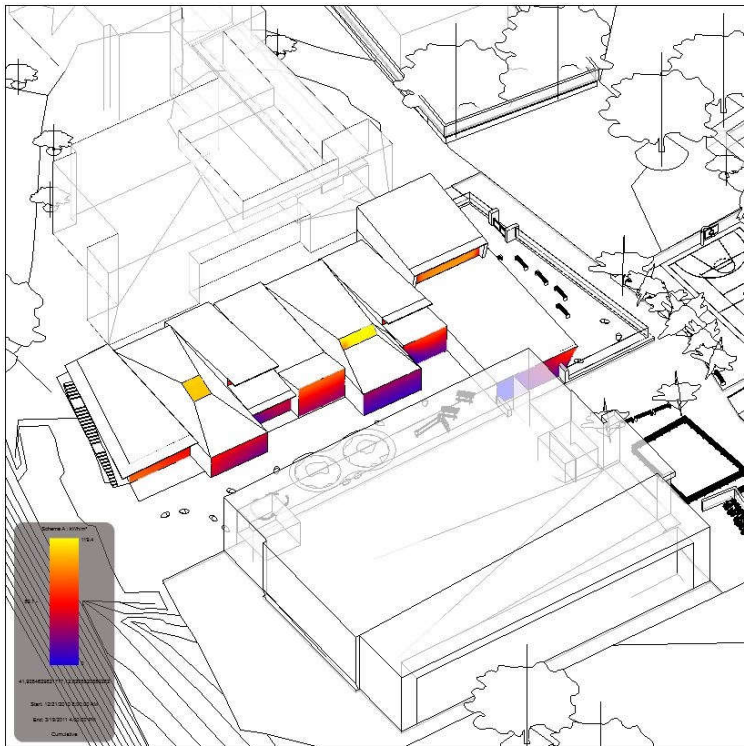
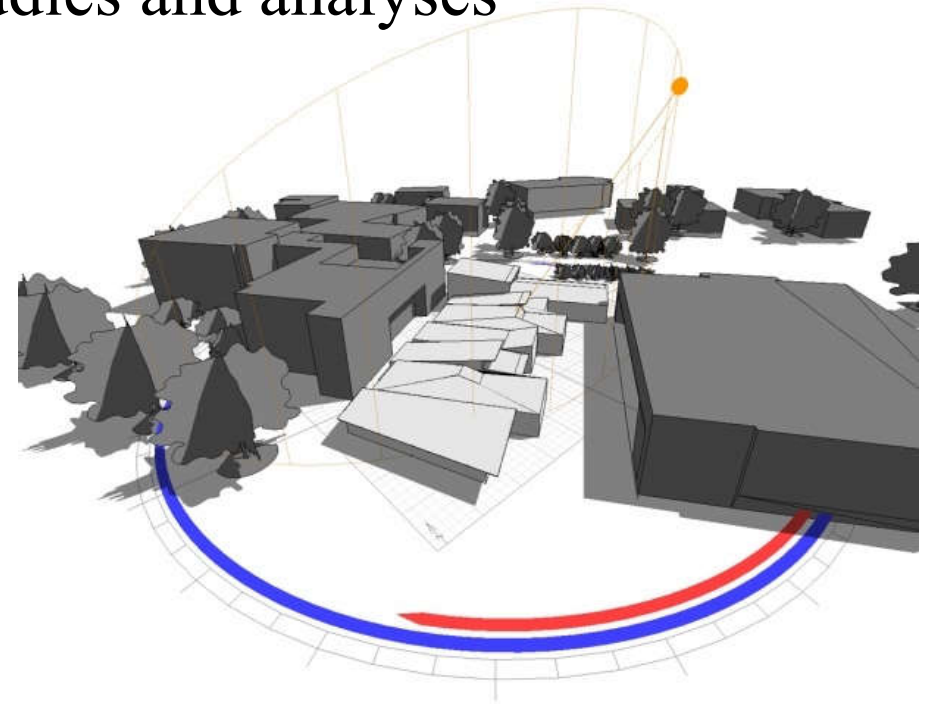
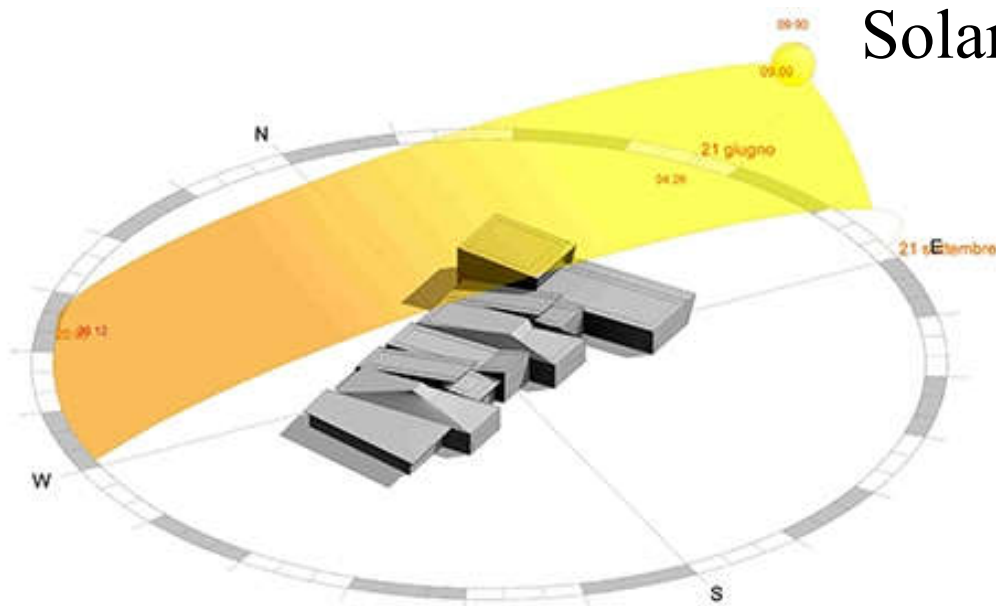
Autodesk Vasari

COURTYARD STUDY



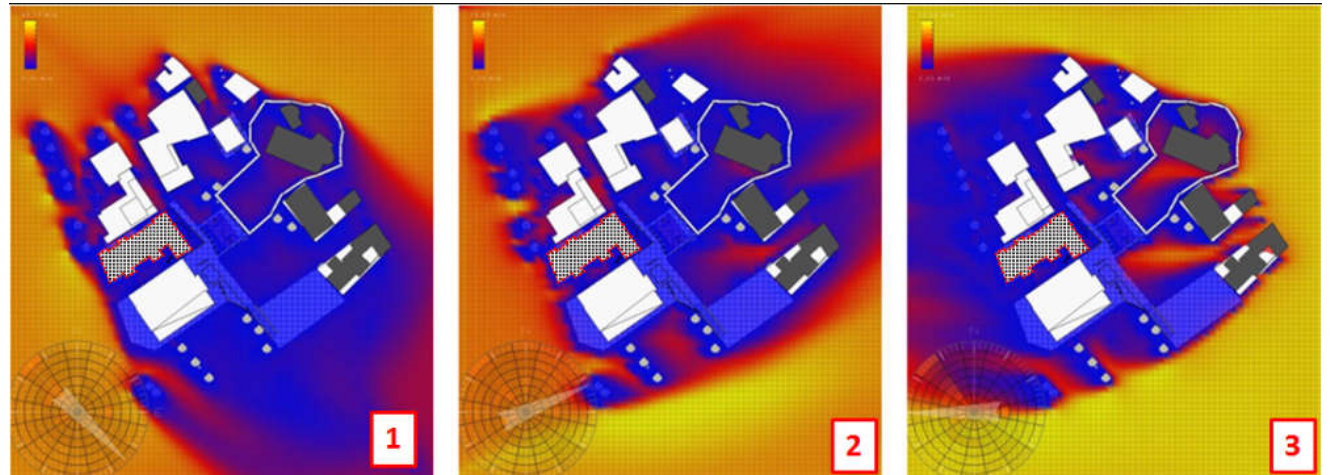
(Source: Autodesk)

Solar studies and analyses



Solar insolation

(Source: Autodesk)

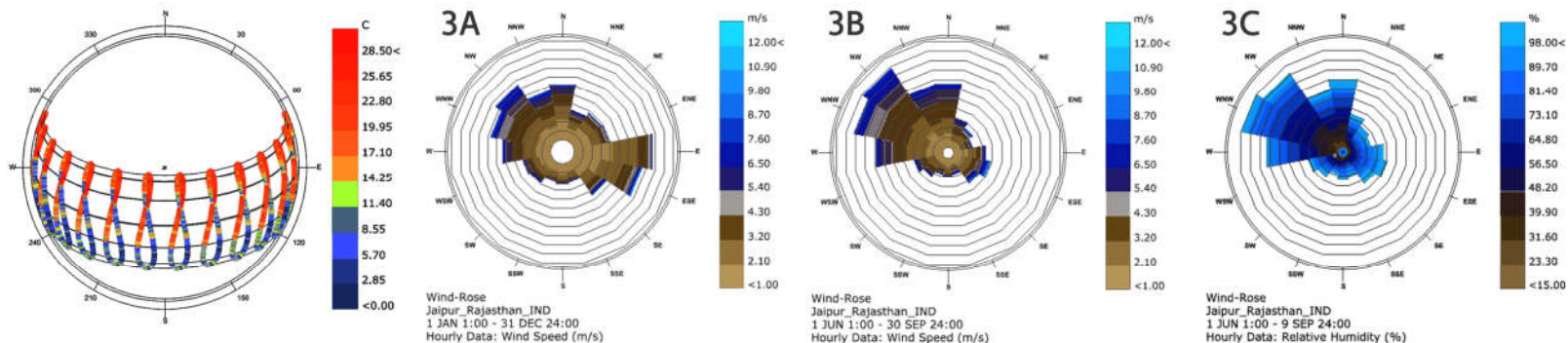


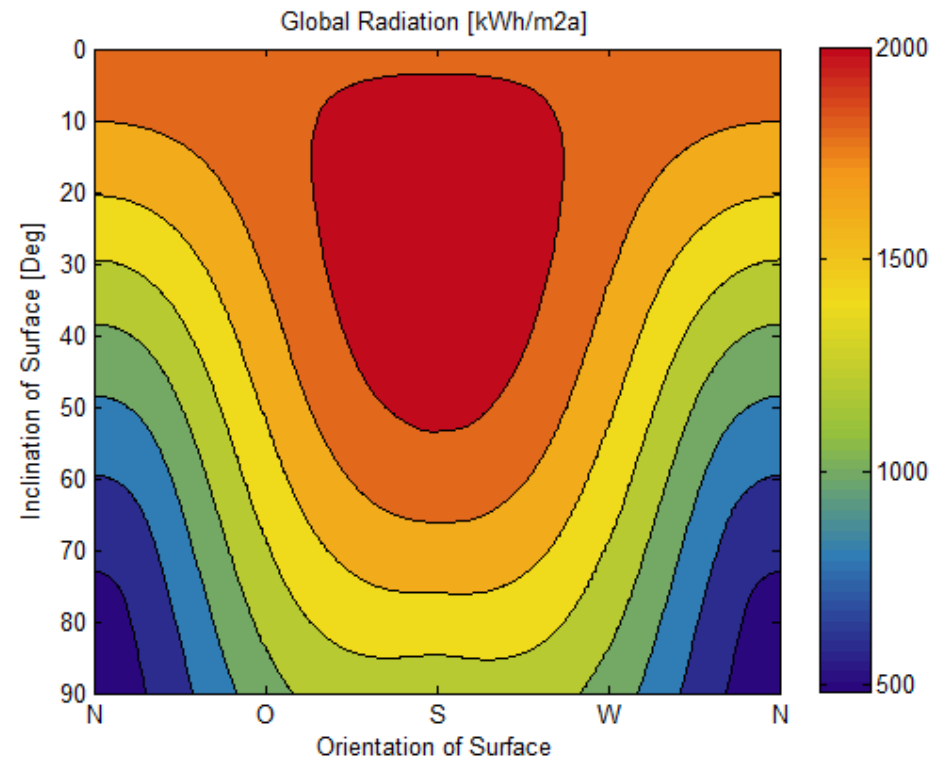
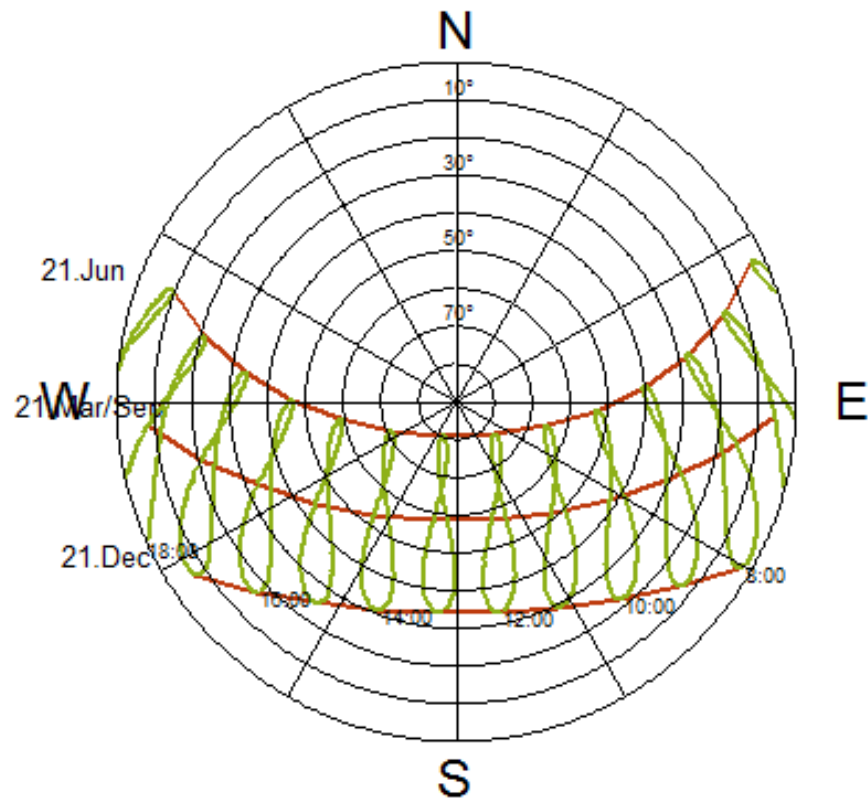
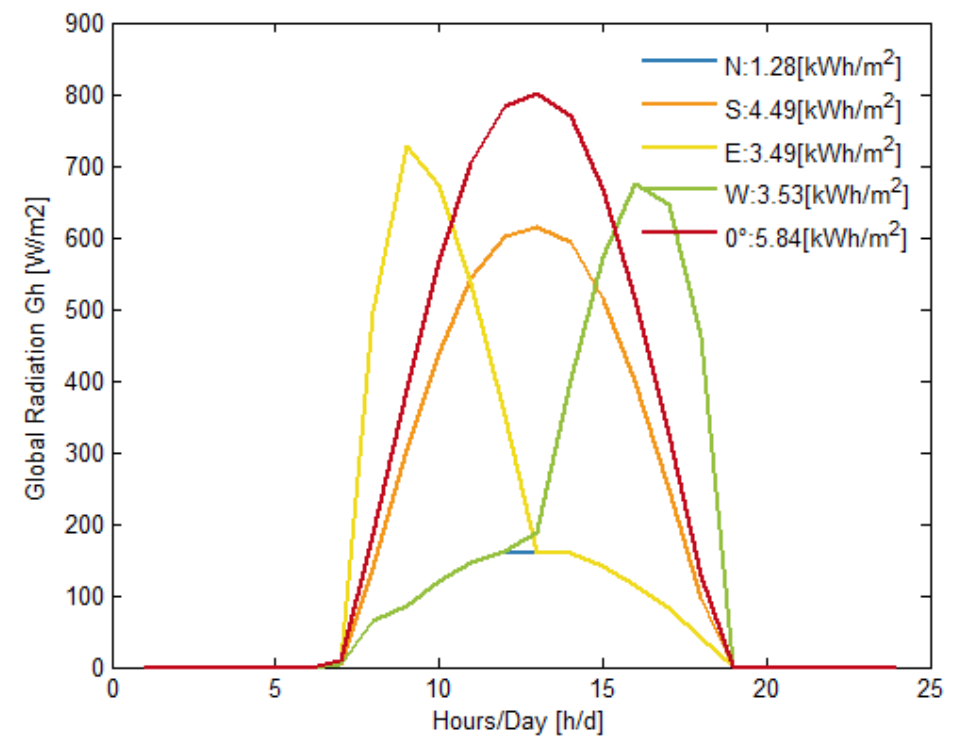
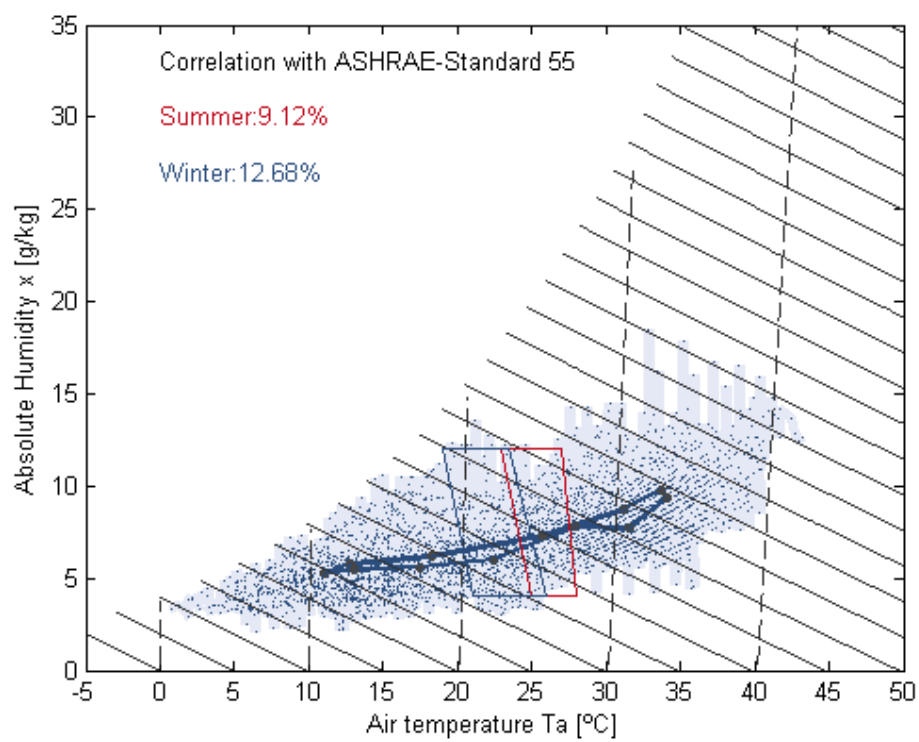
Wind tunnel analysis



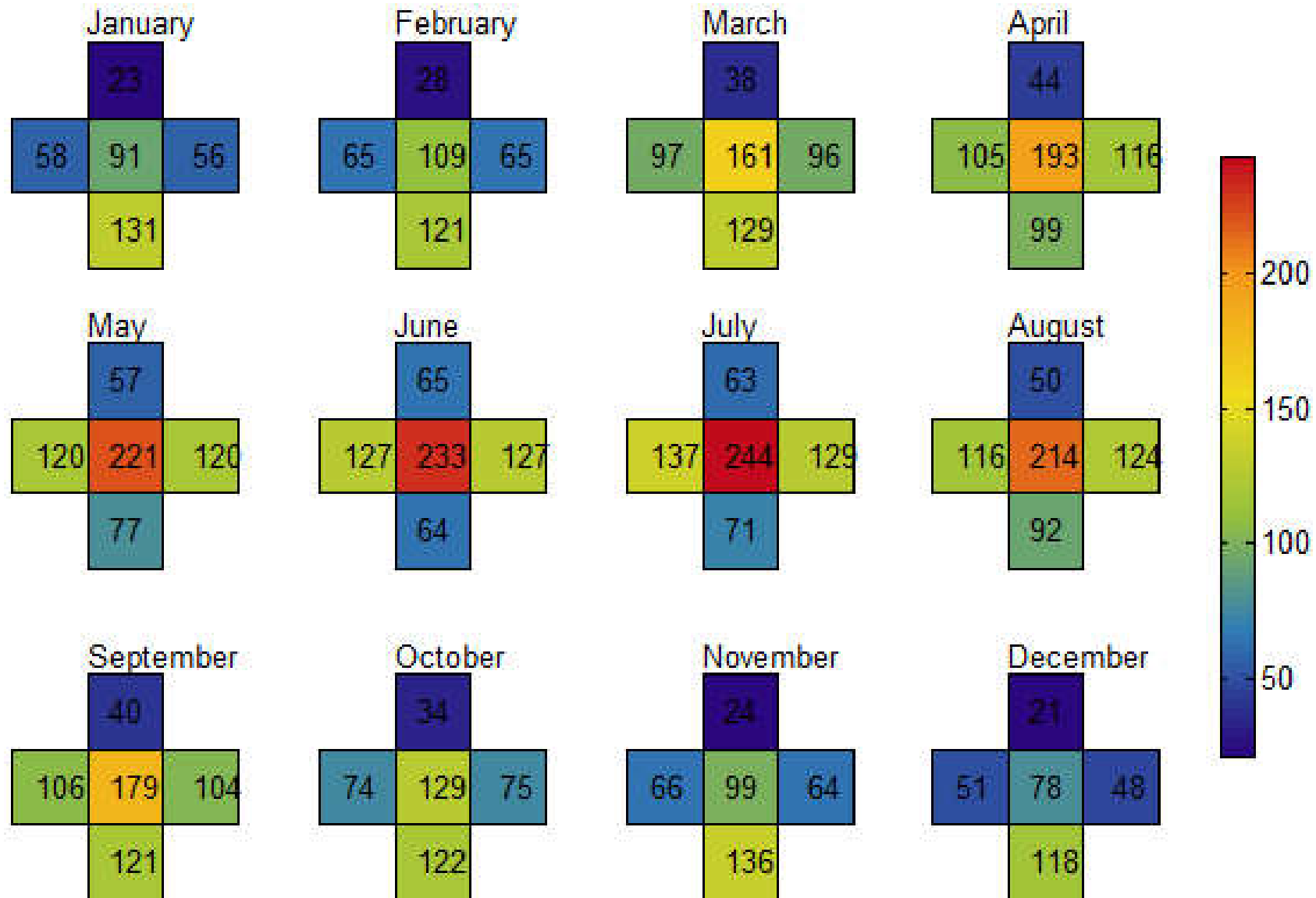
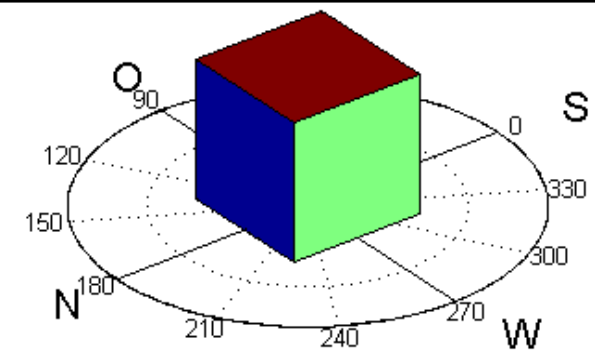
Climate analysis examples

- Climate can influence building design and dictate what passive design strategies are most suitable and effective for the building site
 - Climate refers to the average atmospheric conditions over a long period of time
 - Weather refers to the daily temperatures and atmospheric conditions



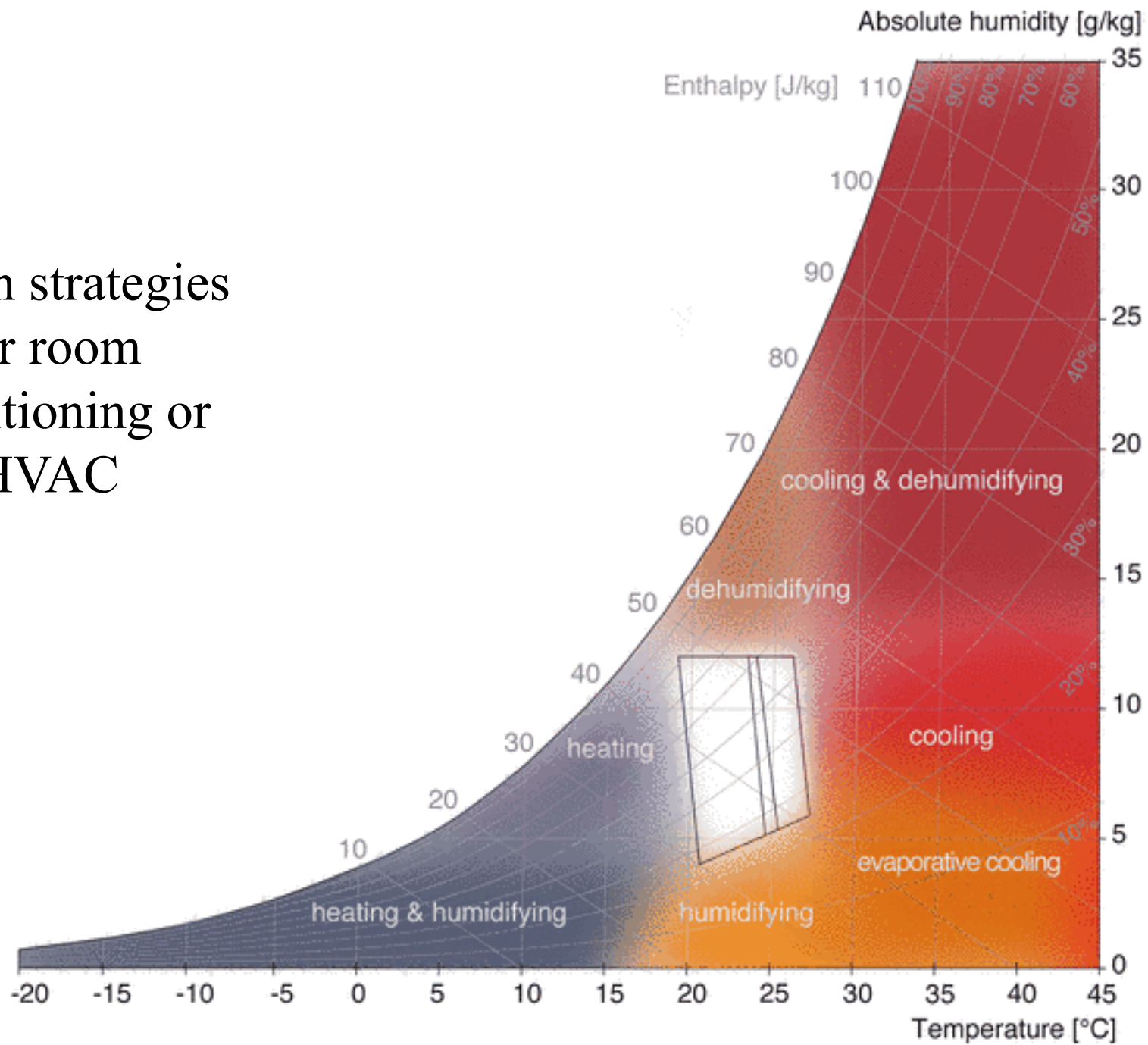


Solar radiation analysis (façade month)



Global Radiation [kWh/m²*Month]

Design strategies for room conditioning or HVAC



Room conditioning according to the outdoor climate shown in psychrometric chart
(cf. Olgay, 1963)

Climate analysis examples



- Energy Design Tools, University of California, Los Angeles (UCLA)
 - <http://www.energy-design-tools.aud.ucla.edu/>
 - **Climate Consultant** (version 6.0)
 - Organize and represent climate information in easy-to-understand ways that show the subtle attributes of climate, and its impact on built form
 - <http://www.energy-design-tools.aud.ucla.edu/climate-consultant/request-climate-consultant.php>
 - Video: Climate Consultant V6.10 (20:46)
<https://youtu.be/bc0dIPP0SBg>



WEATHER DATA SUMMARY

LOCATION: HONG KONG, SAR, CHN**Latitude/Longitude: 22.32° North, 114.17° East, Time Zone from Greenwich 8****Data Source: CityUHK-45007 450070 WMO Station Number, Elevation 65 m**

MONTHLY MEANS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Global Horiz Radiation (Avg Hourly)	235	239	244	268	280	288	373	340	329	353	316	286	Wh/sq.m
Direct Normal Radiation (Avg Hourly)	159	123	112	107	133	146	243	201	186	267	251	233	Wh/sq.m
Diffuse Radiation (Avg Hourly)	142	157	161	185	173	178	182	187	186	176	163	155	Wh/sq.m
Global Horiz Radiation (Max Hourly)	717	856	881	919	969	936	972	953	933	864	797	725	Wh/sq.m
Direct Normal Radiation (Max Hourly)	780	794	750	728	751	735	754	752	774	799	803	795	Wh/sq.m
Diffuse Radiation (Max Hourly)	323	367	401	414	407	411	411	411	397	370	335	309	Wh/sq.m
Global Horiz Radiation (Avg Daily Total)	2538	2691	2906	3370	3670	3855	4925	4331	3999	4048	3460	3056	Wh/sq.m
Direct Normal Radiation (Avg Daily Total)	1719	1387	1335	1354	1745	1952	3216	2558	2270	3063	2746	2482	Wh/sq.m
Diffuse Radiation (Avg Daily Total)	1533	1763	1921	2325	2269	2375	2407	2381	2263	2016	1787	1659	Wh/sq.m
Global Horiz Illumination (Avg Hourly)													lux
Direct Normal Illumination (Avg Hourly)													lux
Dry Bulb Temperature (Avg Monthly)	16	16	19	22	26	27	28	28	27	25	21	17	degrees C
Dew Point Temperature (Avg Monthly)	11	12	15	19	22	25	24	24	23	19	15	10	degrees C
Relative Humidity (Avg Monthly)	74	80	82	84	81	84	79	81	80	72	69	66	percent
Wind Direction (Monthly Mode)	90	90	100	90	60	90	250	240	80	90	90	90	degrees
Wind Speed (Avg Monthly)	2	3	2	3	2	3	3	2	3	3	2	2	m/s
Ground Temperature (Avg Monthly of 3 Depths)	18	19	20	21	24	26	26	26	25	23	20	19	degrees C

LOCATION: HONG KONG, SAR, CHN**Latitude/Longitude:** 22.32° North, 114.17° East, **Time Zone from Greenwich 8****Data Source:** CityUHK-45007 450070 WMO Station Number, **Elevation 65 m****CRITERIA: (Metric Units)****ASHRAE Standard 55, current Handbook of Fundamentals Comfort Model (select Help for definitions)****1. COMFORT: (using ASHRAE Standard 55)**

1.0	Winter Clothing Indoors (1.0 Clo=long pants,sweater)
0.5	Summer Clothing Indoors (.5 Clo=shorts,light top)
1.1	Activity Level Daytime (1.1 Met=sitting,reading)
90.0	Predicted Percent of People Satisfied (100 - PPD)
20.3	Comfort Lowest Winter Temp calculated by PMV model(ET* C)
24.3	Comfort Highest Winter Temp calculated by PMV model(ET* C)
26.7	Comfort Highest Summer Temp calculated by PMV model(ET* C)
84.6	Maximum Humidity calculated by PMV model (%)

2. SUN SHADING ZONE: (Defaults to Comfort Low)

23.8	Min. Dry Bulb Temperature when Need for Shading Begins (°C)
315.5	Min. Global Horiz. Radiation when Need for Shading Begins (Wh/sq.m)

3. HIGH THERMAL MASS ZONE:

8.3	Max. Outdoor Temperature Difference above Comfort High (°C)
1.7	Min. Nighttime Temperature Difference below Comfort High (°C)

4. HIGH THERMAL MASS WITH NIGHT FLUSHING ZONE:

16.7	Max. Outdoor Temperature Difference above Comfort High (°C)
1.7	Min. Nighttime Temperature Difference below Comfort High (°C)

5. DIRECT EVAPORATIVE COOLING ZONE: (Defined by Comfort Zone)

20.0	Max. Wet Bulb set by Max. Comfort Zone Wet Bulb (°C)
6.6	Min. Wet Bulb set by Min. Comfort Zone Wet Bulb (°C)

6. TWO-STAGE EVAPORATIVE COOLING ZONE:

50.0	% Efficiency of Indirect Stage
------	--------------------------------

7. NATURAL VENTILATION COOLING ZONE:

2.0	Terrain Category to modify Wind Speed (2=suburban)
0.2	Min. Indoor Velocity to Effect Indoor Comfort (m/s)
1.5	Max. Comfortable Velocity (per ASHRAE Std. 55) (m/s)

8. FAN-FORCED VENTILATION COOLING ZONE:

0.8	Max. Mechanical Ventilation Velocity (m/s)
3.0	Max. Perceived Temperature Reduction (°C) (Min Vel, Max RH, Max WB match Natural Ventilation)

9. INTERNAL HEAT GAIN ZONE (lights, people, equipment):

12.8	Balance Point Temperature below which Heating is Needed (°C)
------	--

10. PASSIVE SOLAR DIRECT GAIN LOW MASS ZONE:

157.7	Min. South Window Radiation for 5.56°C Temperature Rise (Wh/sq.m)
3.0	Thermal Time Lag for Low Mass Buildings (hours)

11. PASSIVE SOLAR DIRECT GAIN HIGH MASS ZONE:

157.7	Min. South Window Radiation for 5.56°C Temperature Rise (Wh/sq.m)
12.0	Thermal Time Lag for High Mass Buildings (hours)

12. WIND PROTECTION OF OUTDOOR SPACES:

8.5	Velocity above which Wind Protection is Desirable (m/s)
11.1	Dry Bulb Temperature Above or Below Comfort Zone (°C)

13. HUMIDIFICATION ZONE: (defined by and below Comfort Zone)**14. DEHUMIDIFICATION ZONE: (defined by and above Comfort Zone)**

TEMPERATURE RANGE
ASHRAE Standard 55

LOCATION: HONG KONG, SAR, CHN
Latitude/Longitude: 22.32° North, 114.17° East, **Time Zone from Greenwich 8**
Data Source: CityUHK-45007 450070 WMO Station Number, **Elevation 65 m**

LEGEND

- RECORDED HIGH - ○
- DESIGN HIGH -
- AVERAGE HIGH -
- MEAN -
- AVERAGE LOW -
- DESIGN LOW -
- RECORDED LOW - ○

COMFORT ZONE

SUMMER

WINTER

(At 50% Relative Humidity)

DESIGN HIGH:

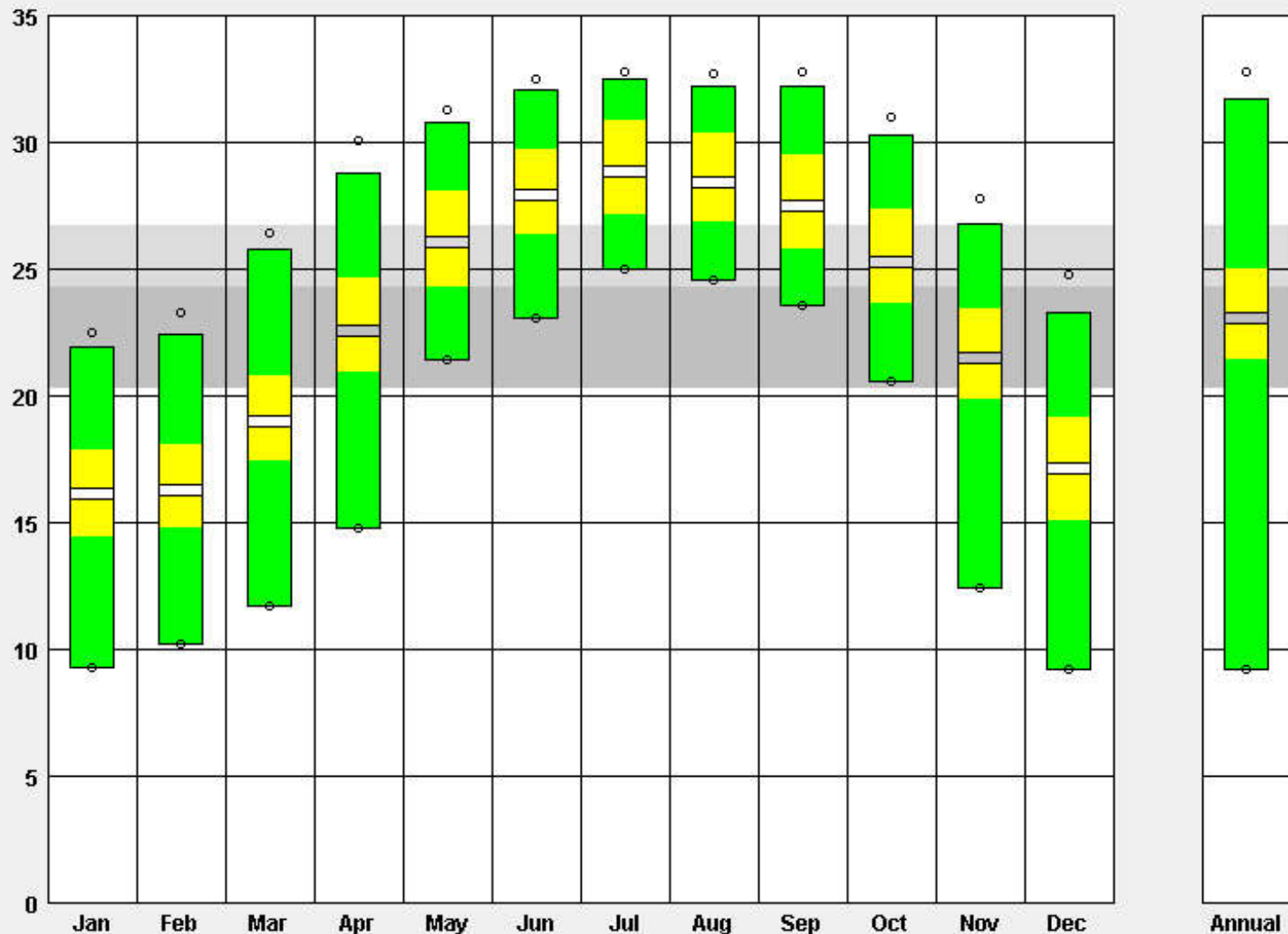
- 1% of Hours Above
- .5% of Hours Above
- 0% of Hours Above

DESIGN LOW:

- 1% of Hours Below
- .5% of Hours Below
- 0% of Hours Below

TEMPERATURE RANGE:

- 10 to 40 °C
- Fit to Data



MONTHLY DIURNAL AVERAGES
ASHRAE Standard 55

LOCATION: HONG KONG, SAR, CHN
Latitude/Longitude: 22.32° North, 114.17° East, **Time Zone from Greenwich** 8
Data Source: CityUHK-45007 450070 WMO Station Number, **Elevation** 65 m

LEGEND

HOURLY AVERAGES

TEMPERATURE: (degrees C)

- DRY BULB MEAN
- WET BULB MEAN
- █ DRY BULB (all hours)

COMFORT ZONE

- SUMMER
- WINTER

(At 50% Relative Humidity)

RADIATION: (Wh/sq.m)

- █ GLOBAL HORIZ
- █ DIRECT NORMAL
- █ DIFFUSE

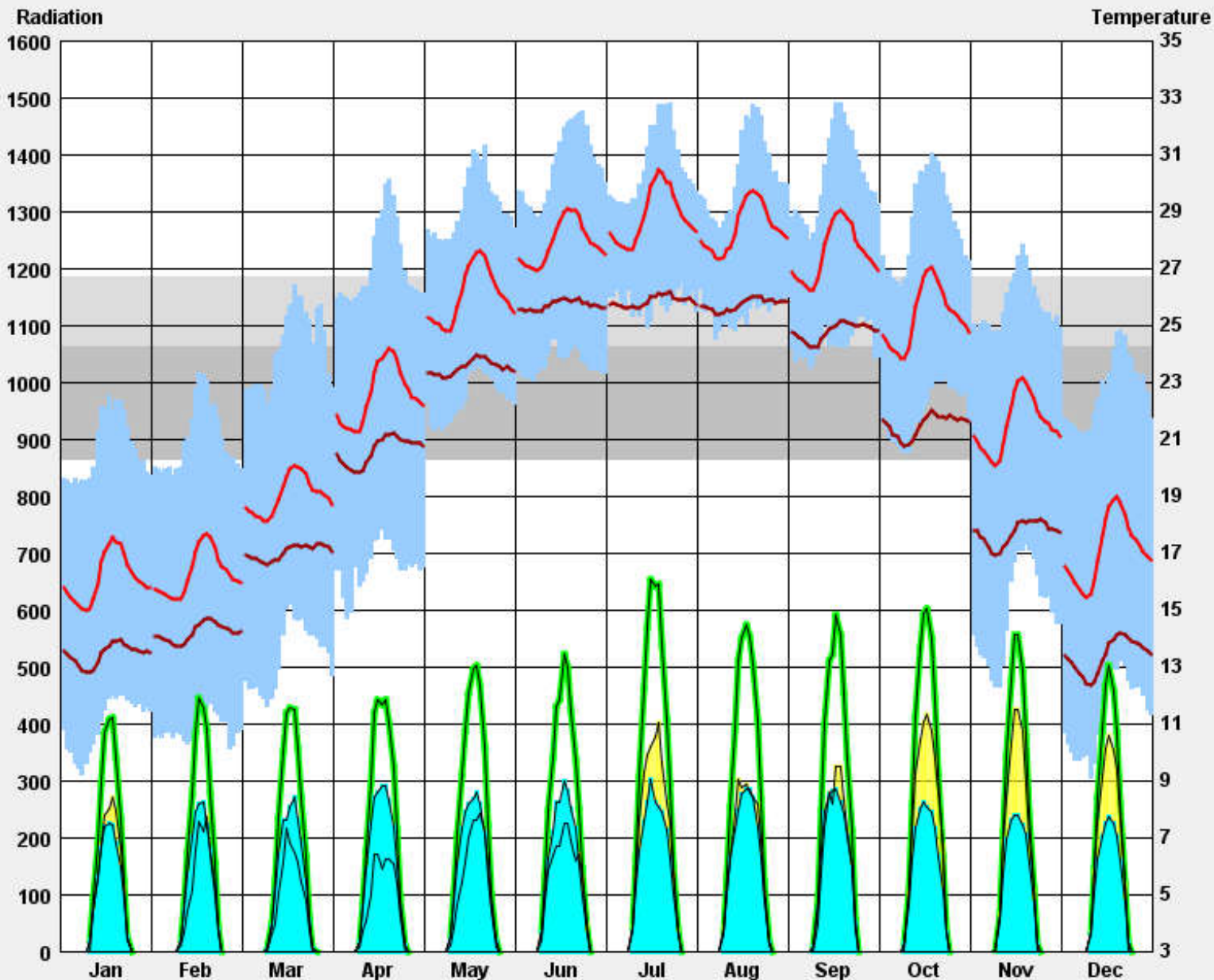
Display Dry Bulb Temp

(all hours)

TEMPERATURE RANGE:

-10 to 40 °C

Fit to Data



LOCATION: HONG KONG, SAR, CHN
Latitude/Longitude: 22.32° North, 114.17° East, **Time Zone from Greenwich 8**
Data Source: CityUHK-45007 450070 WMO Station Number, **Elevation 65 m**

RADIATION RANGE

LEGEND

**HOURLY AVERAGES
 DAYLIT HOURS ONLY**

- RECORDED HIGH - ○
- AVERAGE HIGH - [Yellow bar]
- MEAN - [White bar]
- AVERAGE LOW - [Yellow bar]
- RECORDED LOW - ○

RECORDED:

- [Yellow bar] DIRECT NORMAL
 - [Green bar] GLOBAL HORIZONTAL
 - [Orange bar] TOTAL SURFACE
- (Wh/sq.m per hour)

THEORETICAL:

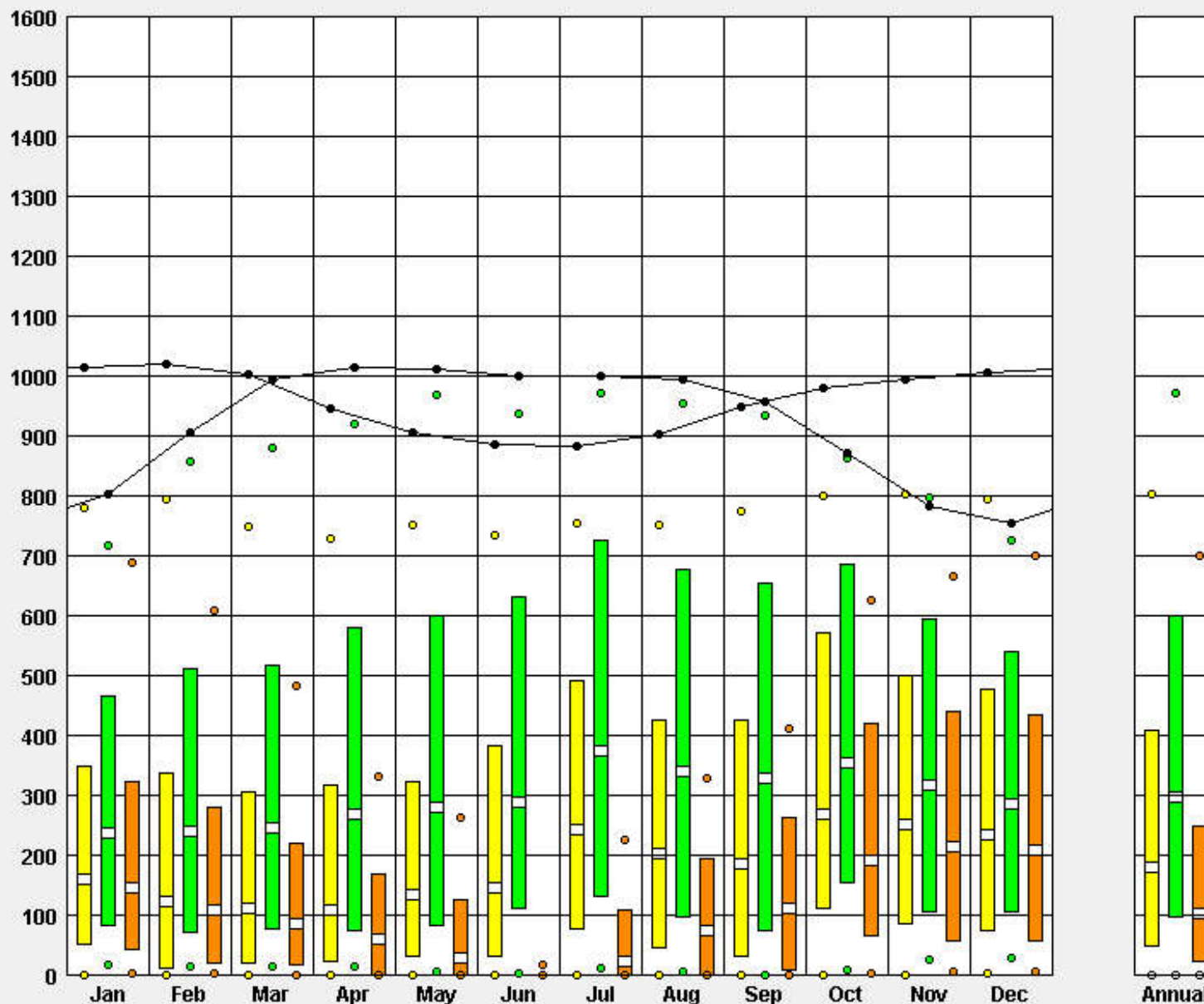
-

Tilted Surface Radiation Input:

- Tilt degrees from Horizontal
(Vertical = 90°)
- Bearing degrees from South
(South = 0°, West = +90°)
- % Ground Reflectance
(20% = grass)

PLOT:

- Hourly Avg
- Daily Total



SKY COVER RANGE

LOCATION: HONG KONG, SAR, CHN


Latitude/Longitude: 22.32° North, 114.17° East, Time Zone from Greenwich 8


Data Source: CityUHK-45007 450070 WMO Station Number, Elevation 65 m


LEGEND

Total Cloud Cover 100%

RECORDED HIGH - ○

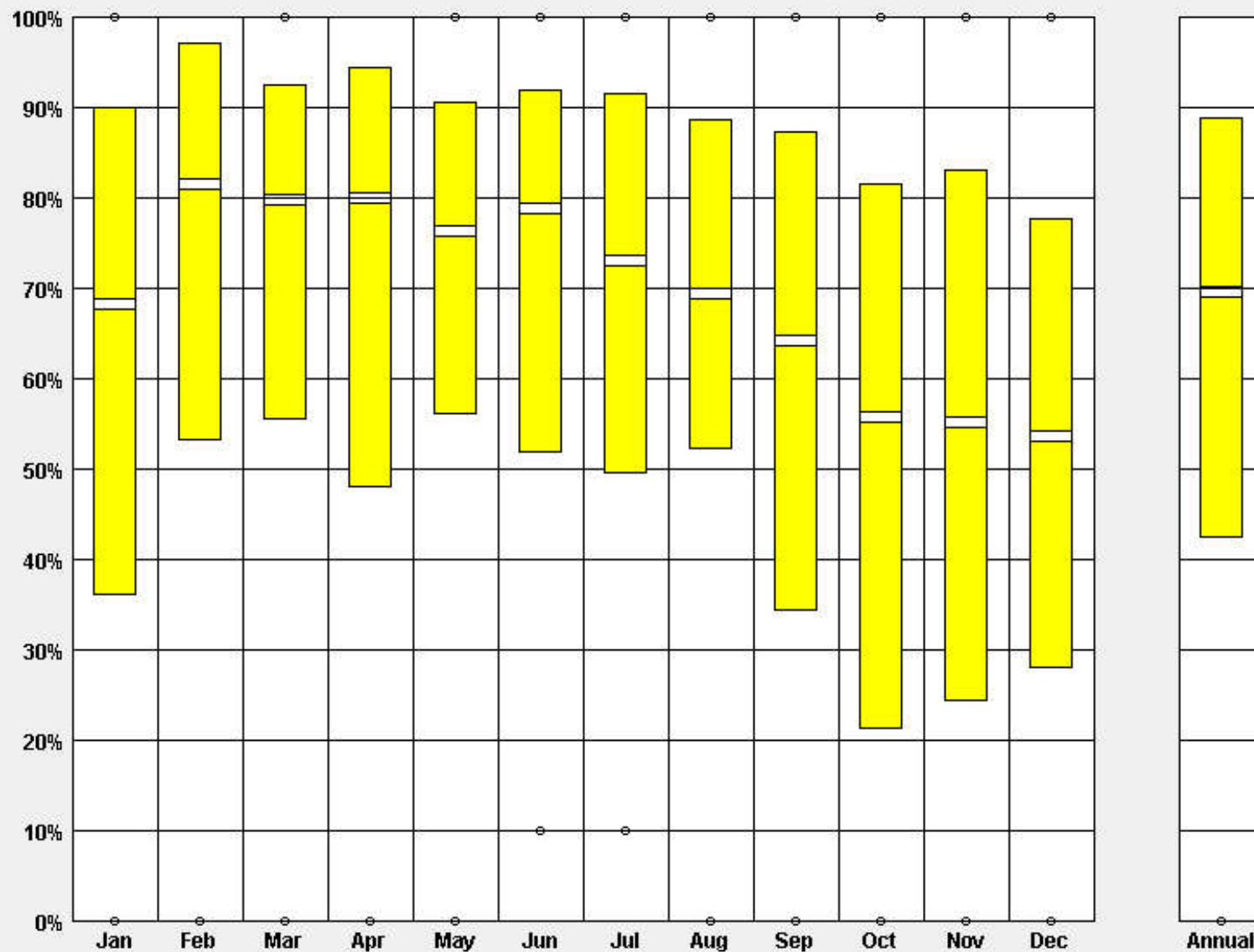
AVERAGE HIGH - 

MEAN - 

AVERAGE LOW - 

RECORDED LOW - ○

Clear Skies 0



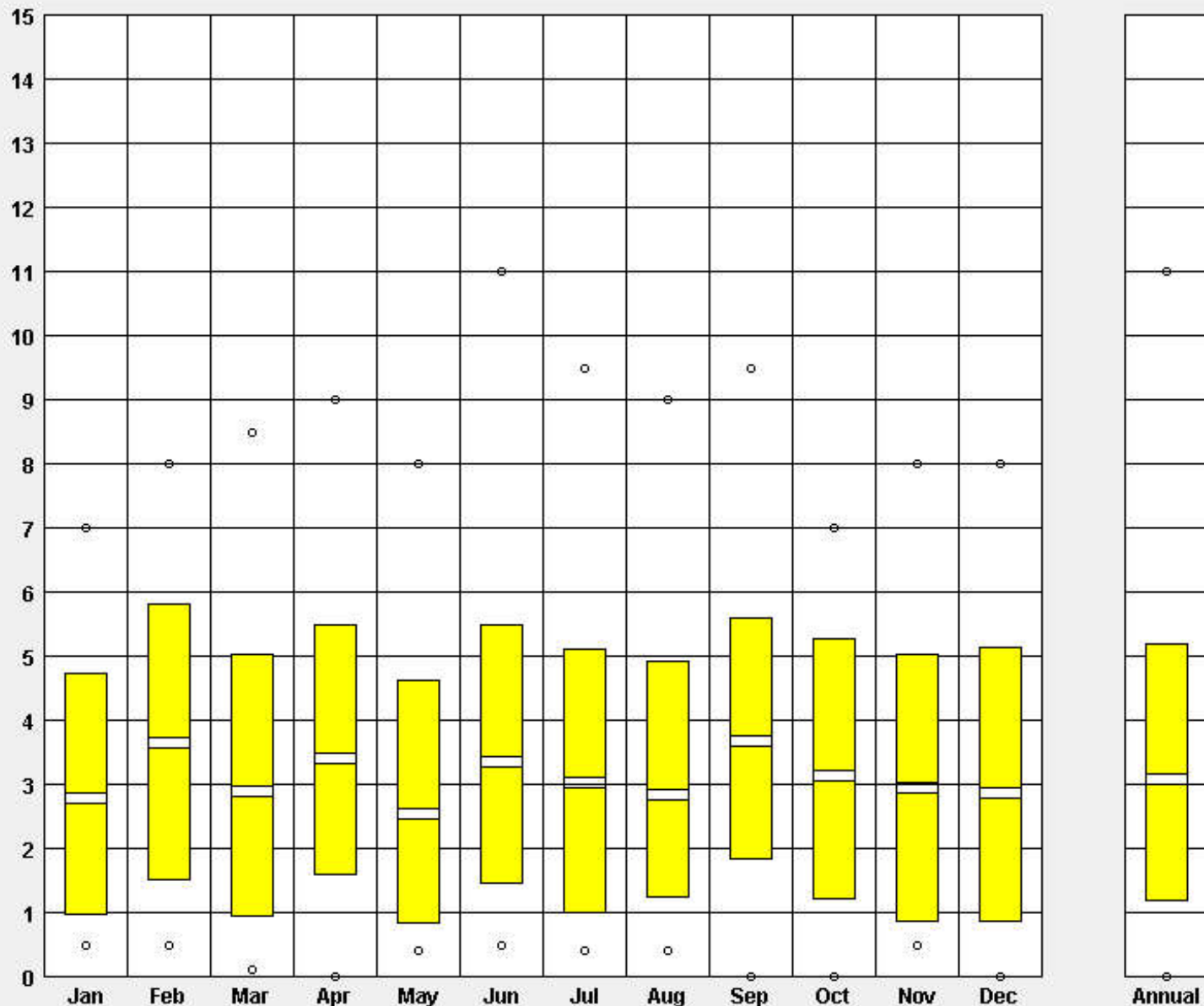
WIND VELOCITY RANGE

LOCATION: HONG KONG, SAR, CHN
Latitude/Longitude: 22.32° North, 114.17° East, **Time Zone from Greenwich 8**
Data Source: CityUHK-45007 450070 WMO Station Number, **Elevation 65 m**

LEGEND

RECORDED HIGH - ○
 AVERAGE HIGH -
 MEAN -
 AVERAGE LOW -
 RECORDED LOW - ○
 (m/s)

WIND VELOCITY:
 0 to 27 m/s
 Fit to Data

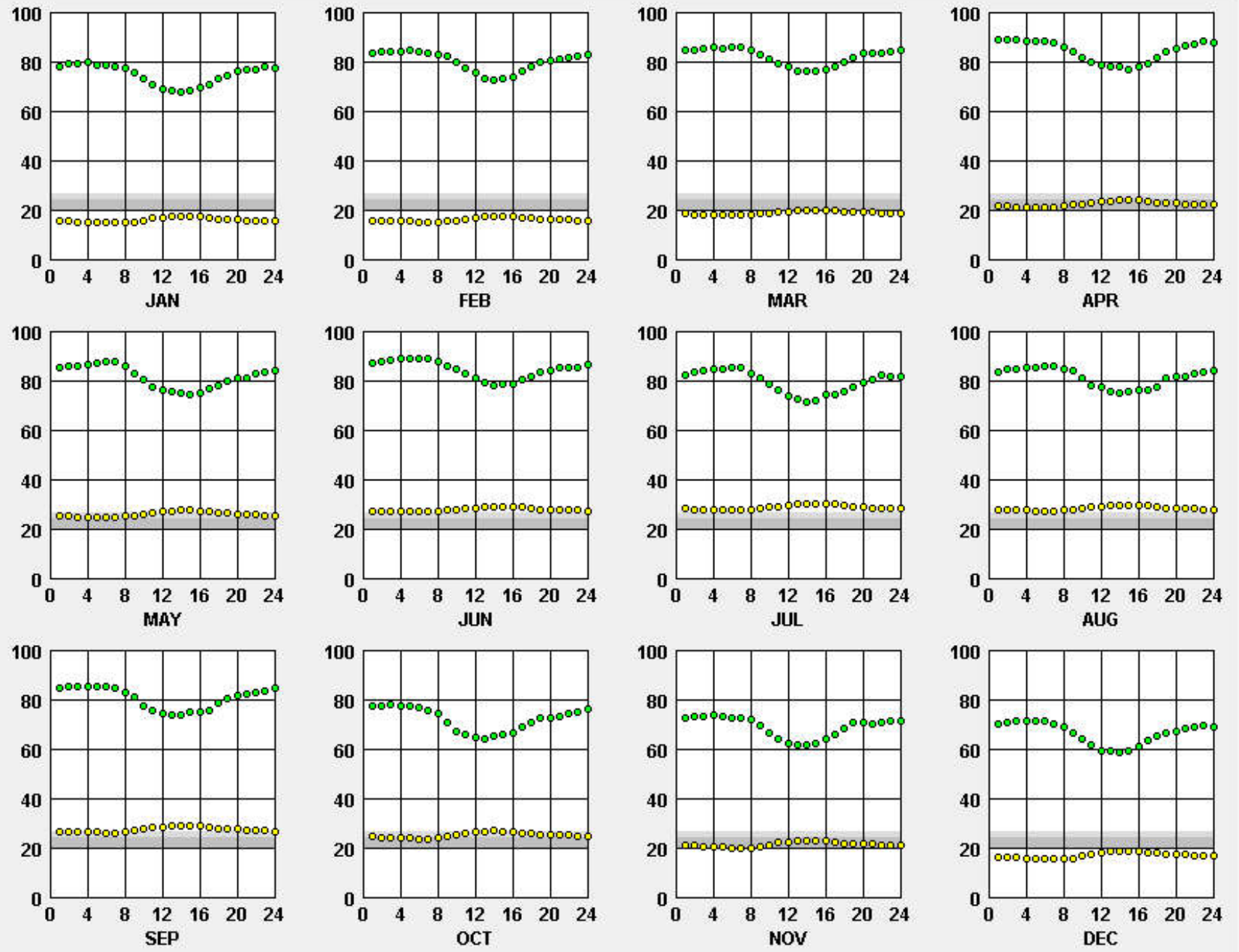


DRY BULB X RELATIVE HUMIDITY
ASHRAE Standard 55

LOCATION: HONG KONG, SAR, CHN
Latitude/Longitude: 22.32° North, 114.17° East, **Time Zone from Greenwich** 8
Data Source: CityUHK-45007 450070 WMO Station Number, **Elevation** 65 m

LEGEND

- Dry Bulb ●
- Humidity ●
- Comfort Zone
- Summer
- Winter
- At 50%
- Relative Humidity



LOCATION: HONG KONG, SAR, CHN
Latitude/Longitude: 22.32° North, 114.17° East, **Time Zone from Greenwich 8**
Data Source: CityUHK-45007 450070 WMO Station Number, **Elevation 65 m**

SUN SHADING CHART

LEGEND

- **WARMHOT > 27°C**
 (SHADE NEEDED)
 1052 Hours Exposed
 375 Hours Shaded
- **COMFORT > 20°C**
 (SHADE HELPS)
 432 Hours Exposed
 362 Hours Shaded
- **COOL/COLD < 20°C**
 (SUN NEEDED)
 121 Hours Exposed
 236 Hours Shaded

PLOT MONTHS:

WINTER SPRING

December 21 to June 21

SUMMER FALL

June 21 to December 21

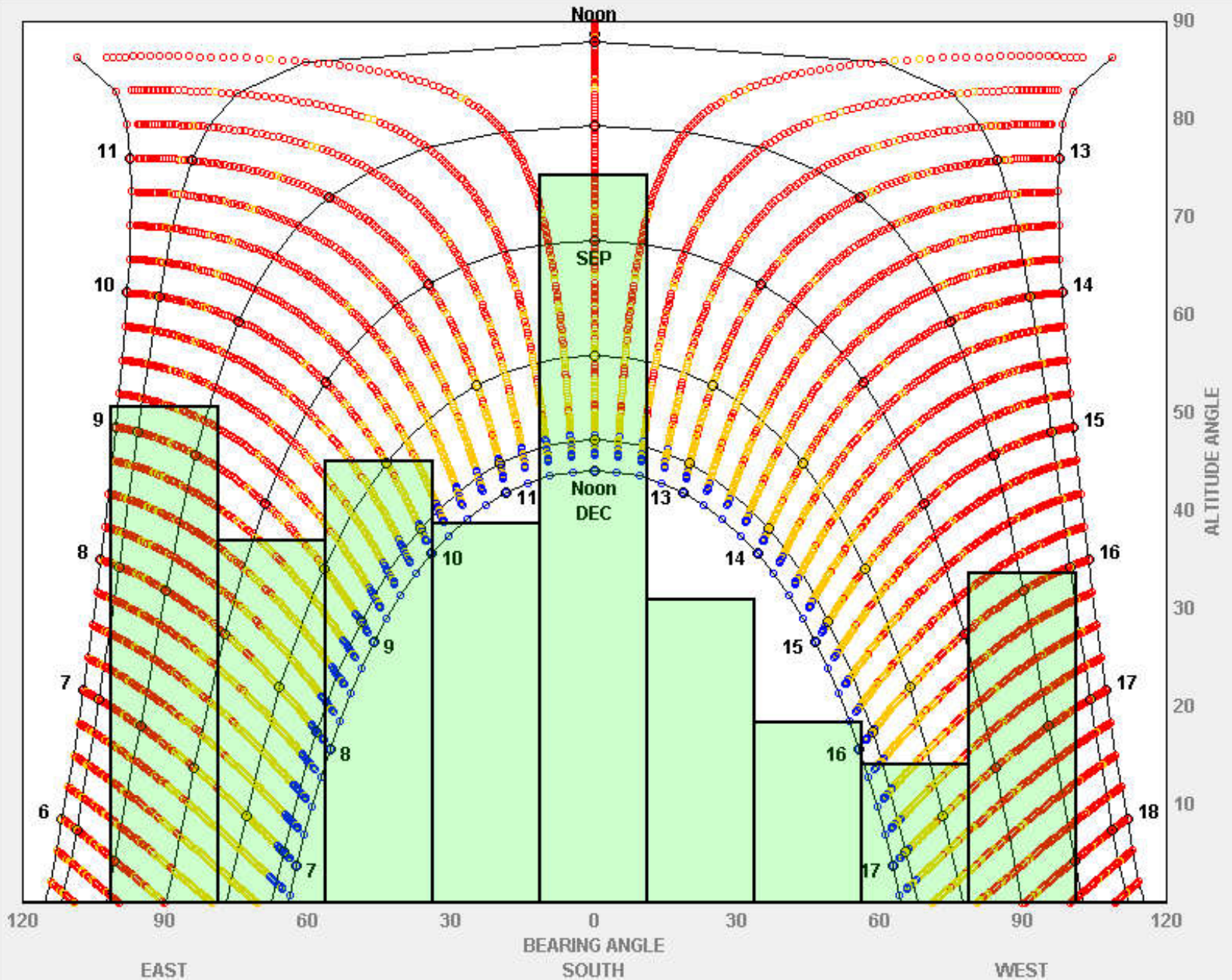
Display Grid

Display Shading Calculator

Display Obstruction Elevation

Input Obstructions

Display Opposite Direction



SUN CHART

LOCATION: HONG KONG, SAR, CHN
Latitude/Longitude: 22.32° North, 114.17° East, **Time Zone from Greenwich 8**
Data Source: CityUHK-45007 450070 WMO Station Number, **Elevation 65 m**

LEGEND

- **WARM/HOT > 27°C**
(SHADE NEEDED)
- **COMFORT > 20°C**
(SHADE HELPS)
- **COOL/COLD < 20°C**
(SUN NEEDED)

✱ GNOMON POSITION

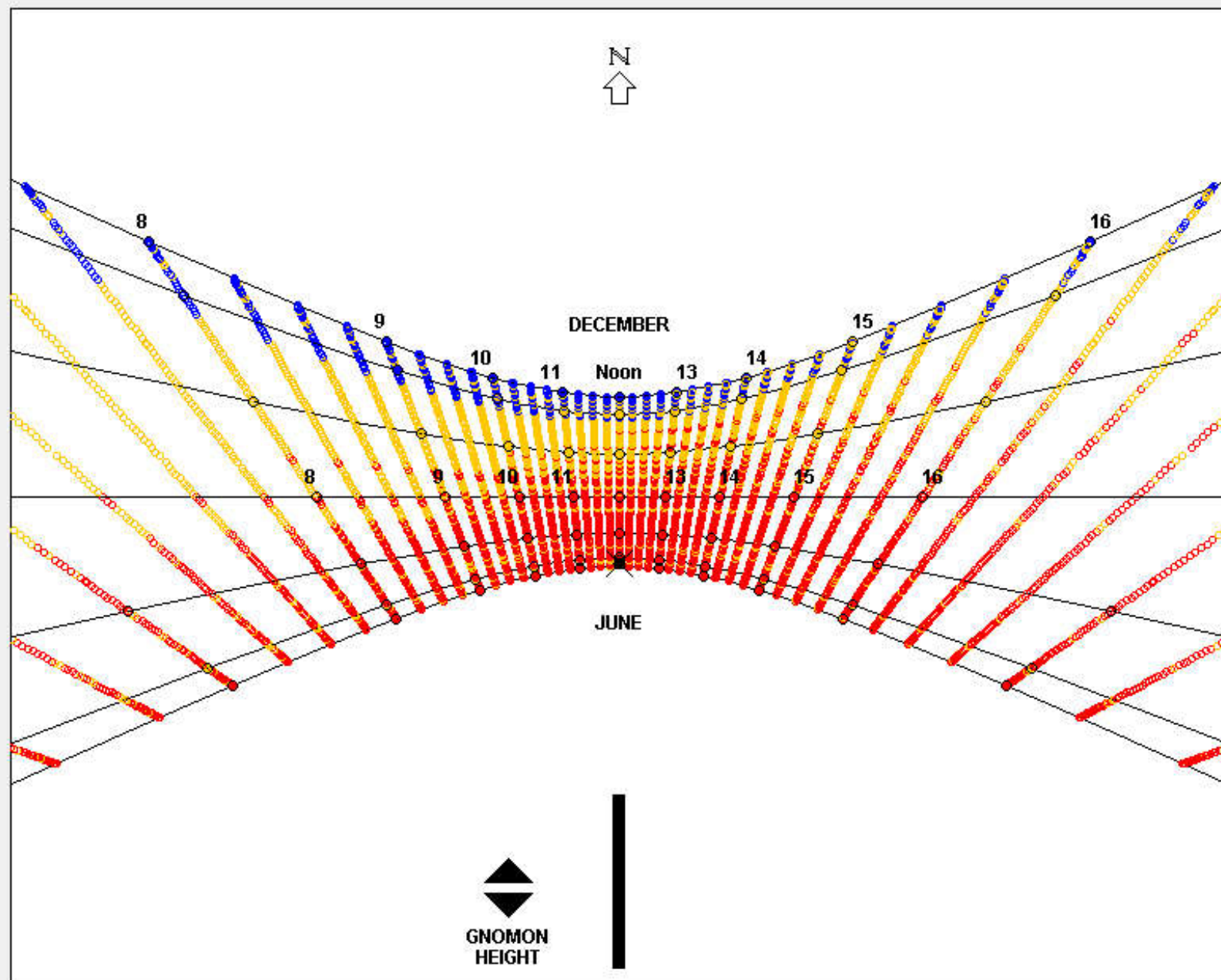
PLOT MONTHS:

WINTER SPRING

○ December 21 to June 21

SUMMER FALL

● June 21 to December 21



LOCATION: HONG KONG, SAR, CHN
Latitude/Longitude: 22.32° North, 114.17° East, **Time Zone from Greenwich 8**
Data Source: CityUHK-45007 450070 WMO Station Number, **Elevation 65 m**

TIMETABLE PLOT

LEGEND

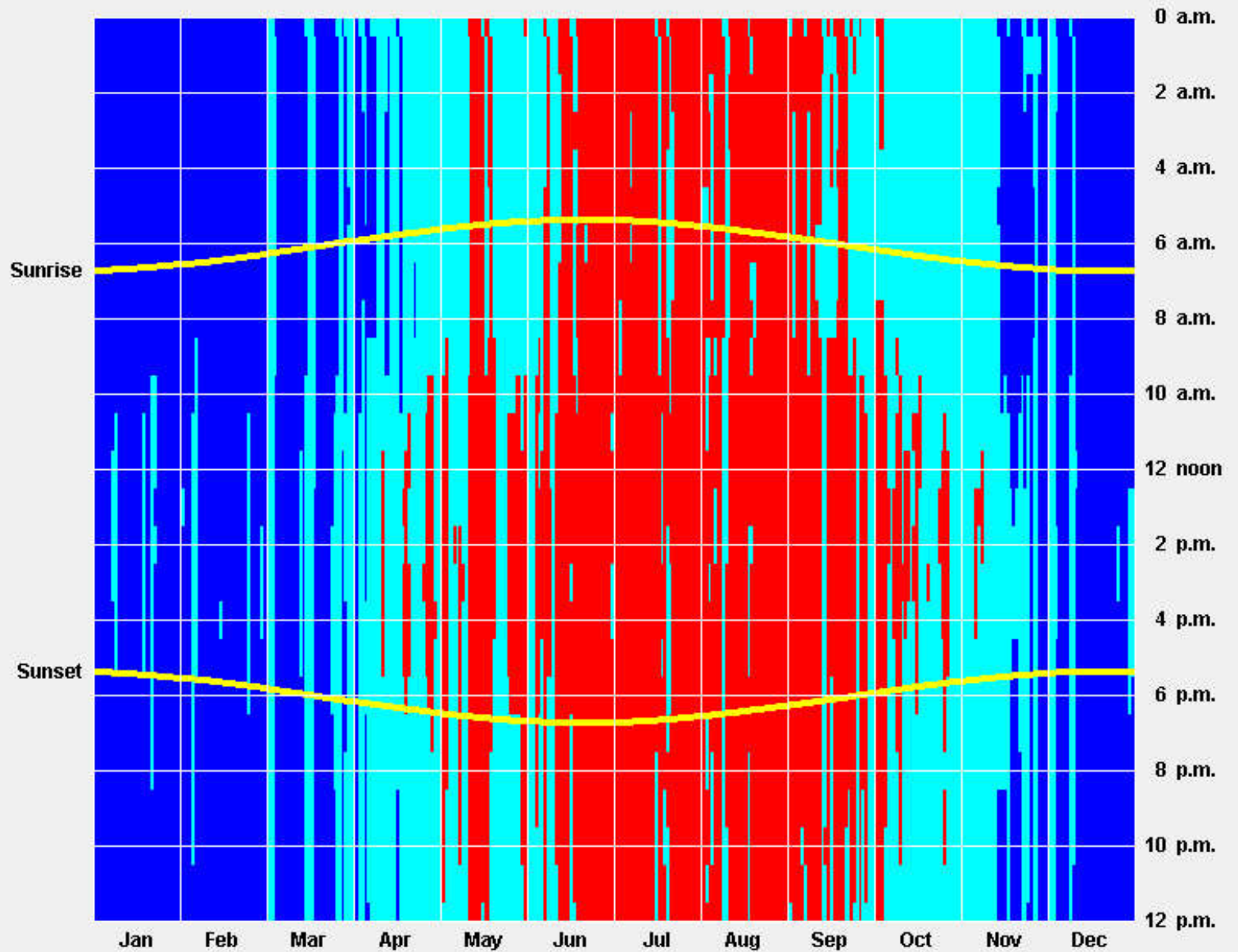
DRY BULB TEMP
(degrees C)

- 67% < 0
- 21% 0 - 21
- 6% 21 - 27
- 3% 27 - 38
- 1% > 38

PLOT:

DRY BULB TEMP

Monthly Avg Daily



3D CHARTS

LOCATION:

HONG KONG, SAR, CHN

Latitude/Longitude:

22.32° North, 114.17° East, Time Zone from Greenwich 8

Data Source:

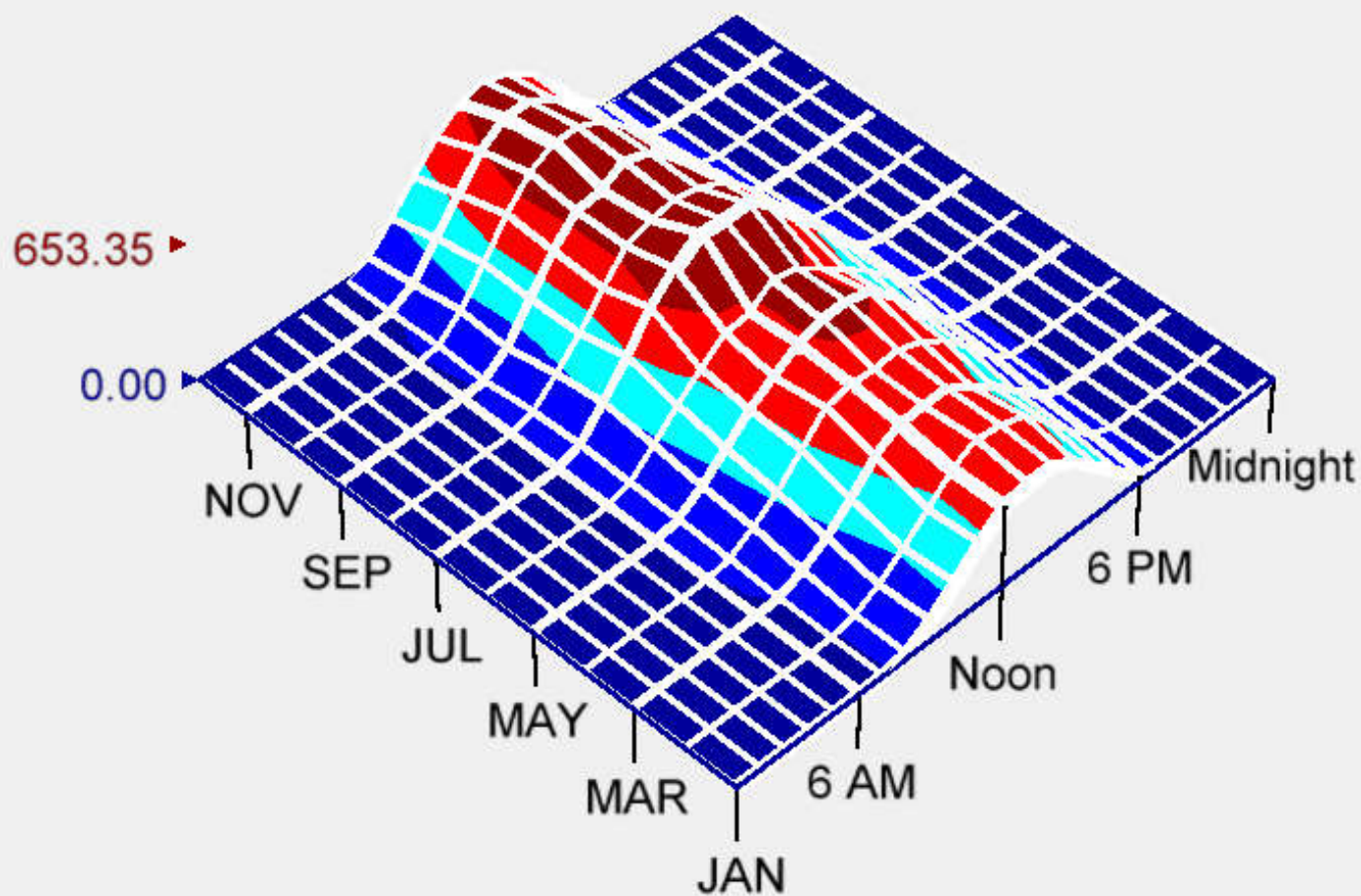
CityUHK-45007 450070 WMO Station Number, Elevation 65 m

LEGEND

GLOBAL HORIZ RADIATION

(Wh/sq.m)

49%	■	Night Time
15%	■	4 - 158
10%	■	158 - 316
14%	■	316 - 474
9%	■	> 474

PLOT: Not Shaded Shaded

GLOBAL HORIZ RADIATION ▼

 Monthly Avg Daily

PSYCHROMETRIC CHART

ASHRAE Standard 55

LOCATION: HONG KONG, SAR, CHN
Latitude/Longitude: 22.32° North, 114.17° East, **Time Zone from Greenwich** 8
Data Source: CityUHK-45007 450070 WMO Station Number, **Elevation** 65 m

LEGEND

COMFORT INDOORS

- 100% ■ COMFORTABLE
- 0% ■ NOT COMFORTABLE

PLOT: COMFORT INDOORS

Hourly Daily Min/Max

All Hours Selected Hours

1 a.m. through midnight

All Months Selected Months

JAN through DEC

One Month JAN Next Month

One Day 1 Next Day

One Hour 1 a.m. Next Hour

TEMPERATURE RANGE:

-10 to 40 °C Fit to Data

Display Design Strategies

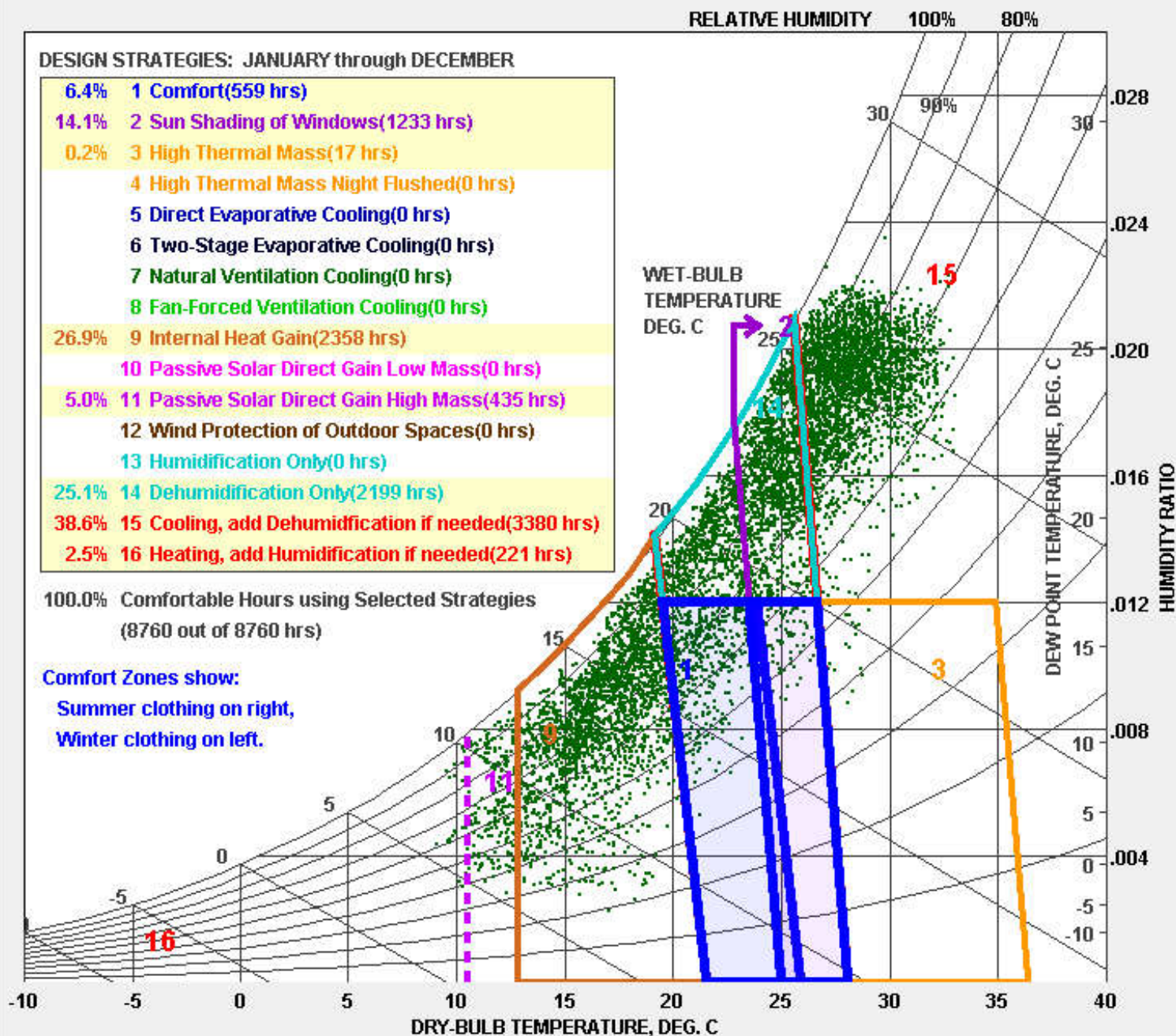
Show Best set of Design Strategies

DESIGN STRATEGIES: JANUARY through DECEMBER

- 6.4% 1 Comfort(559 hrs)
- 14.1% 2 Sun Shading of Windows(1233 hrs)
- 0.2% 3 High Thermal Mass(17 hrs)
- 4 High Thermal Mass Night Flushed(0 hrs)
- 5 Direct Evaporative Cooling(0 hrs)
- 6 Two-Stage Evaporative Cooling(0 hrs)
- 7 Natural Ventilation Cooling(0 hrs)
- 8 Fan-Forced Ventilation Cooling(0 hrs)
- 26.9% 9 Internal Heat Gain(2358 hrs)
- 10 Passive Solar Direct Gain Low Mass(0 hrs)
- 5.0% 11 Passive Solar Direct Gain High Mass(435 hrs)
- 12 Wind Protection of Outdoor Spaces(0 hrs)
- 13 Humidification Only(0 hrs)
- 25.1% 14 Dehumidification Only(2199 hrs)
- 38.6% 15 Cooling, add Dehumidification if needed(3380 hrs)
- 2.5% 16 Heating, add Humidification if needed(221 hrs)

100.0% Comfortable Hours using Selected Strategies
 (8760 out of 8760 hrs)

Comfort Zones show:
 Summer clothing on right,
 Winter clothing on left.



DESIGN GUIDELINES (for the Full Year)**ASHRAE Standard 55**

User Modified Design Strategies, User Modified Criteria

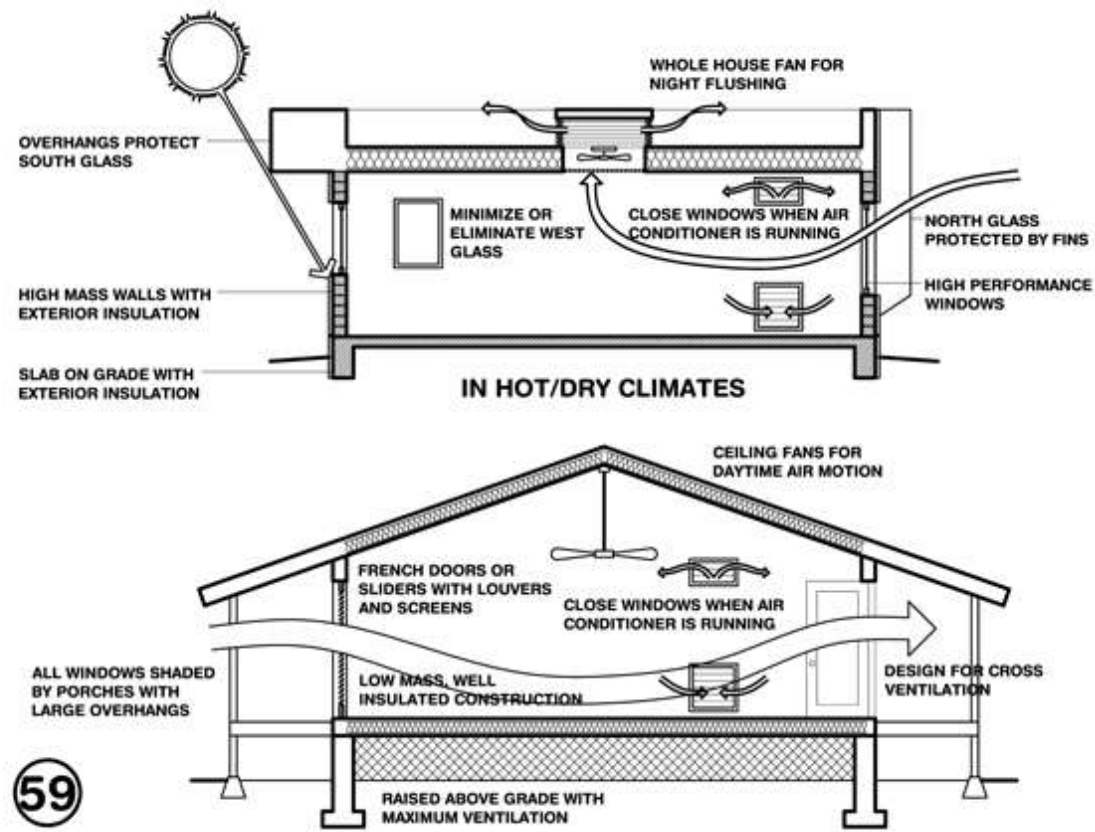
LOCATION:**HONG KONG, SAR, CHN****Latitude/Longitude:** 22.32° North, 114.17° East, **Time Zone from Greenwich 8****Data Source:** CityUHK-45007 450070 WMO Station Number, **Elevation 65 m**

Assuming only the Design Strategies that were selected on the Psychrometric Chart, 100.0% of the hours will be Comfortable.

This list of Design guidelines applies specifically to this particular climate, starting with the most important first. Click on a Guideline to see a sketch of how this Design Guideline shapes building design. (See Help for more details.)

- 59 In this climate air conditioning will always be needed, but can be greatly reduced if building design minimizes overheating
- 68 Traditional passive homes in hot humid climates
- 65 Traditional passive homes in warm humid climates
- 30 High performance glazing on all orientations
- 37 Window overhangs (designed for this latitude)
- 38 Raise the indoor comfort thermostat setpoint
- 56 Screened porches and patios can provide passive cooling
- 17 Use plant materials (bushes, trees, ivy-covered walls)
- 32 Minimize or eliminate west facing glazing to reduce overheating
- 57 Orient most of the glass to the north, shaded
- 46 High Efficiency air conditioner or heat pump (with a radiant barrier)
- 26 A radiant barrier (shiny foil) will help reduce radiative heat gain
- 25 In wet climates well ventilated attics with pitched roofs
- 11 Heat gain from lights, people, and equipment
- 18 Keep the building small (right-sized) because of high energy costs
- 33 Long narrow building floorplan can help maximize natural ventilation
- 35 Good natural ventilation can reduce or eliminate the need for air conditioning
- 43 Use light colored building materials and cool roofs
- 27 If soil is moist, raise the building high above ground
- 42 On hot days ceiling fans or indoor air motion

Design Guideline 59



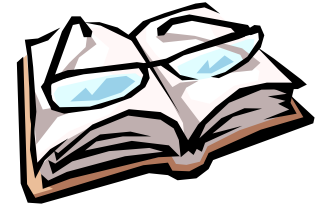
59

In this climate air conditioning will always be needed, but can be greatly reduced if building design minimizes overheating

CLOSE

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Further Reading



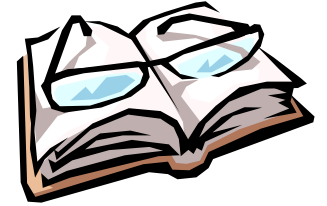
- Learn everything about building performance analysis: Autodesk Insight webinar series

<https://blogs.autodesk.com/revit/2018/07/06/autodesk-insight-webinar-series/>

- Autodesk Insight webinar part 1: Learn everything about Insight (1:02:20) <https://youtu.be/1nkK4yjqCfQ>
- Autodesk Insight webinar part 2: Tips and Tricks (1:01:53) <https://youtu.be/7CrG6hw1Wdo>
- Autodesk Insight webinar part 3: Practical examples (58:53) <https://youtu.be/ftJtJ2DU1OI>



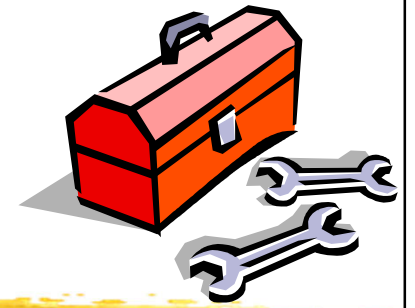
Further Reading



- IES VE YouTube Channel <https://www.youtube.com/user/IESVE>
 - Climate Analysis & Weather (1:26) <https://youtu.be/wjfLM4wBoec>
 - Solar Shading (2:42) <https://youtu.be/KmRUa3MpUbU>
 - Daylight Simulation and Lighting Design (2:22) <https://youtu.be/SdwROMRN2Bk>
 - Daylighting Visualisation (1:39) <https://youtu.be/lqdM3lxW0J0>
 - Dynamic Daylighting (3:41) <https://youtu.be/XIJFLQI4SLI>
 - Airflow (3:16) https://youtu.be/L_NlsqZ4LIM
 - Whole Building Energy Simulation (2:45) <https://youtu.be/h1aISHcg-yg>
 - Renewable Energy Design & Optimization (1:56) https://youtu.be/h2O_YGwBLto



Useful Tools



- ClimateTool <http://www.climate-tool.com>
- Software by Andrew Marsh <http://andrewmarsh.com/software/>
 - Psychrometric Chart <http://andrewmarsh.com/software/psychro-chart-web/>,
<https://drajmarsh.bitbucket.io/psychro-chart2d.html>
 - Weather Data <http://andrewmarsh.com/software/weather-data-web/>,
<https://drajmarsh.bitbucket.io/weather-data.html>
 - 2D Sun-Path <http://andrewmarsh.com/software/sunpath2d-web/>,
<https://drajmarsh.bitbucket.io/sunpath2d.html>
 - 3D Sun-Path <http://andrewmarsh.com/software/sunpath3d-web/>,
<https://drajmarsh.bitbucket.io/shading-box.html>
 - Dynamic Daylighting <http://andrewmarsh.com/software/daylight-box-web/>,
<https://drajmarsh.bitbucket.io/daylight-box.html>
 - Dynamic Overshadowing <http://andrewmarsh.com/software/shading-box-web/>,
<https://drajmarsh.bitbucket.io/shading-box.html>