MEBS6020 Sustainable Building Design

http://www.hku.hk/bse/MEBS6020/

Analysis Methods for Sustainable Building Projects (I)

Dr. Sam C. M. Hui

Department of Mechanical Engineering

The University of Hong Kong

E-mail: cmhui@hku.hk

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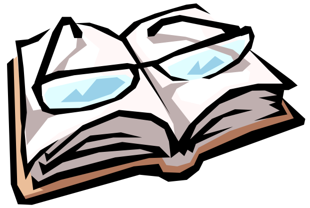
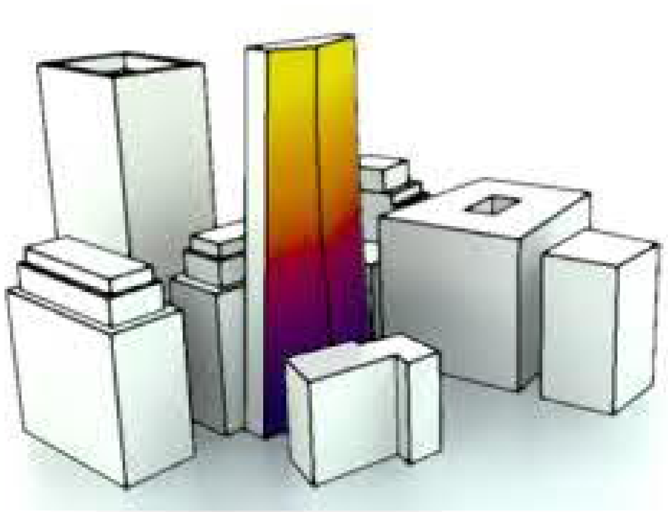
Contents

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

Project phases and analysis



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

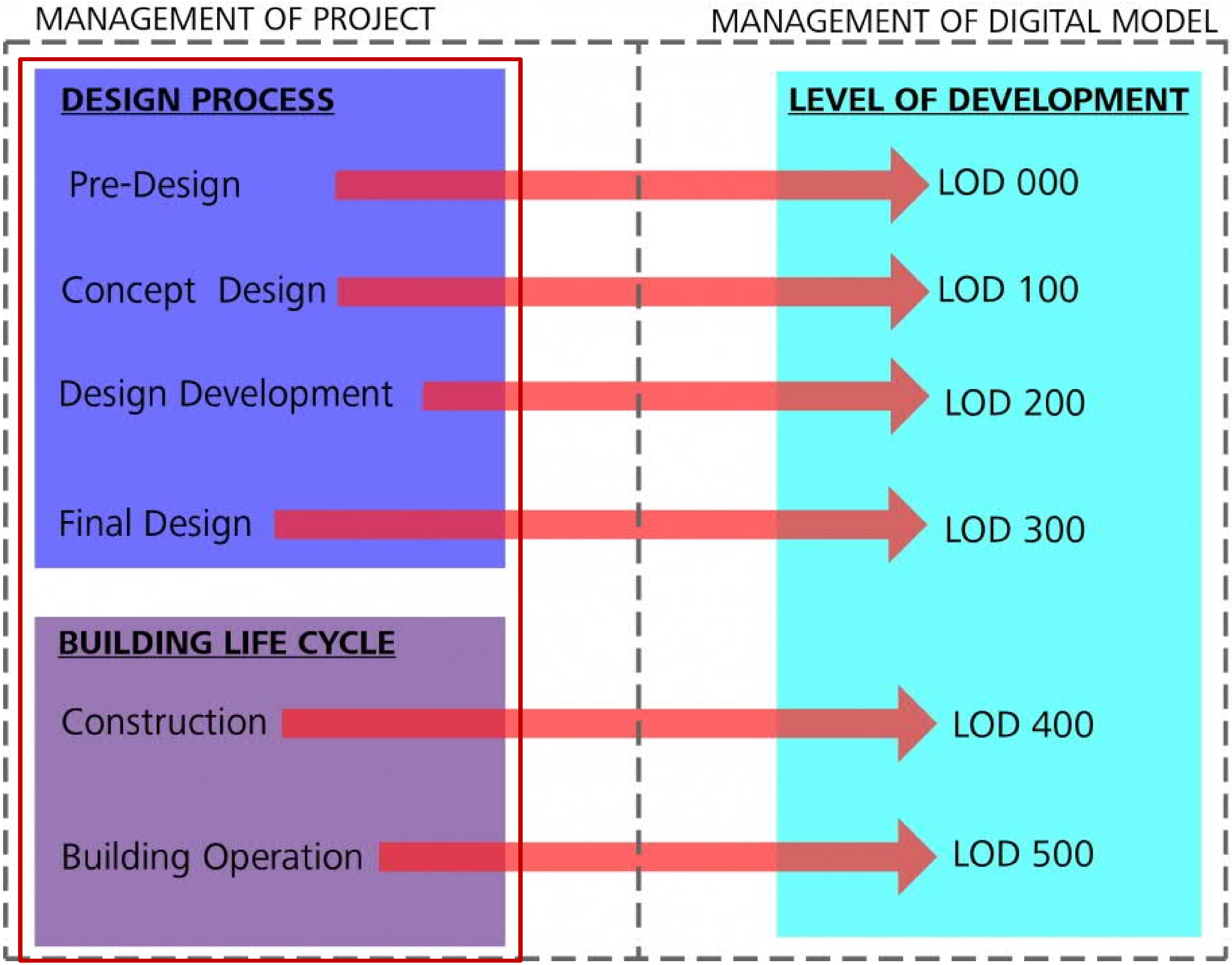


Project phases and analysis

- 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)

(See also: http://en.wikipedia.org/wiki/Building_information_modeling)

Design process of buildings and level of development (LOD)



(Source: http://sustainabilityworkshop.autodesk.com/buildings/project-phases-level-development)

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).

(Source: http://sustainabilityworkshop.autodesk.com/buildings/project-phases-level-development)

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.

(Source: http://sustainabilityworkshop.autodesk.com/buildings/project-phases-level-development)

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.

(Source: http://sustainabilityworkshop.autodesk.com/buildings/project-phases-level-development)

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).

(Source: http://sustainabilityworkshop.autodesk.com/buildings/project-phases-level-development)

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.

(Source: http://sustainabilityworkshop.autodesk.com/buildings/project-phases-level-development)

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?

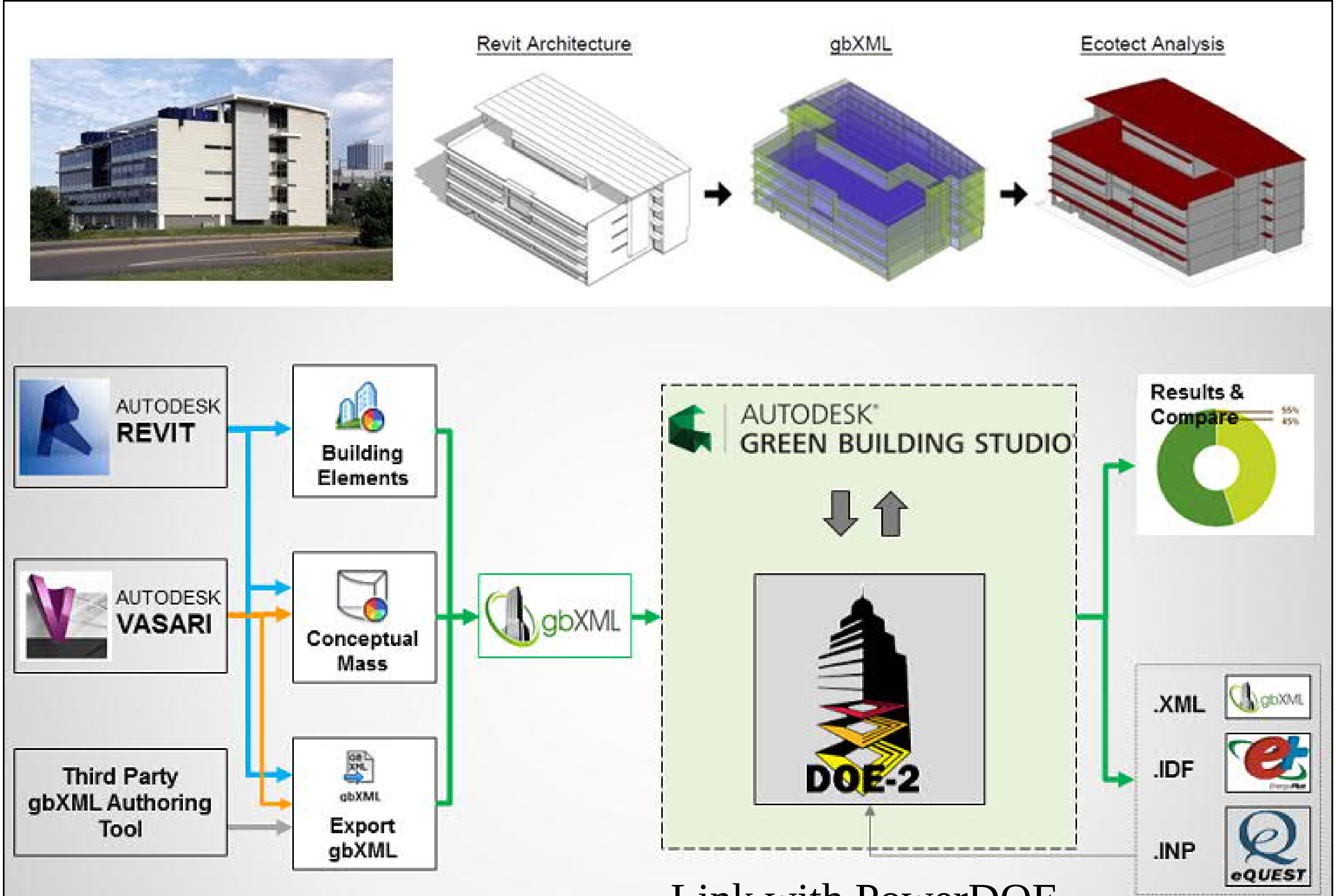
Building Performance Analysis (BPA) Actions:

- 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.

(Source: http://sustainabilityworkshop.autodesk.com/buildings/project-phases-level-development)

Building design tools

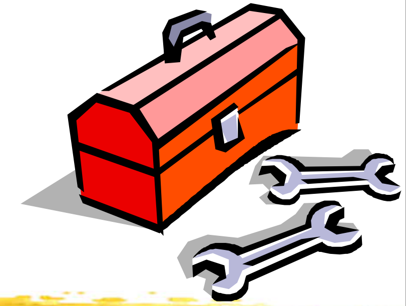
- Autodesk Building Design Tools
  - http://sustainabilityworkshop.autodesk.com/buildings/autodesk-building-design-tools
  - Revit and Vasari (building information modelling BIM)
  - Green Building Studio
  - Ecotect
  - Simulation CFD
  - 3ds Max Design (lighting simulation)



Link with PowerDOE, eQUEST or EnergyPlus

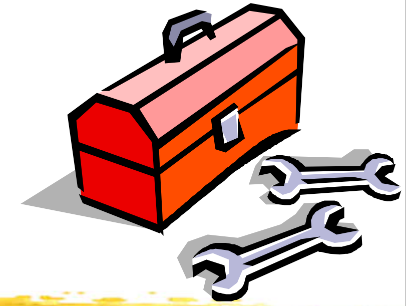
(Source: Autodesk)

Building design tools



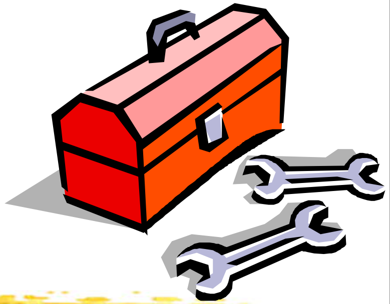
- Autodesk Revit (http://www.autodesk.com/products/revit-family/overview)
  - Building Information Modeling (BIM) software
  - To support design, analysis, collaboration, documentation and visualization
- Autodesk Vasari (http://autodeskvasari.com/)
  - An easy-to-use, expressive design tool for creating building concepts with integrated analysis for energy and carbon

Building design tools



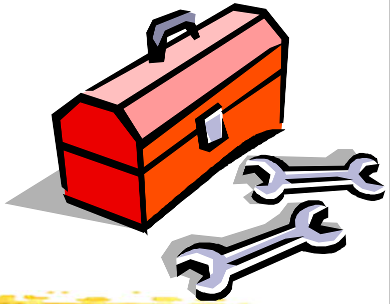
- gbXML (green building extensible markup language) [http://www.gbxml.org/]
  - Open schema designed to transfer essential information contained within a 3D building information model BIM (such as walls, windows, and room areas)
  - Allows for a consistent way to share information for engineering analysis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

Building design tools

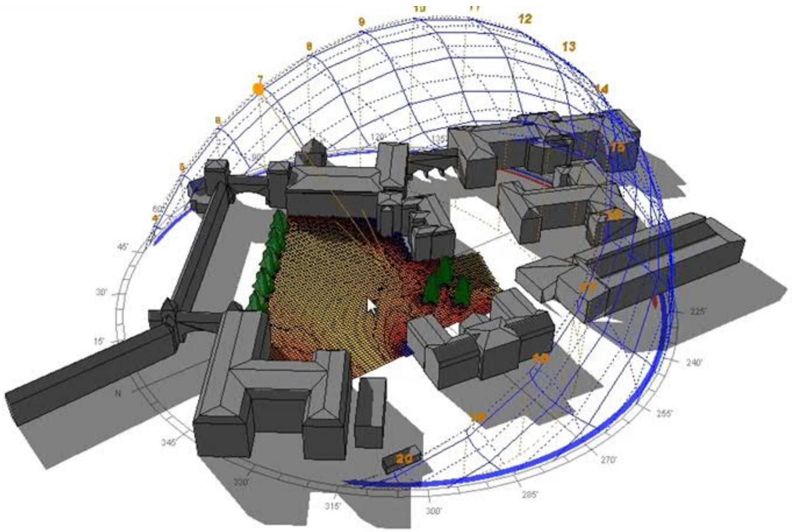


- Green Building Studio
  - www.autodesk.com/greenbuildingstudio
  - A web-/cloud- based service for use in evaluating the environmental impact of building design and design alternatives. It can assess:
    - Energy and carbon results (e.g. EnergyPlus, eQUEST)
    - Water usage data
    - Photovoltaic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

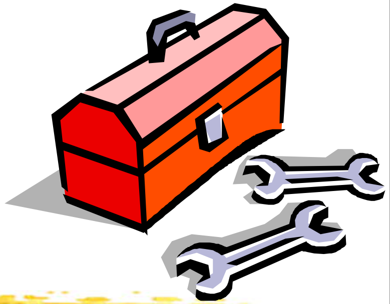
Building design tools



- Ecotect (http://sustainabilityworkshop.autodesk.com/software/ecotect)
  - A software tool that evaluates the performance based on climate and environmental factors
  - It can assess:
    - Weather and human comfort
    - Whole building energy analyses
    - Thermal performance
    - Solar radiation and shading
    - Daylighting, shadows and reflections
  - Use data visualization to show the analysis results

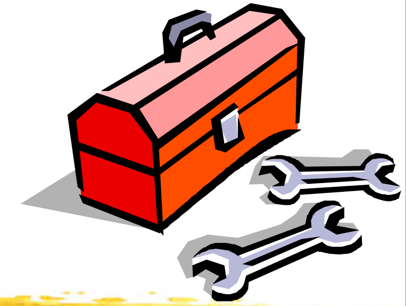


Building design tools

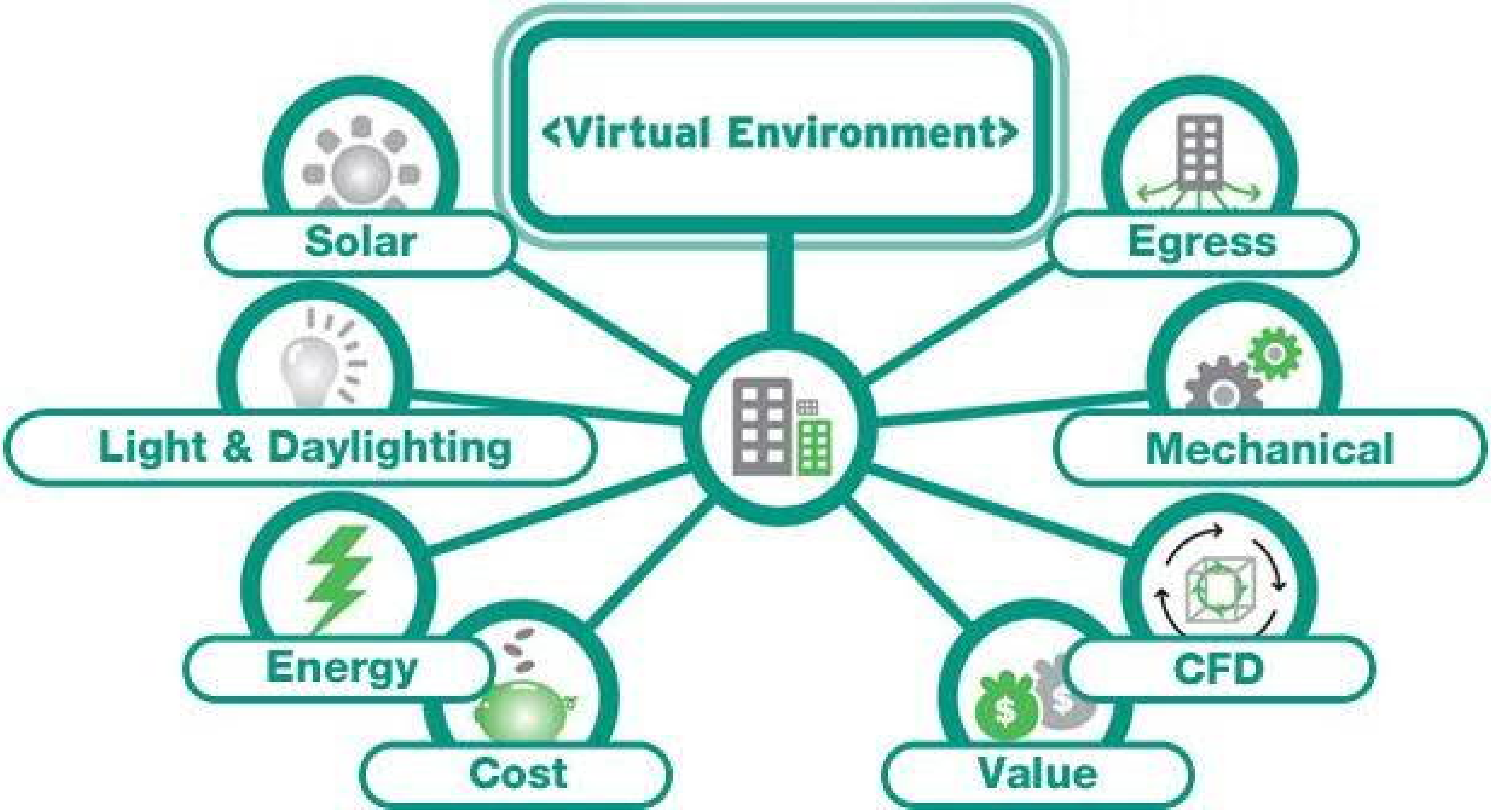


- Typical functions:
  - **Sunpath** - visualize site-specific shadows
  - **Solar radiation** - quantify the incident solar radiation striking the building surfaces
  - **Wind data** - see the wind rose diagram (showing wind direction, frequency and speed)
  - **External wind simulations** - simulate the airflow (wind speed and pressure) with basic CFD
  - **Conceptual energy analysis** - quick feedback on the expected energy use and compare the effectiveness of building form, orientation and envelope design options

Building design tools



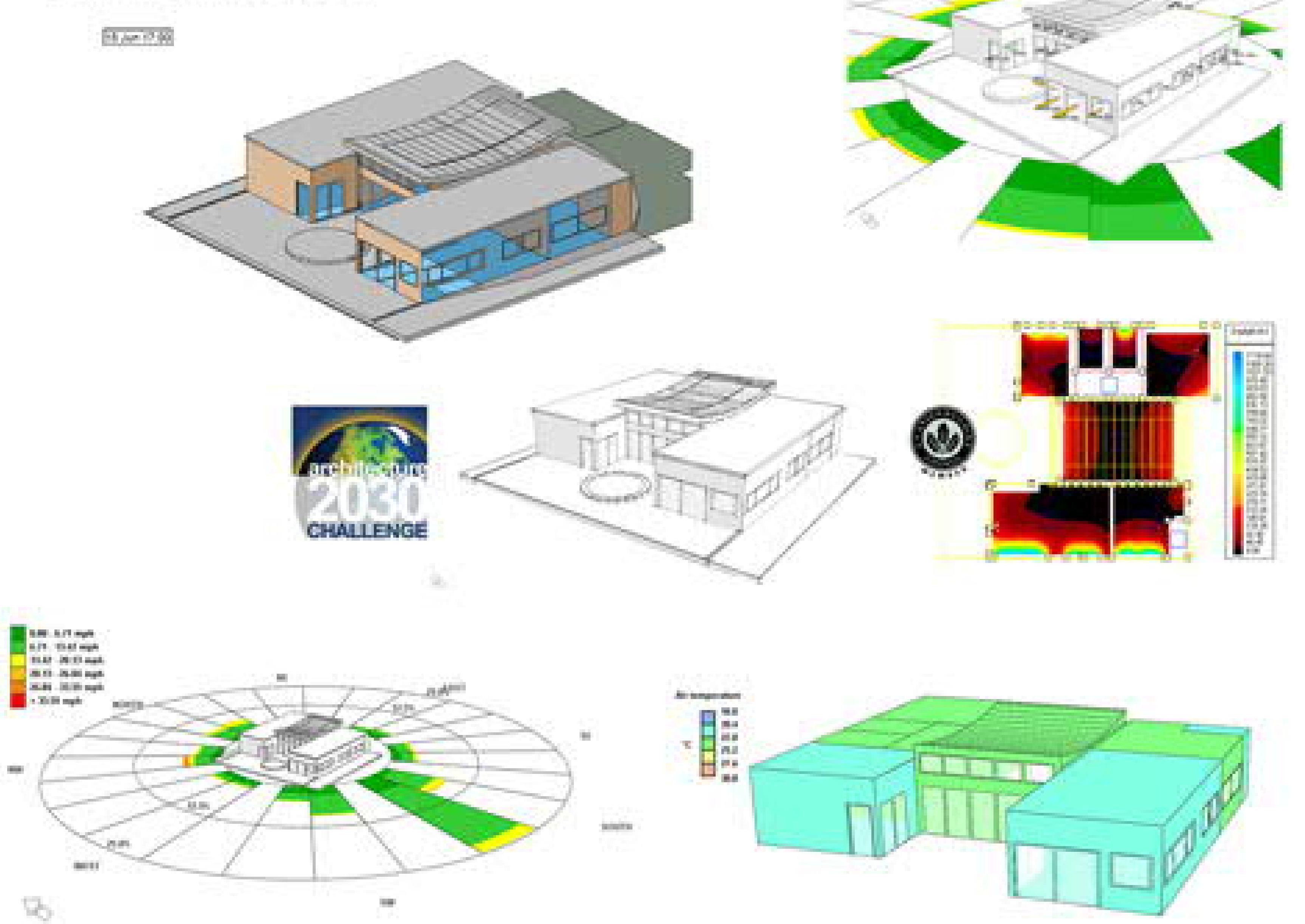
- IES <Virtual Environment> (www.iesve.com)
  - IES = Integrated Environmental Solutions
  - Modules:
    - Model Building (3D)
    - Climate, Light, Solar
    - Airflow, Energy/Carbon, HVAC
    - BREEAM, LEED
    - UK & Ireland Regulations, Egress
    - Global Compliance (e.g. OTTV)
    - Value/Cost (life cycle)/Environmental Impact



(Source: IES-VE)

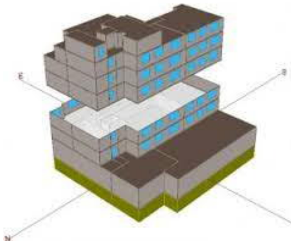
IES VE SketchUp Plug-in

Launch <Virtual Environment>

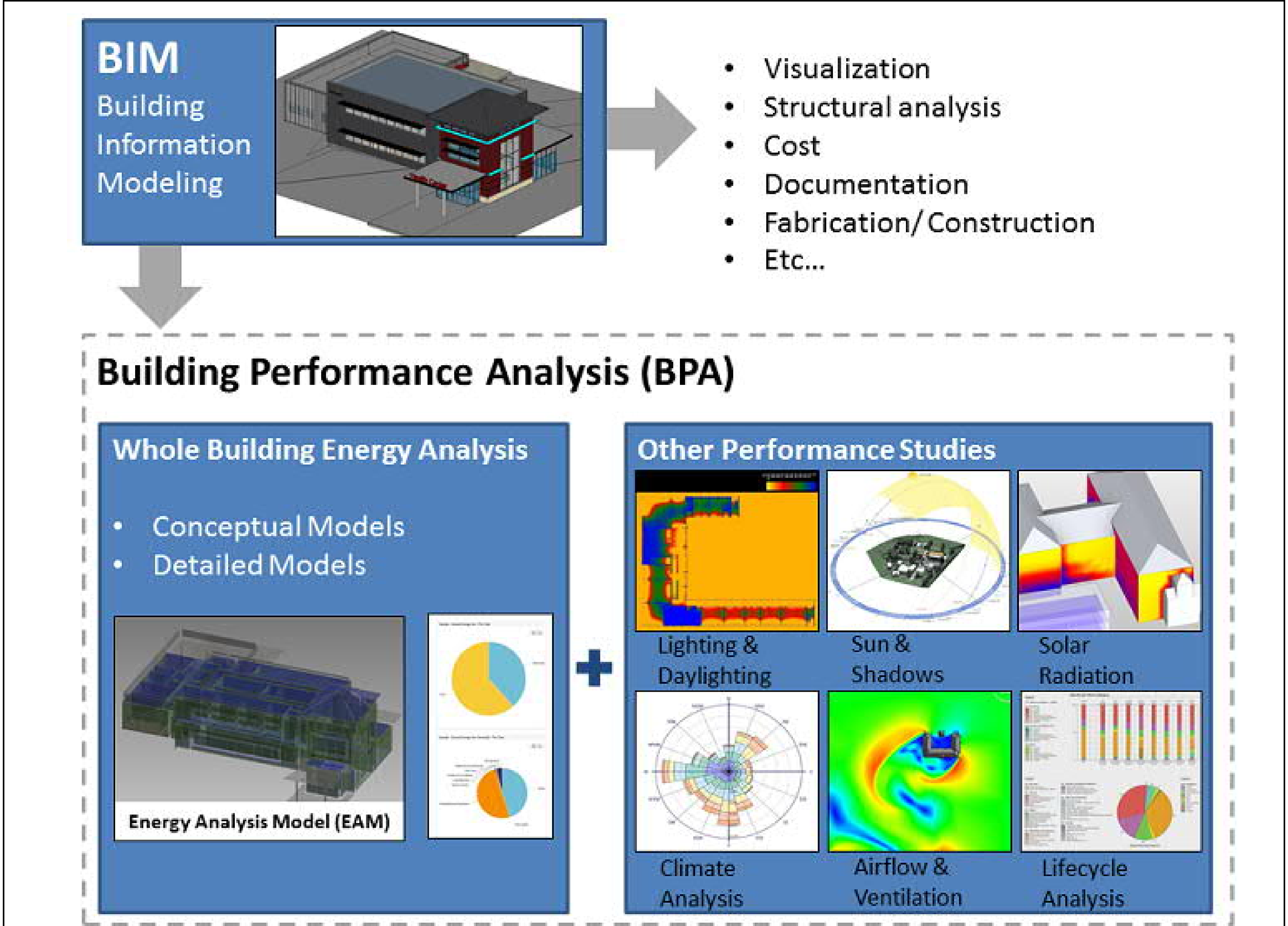


(Source: IES-VE)

Building performance analysis

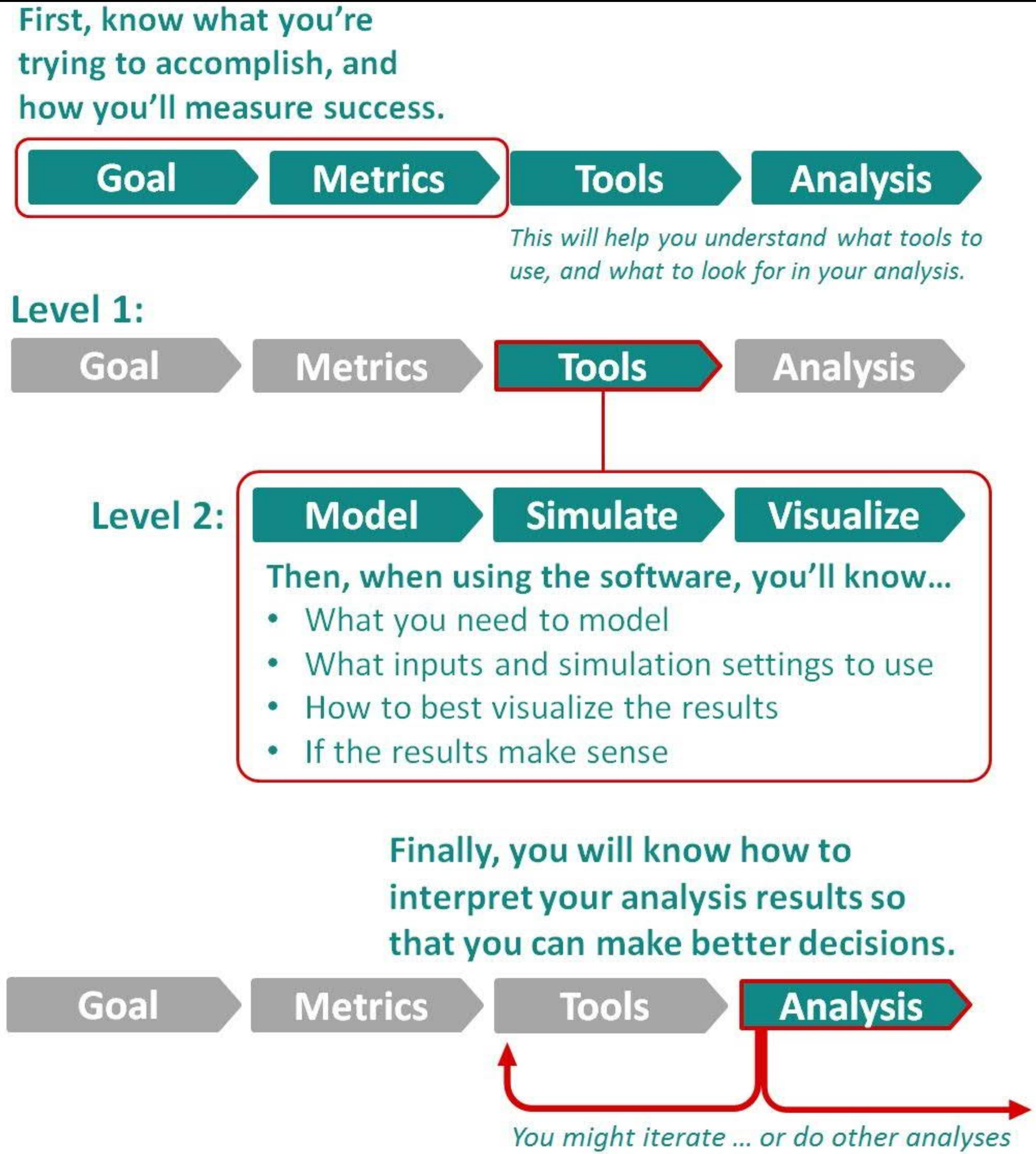


- Autodesk Sustainability Workshop
  - Building Performance Analysis (BPA) http://sustainabilityworkshop.autodesk.com/buildings/building-performance-analysis-bpa
- Autodesk Building Performance Analysis (BPA) Certificate Program (4:32)
  - http://www.youtube.com/watch?v=4-g9p6JLktI
- Autodesk BPA Help
  - http://help.autodesk.com/view/BUILDING_PERFORMANCE_ANALYSIS/ENU/



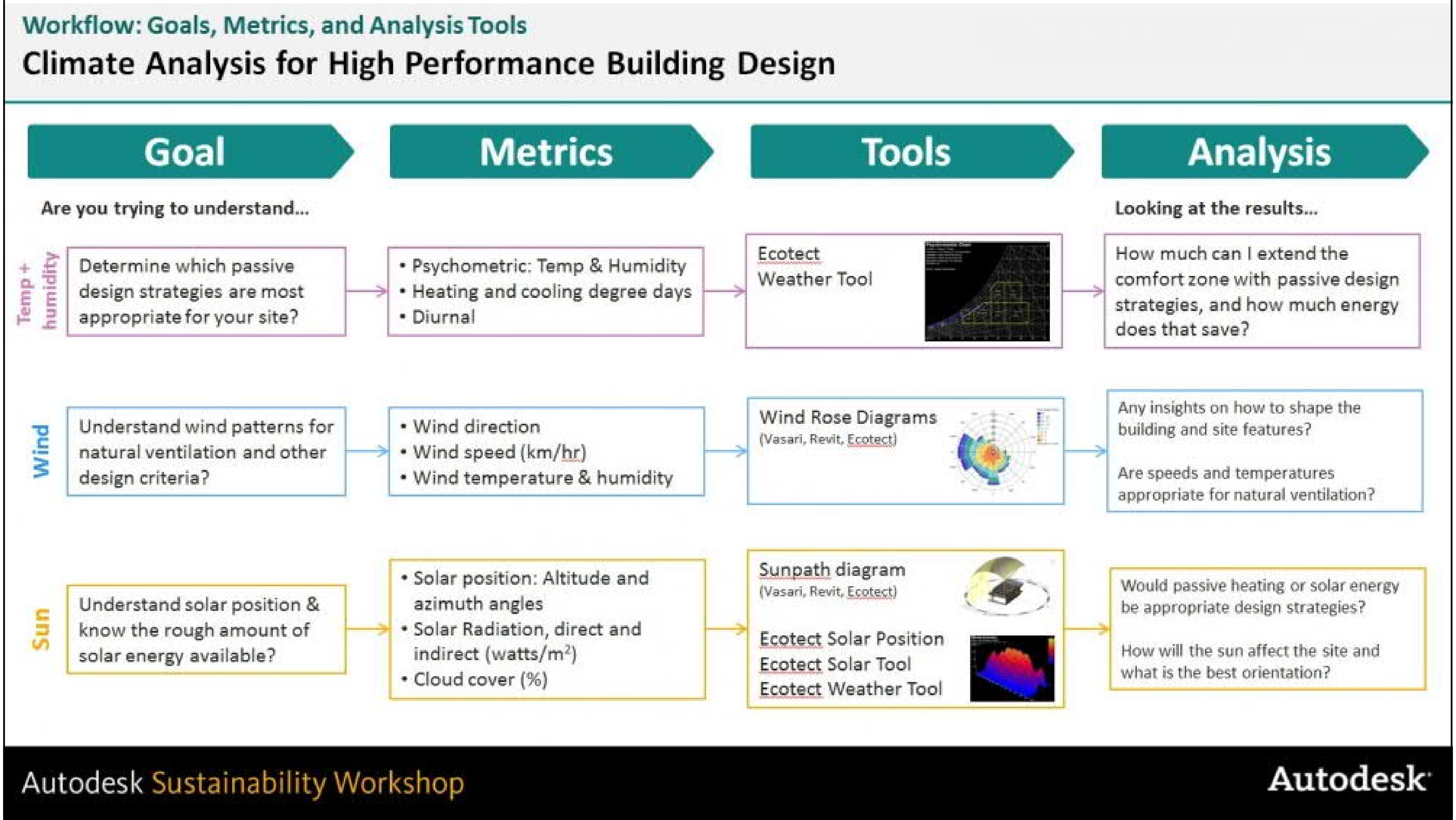
(Source: Autodesk)

Building performance analysis workflows



(Source: http://sustainabilityworkshop.autodesk.com/buildings/bpa-workflows)

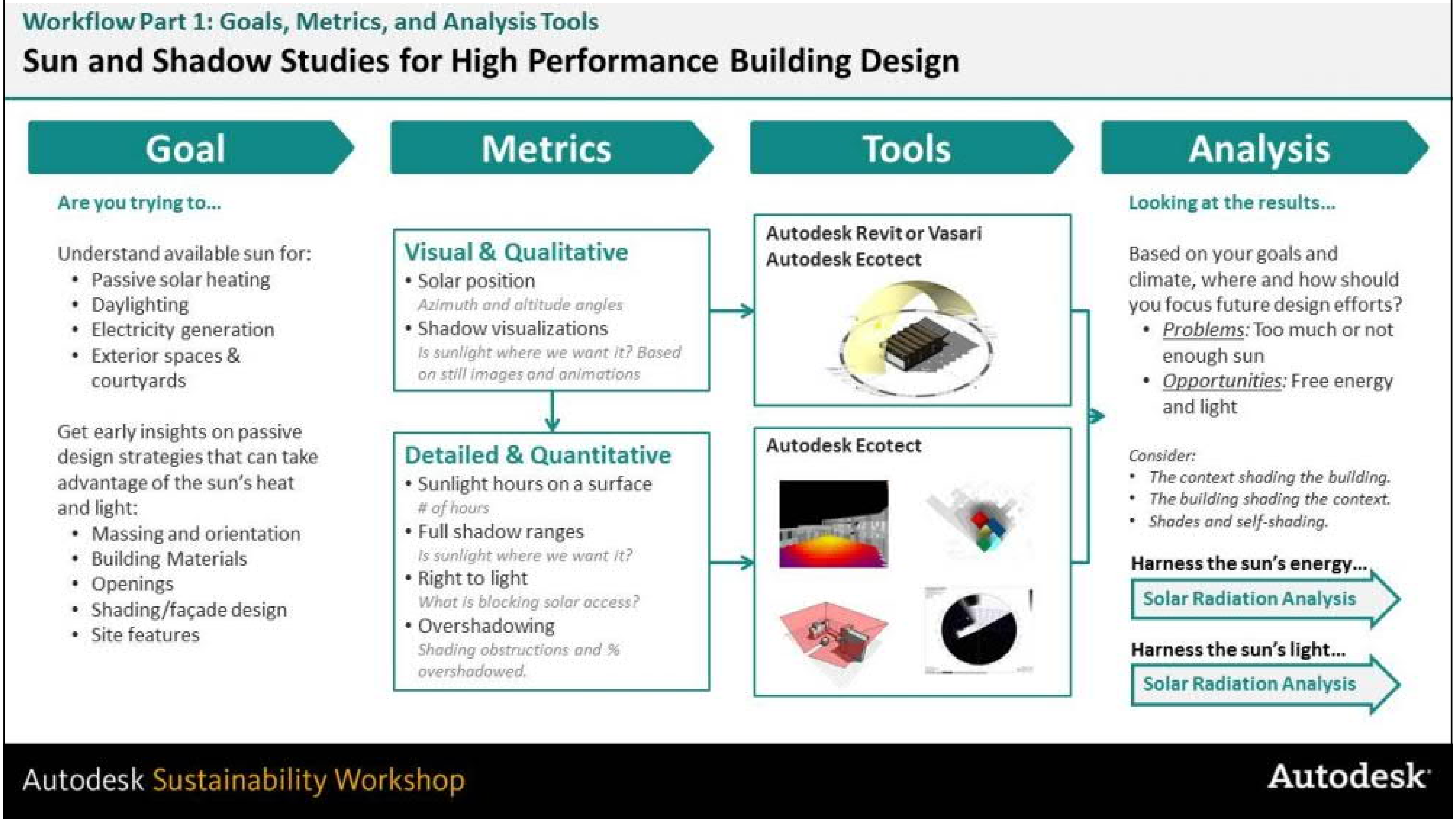
Climate analysis



(See also: http://sustainabilityworkshop.autodesk.com/buildings/climate-analysis,
http://sustainabilityworkshop.autodesk.com/buildings/climate-analysis-bim)

(Source: Autodesk)

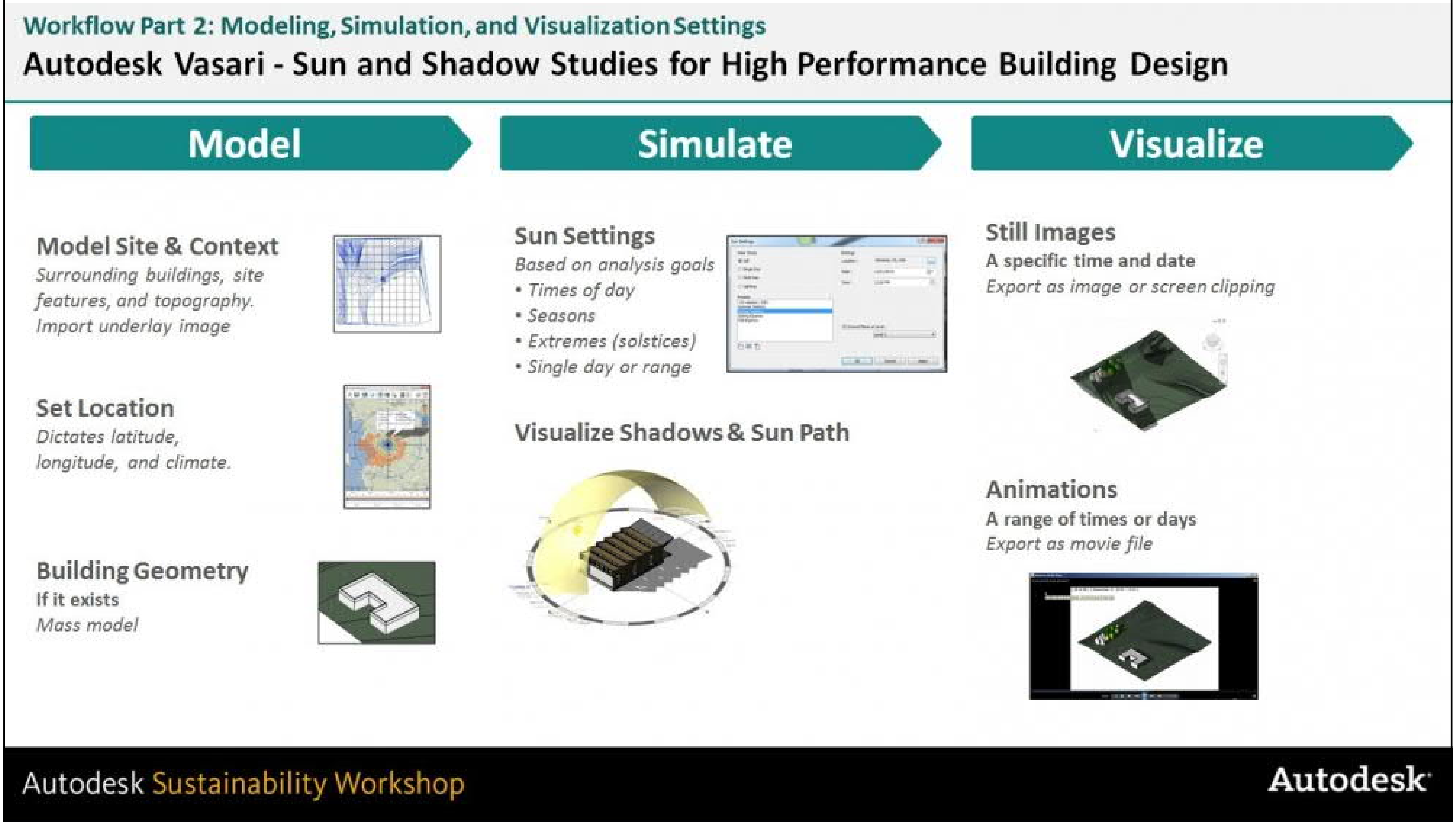
Sun and shadow studies



(See also: http://sustainabilityworkshop.autodesk.com/buildings/sun-and-shadow-studies-bim)

(Source: Autodesk)

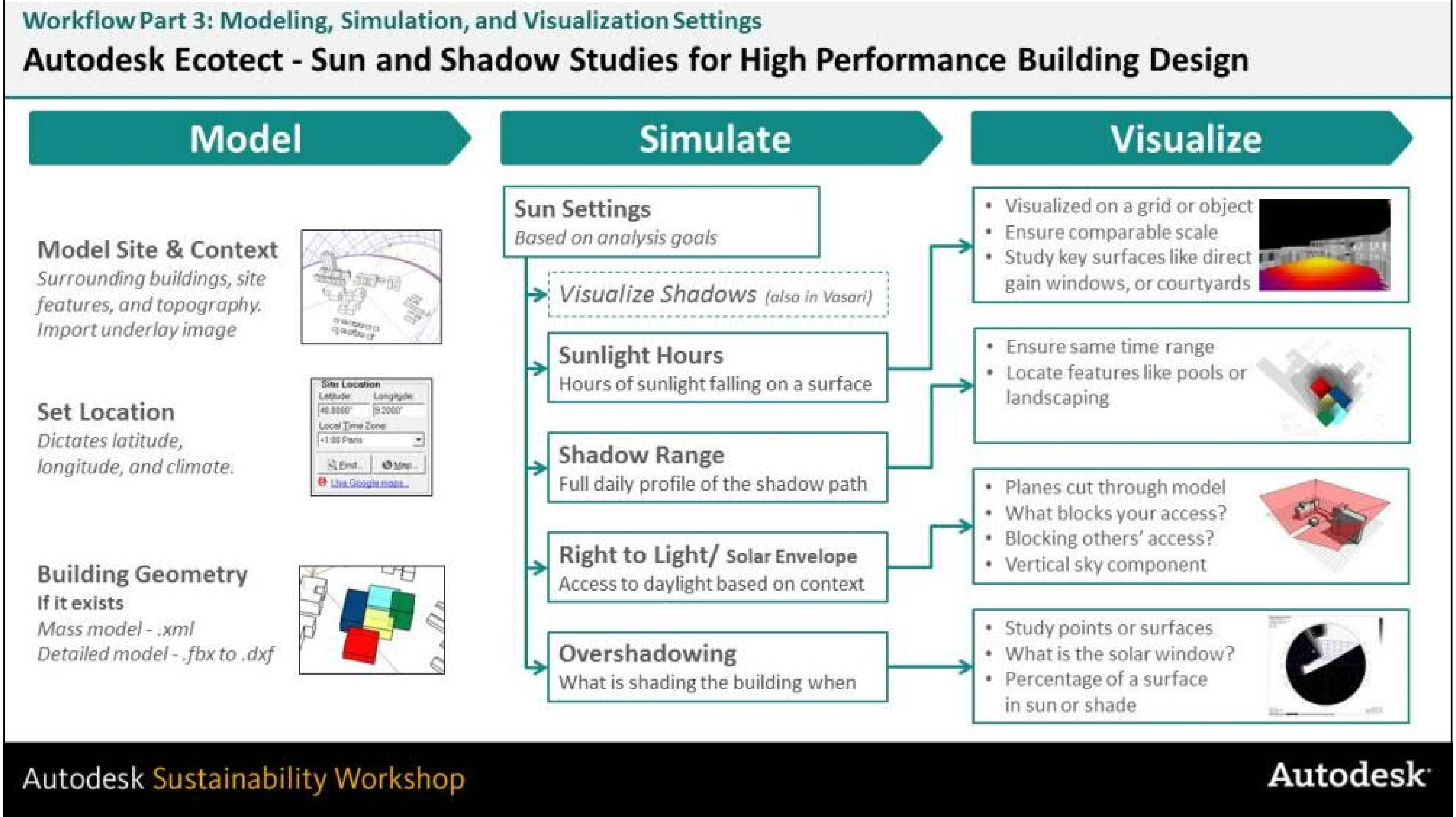
Sun and shadow studies (cont'd)



(See also: http://sustainabilityworkshop.autodesk.com/buildings/vasarirevit-sunpath-visualization)

(Source: Autodesk)

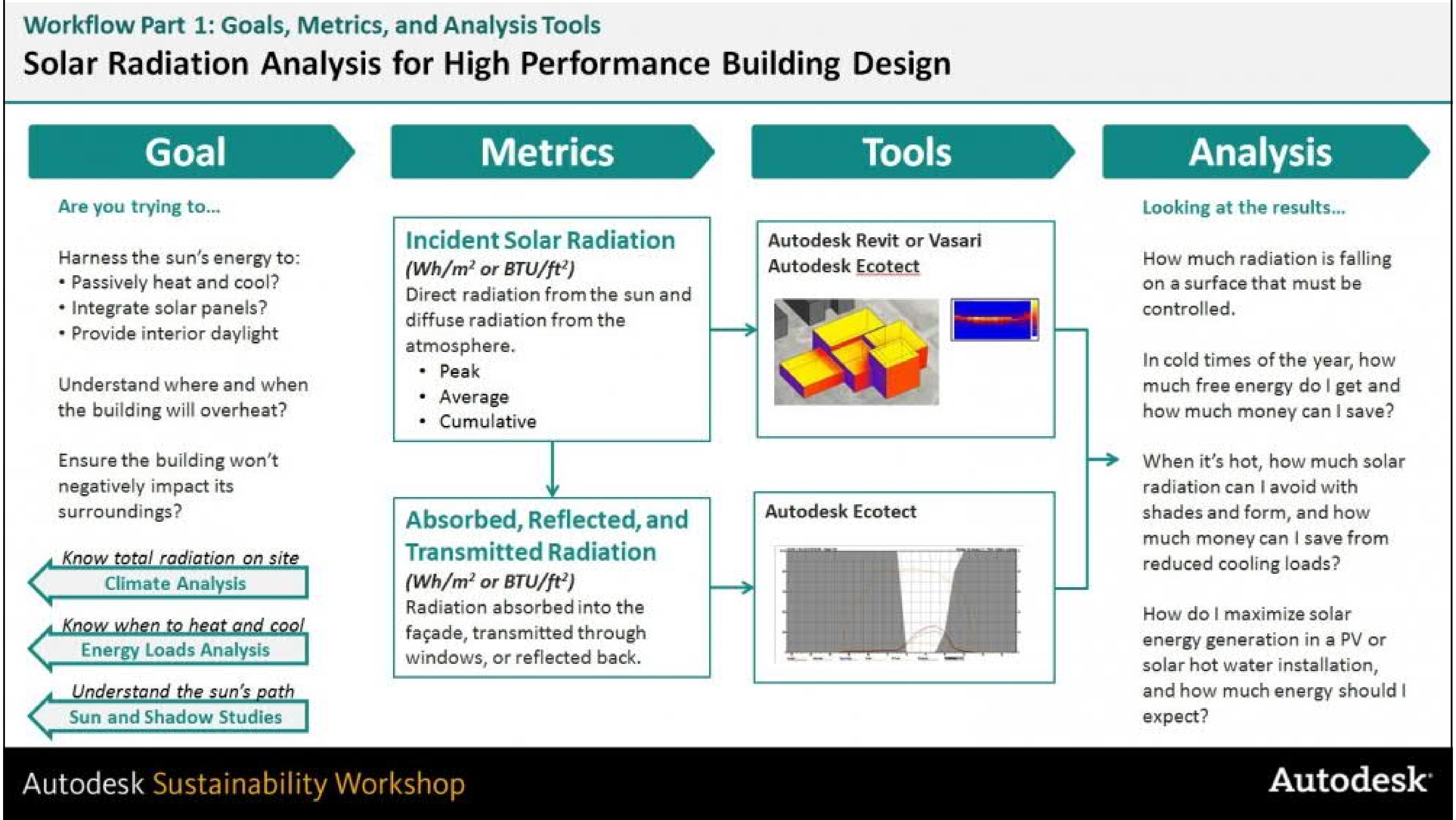
Sun and shadow studies (cont'd)



(See also: http://sustainabilityworkshop.autodesk.com/buildings/ecotect-shading-masks-calculations,
http://sustainabilityworkshop.autodesk.com/buildings/ecotect-shadows-sunlight-hours,
http://sustainabilityworkshop.autodesk.com/buildings/ecotect-right-light-and-solar-envelope)

(Source: Autodesk)

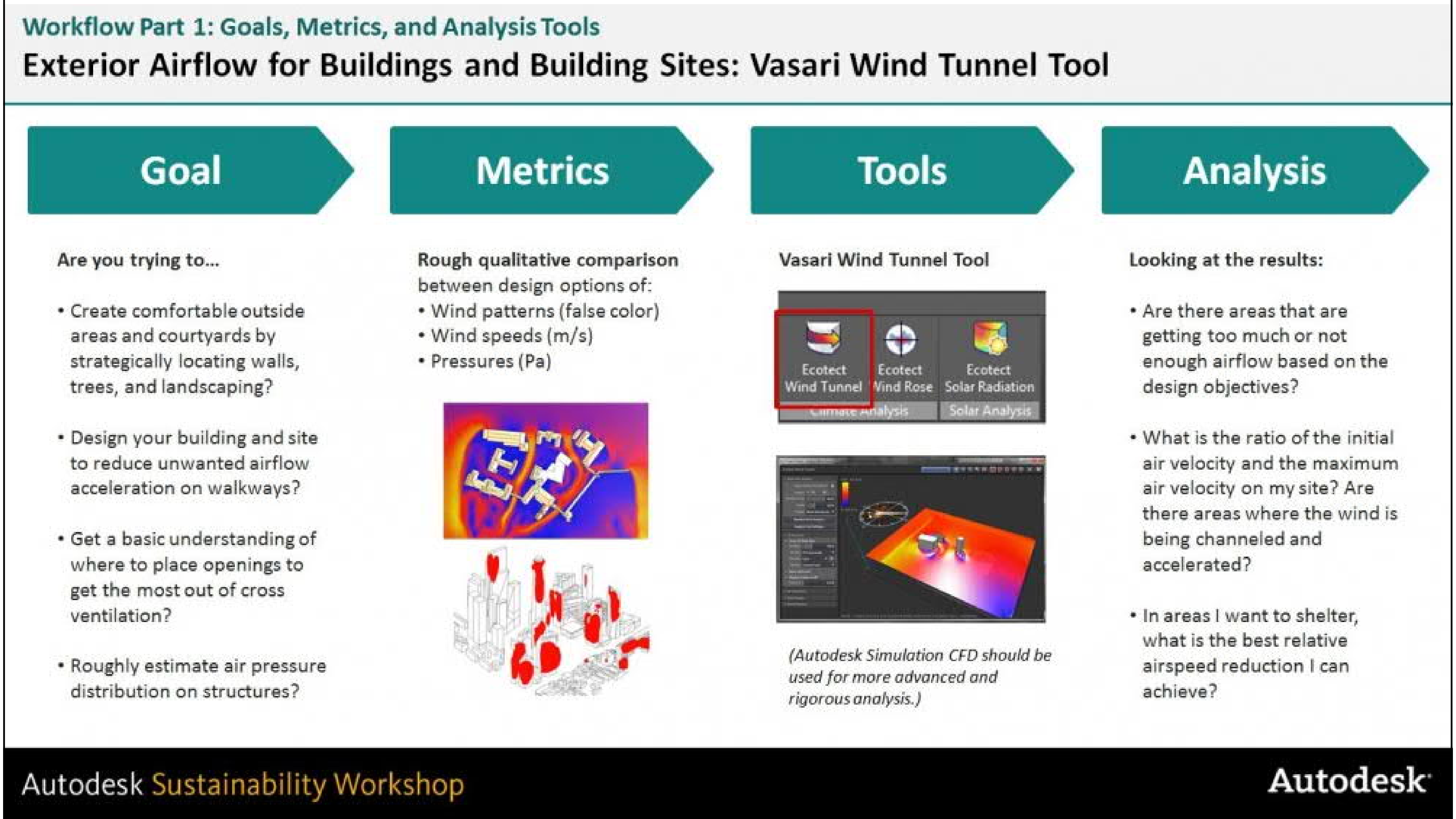
Solar loads/solar radiation analysis



(See also: http://sustainabilityworkshop.autodesk.com/buildings/solar-loads-analysis-bim)

(Source: Autodesk)

Analysis of exterior airflow for buildings and building sites



(See also: http://sustainabilityworkshop.autodesk.com/buildings/vasari-wind-tunnel-exterior-flows)

(Source: Autodesk)

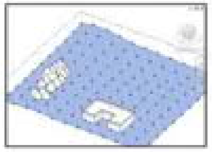
Analysis of exterior airflow for buildings and building sites (cont'd)

Workflow Part 2: Modeling, Simulation, and Visualization Settings

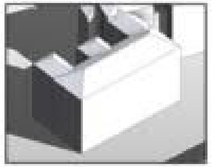
Vasari Wind Tunnel Tool for Exterior Airflow for Buildings and Building Sites

Model

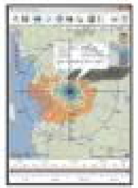
Model Site Context
Surrounding buildings and topography (as masses)



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.*

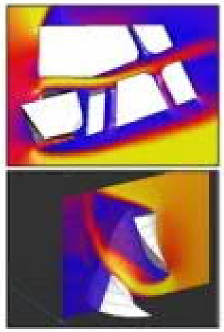
Wind Speed & Direction
- *Use wind rose diagram data for guidance.*
- *Consider time of year & day*
- *Be careful of the scale & units*

2D vs. 3D Analysis
- *3D analysis is recommended for more accurate results, but takes longer.*

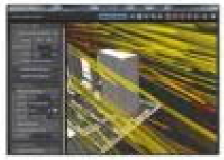
Run the simulation until it stabilizes.
- *When the image is moving, it's not showing the wind. It's calculating.*

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.*



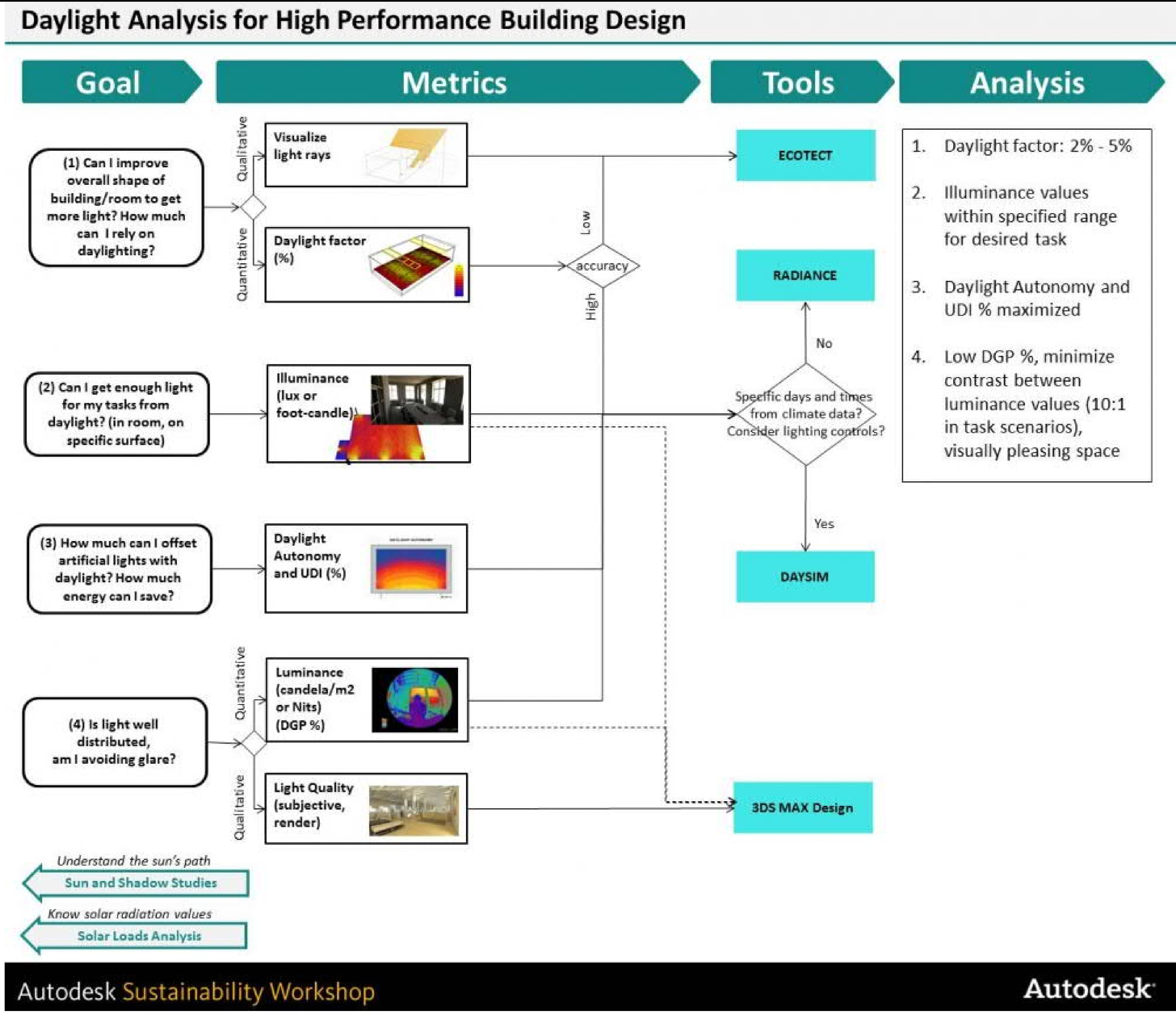
Point cloud & ISO Surf.
- *Interrogate the model to better understand patterns of specific speeds and pressures.*

Autodesk Sustainability Workshop

Autodesk

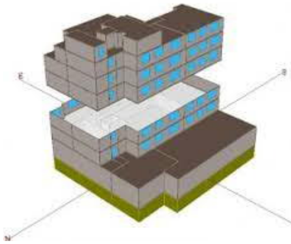
(See also: http://sustainabilityworkshop.autodesk.com/buildings/vasari-wind-tunnel-exterior-flows)

(Source: Autodesk)



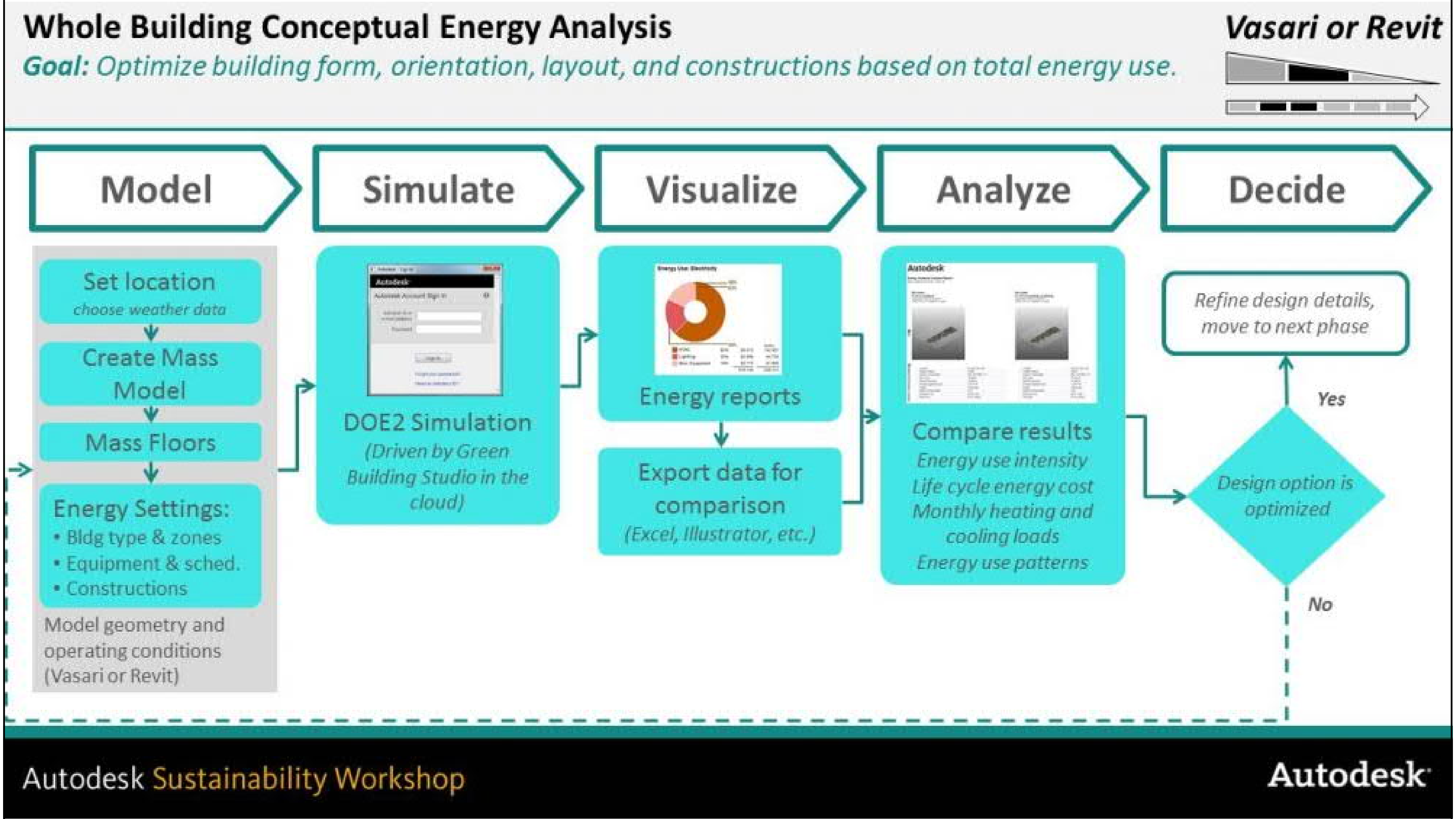
(See also: http://sustainabilityworkshop.autodesk.com/buildings/daylight-analysis-bim)

Building performance analysis



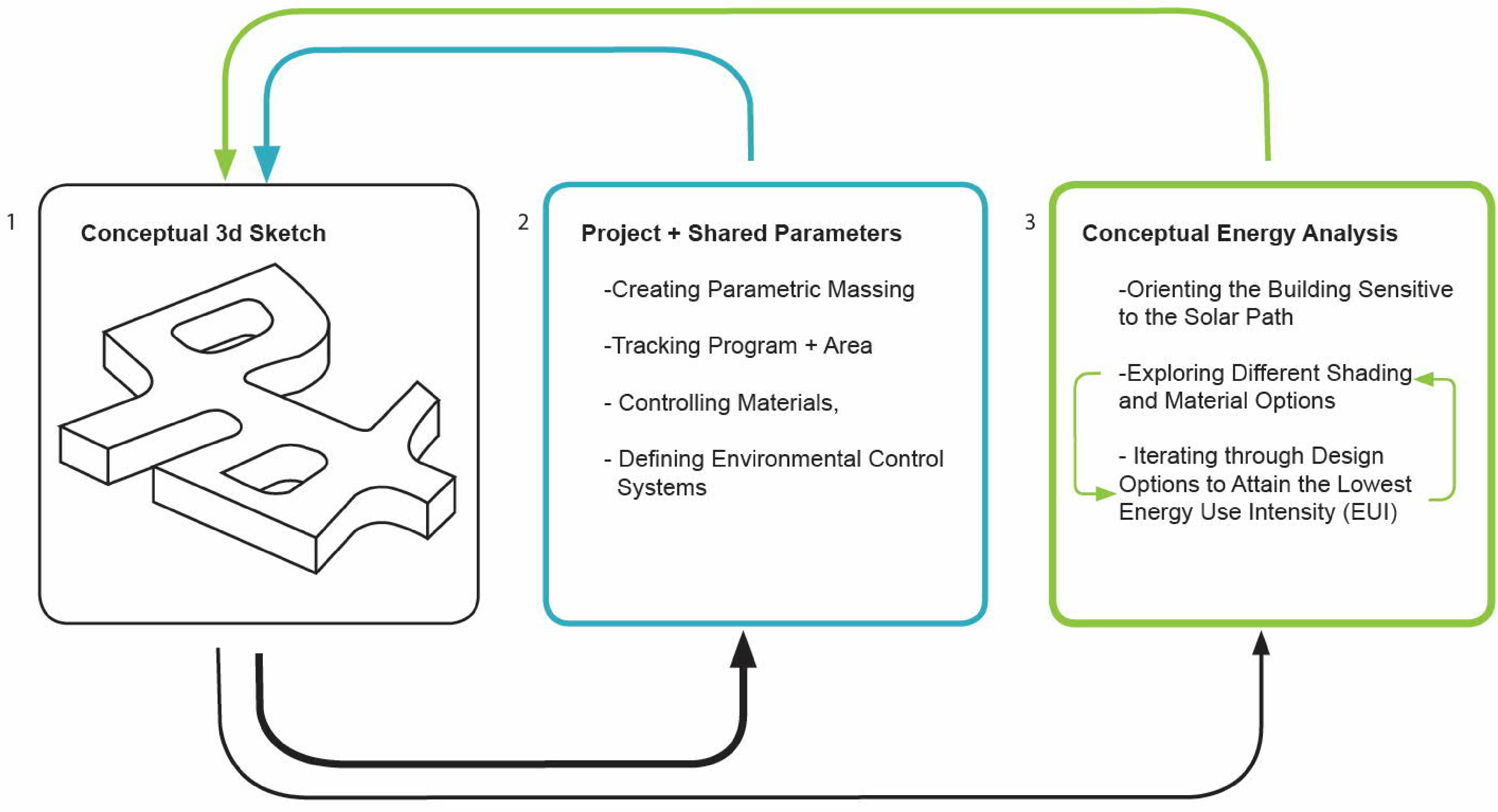
- Whole building energy analysis
  - Simulate expected energy use in the building
  - Track the effectiveness of individual passive design strategies and energy efficiency measures
  - The sophistication and precision of the tools and analysis will increase as one moves along
    - Conceptual energy analysis (early design stage)
      - http://sustainabilityworkshop.autodesk.com/buildings/conceptual-energy-analysis
    - Detailed energy analysis

Whole building conceptual energy analysis



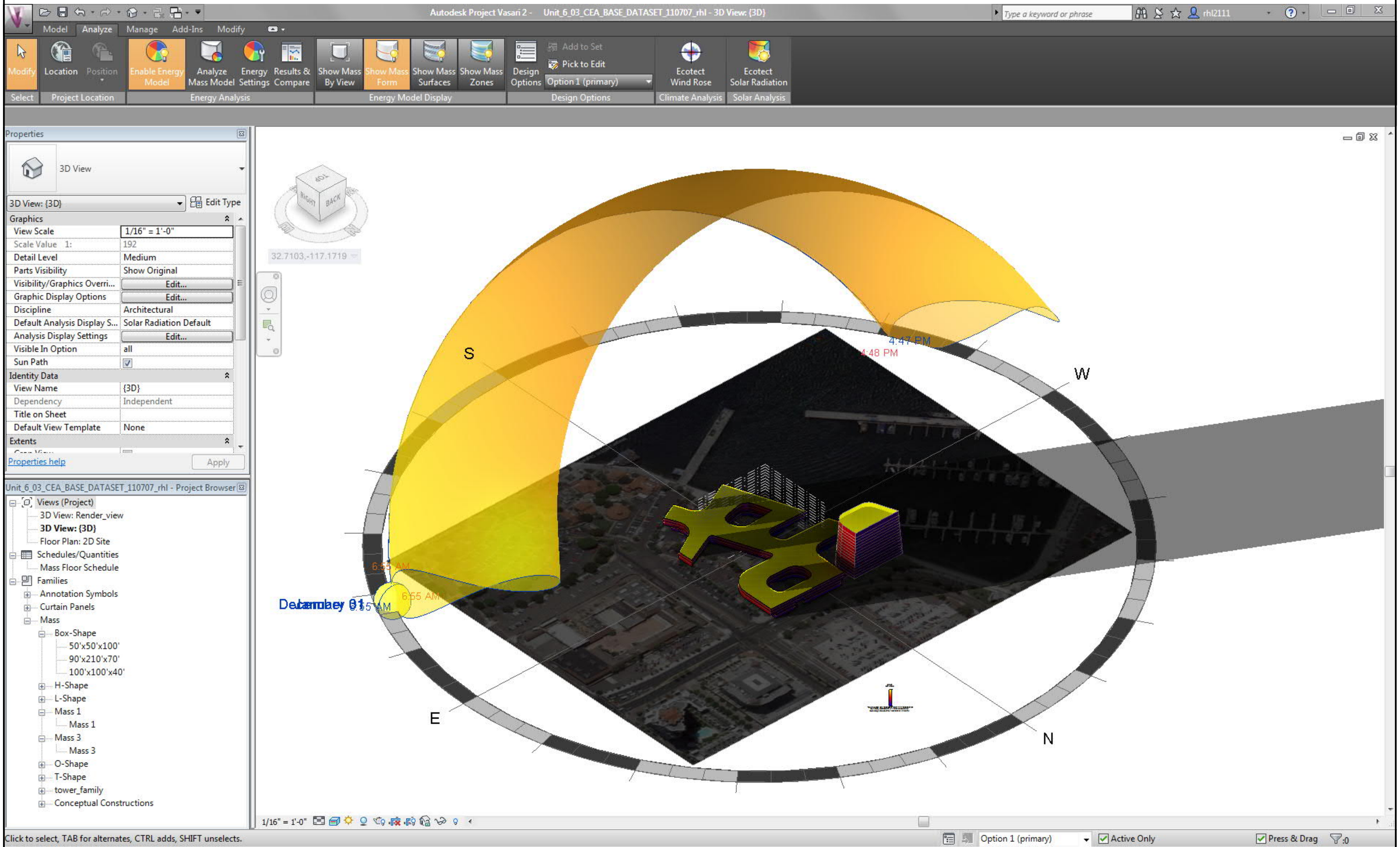
(Source: Autodesk)

Performance based conceptual design and energy analysis



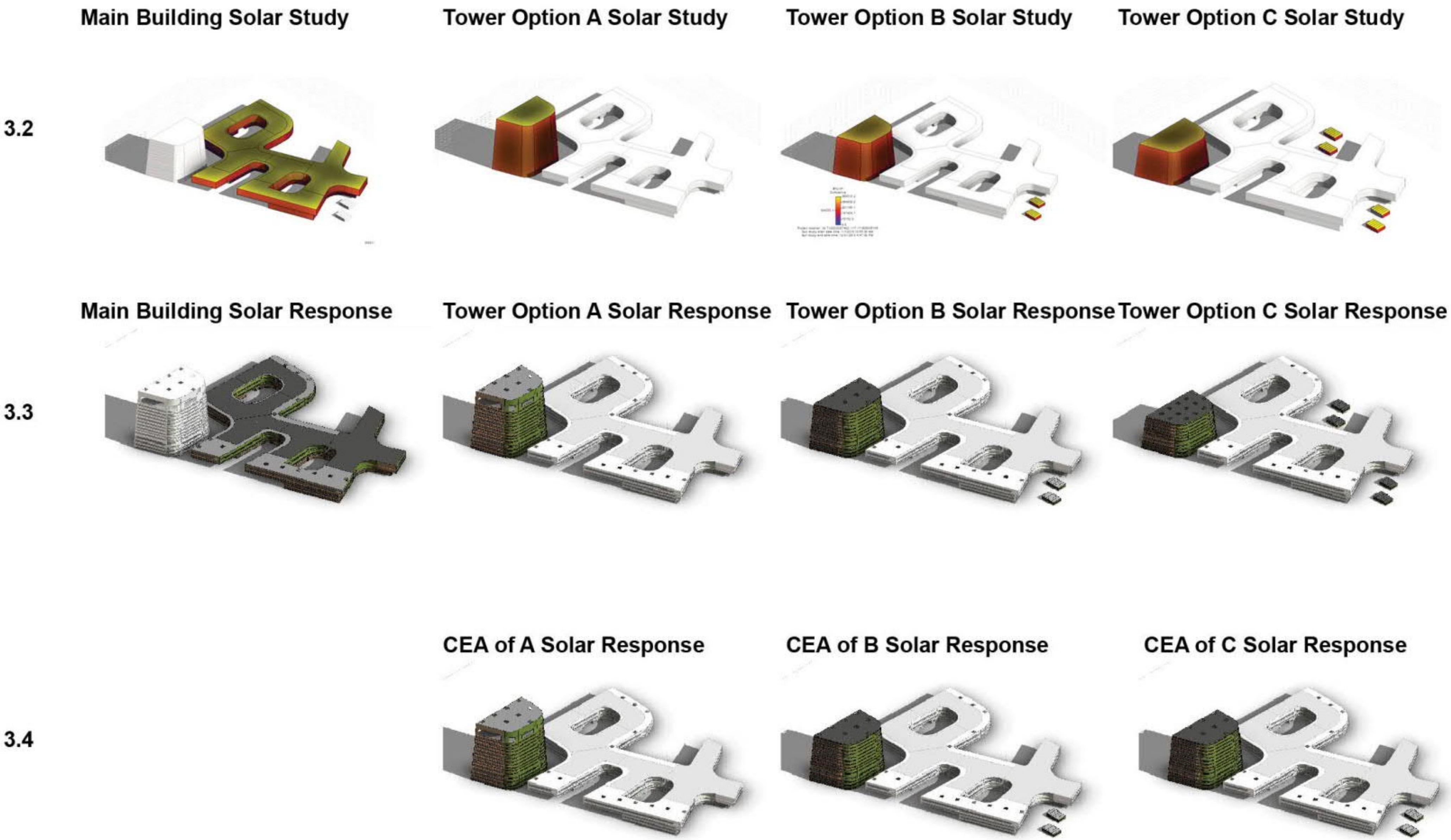
(Source: Autodesk)

Conceptual energy analysis: study how the sun affects the design



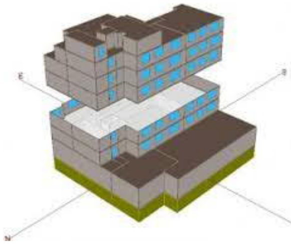
(Source: Autodesk)

Solar study and solar response for different design options

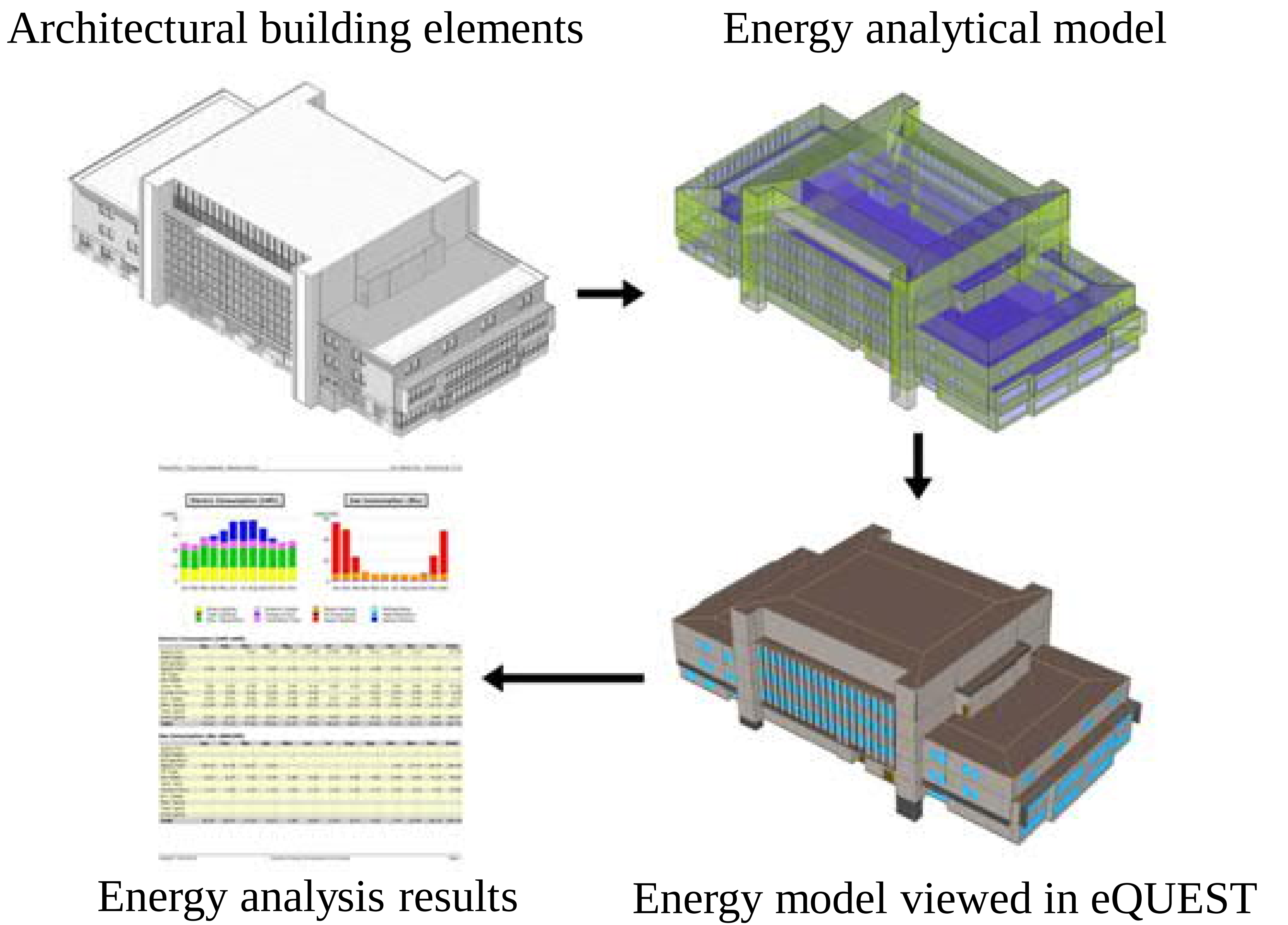


(Source: Autodesk)

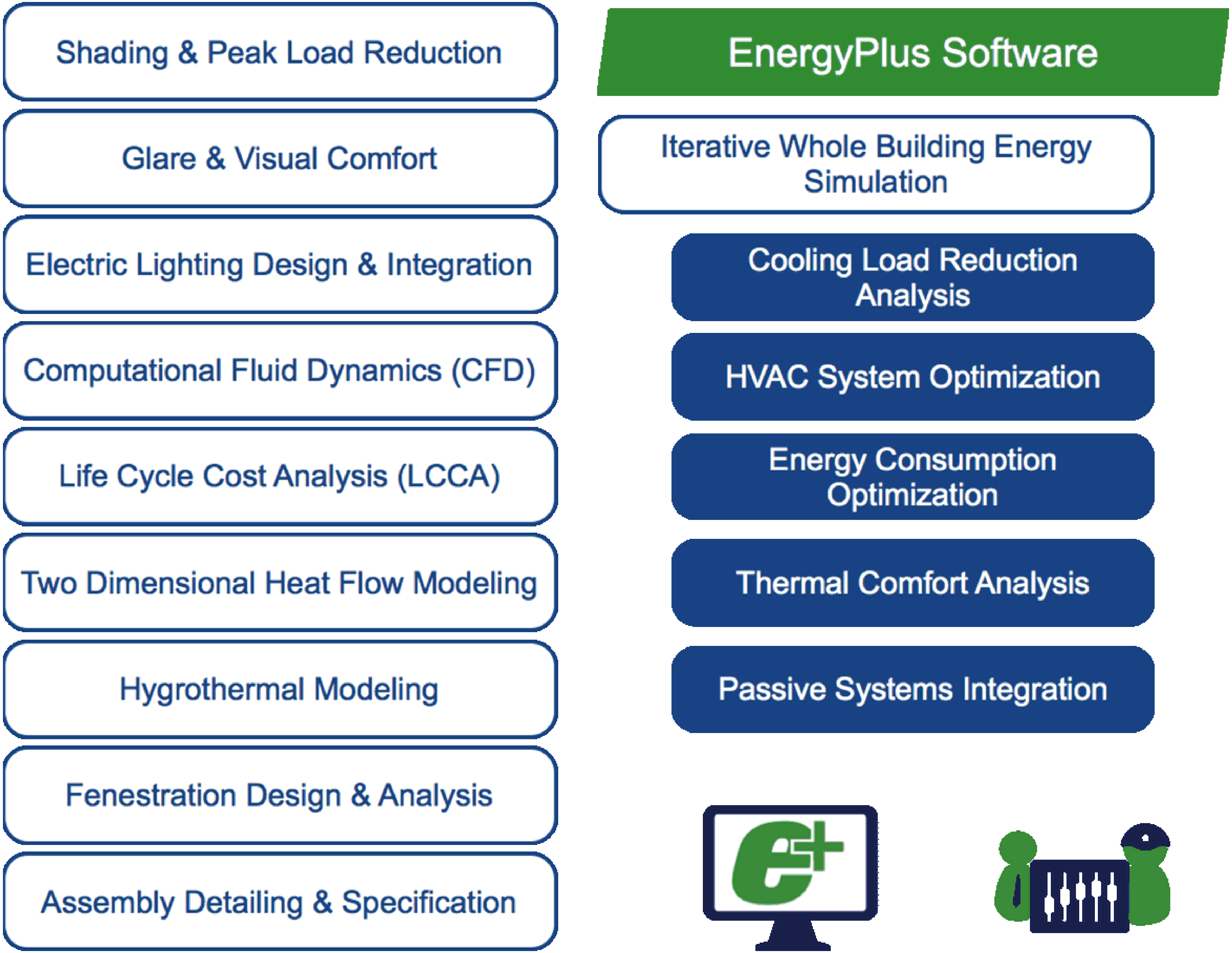
Building performance analysis



- 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



(Source: Autodesk)



(Source: www.synergyefficiency.solutions)

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
- See also:
  - http://sustainabilityworkshop.autodesk.com/buildings/climate-analysis
  - http://sustainabilityworkshop.autodesk.com/buildings/climate-analysis-bim

Climate analysis examples

- Energy Design Tools, University of California, Los Angeles (UCLA)
  - http://www.energy-design-tools.aud.ucla.edu/
  - Climate Consultant (version 5.5)
    - 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
    - Climate Consultant 5.4 Overview (9:54) http://www.youtube.com/watch?v=7pxpmdZptDM

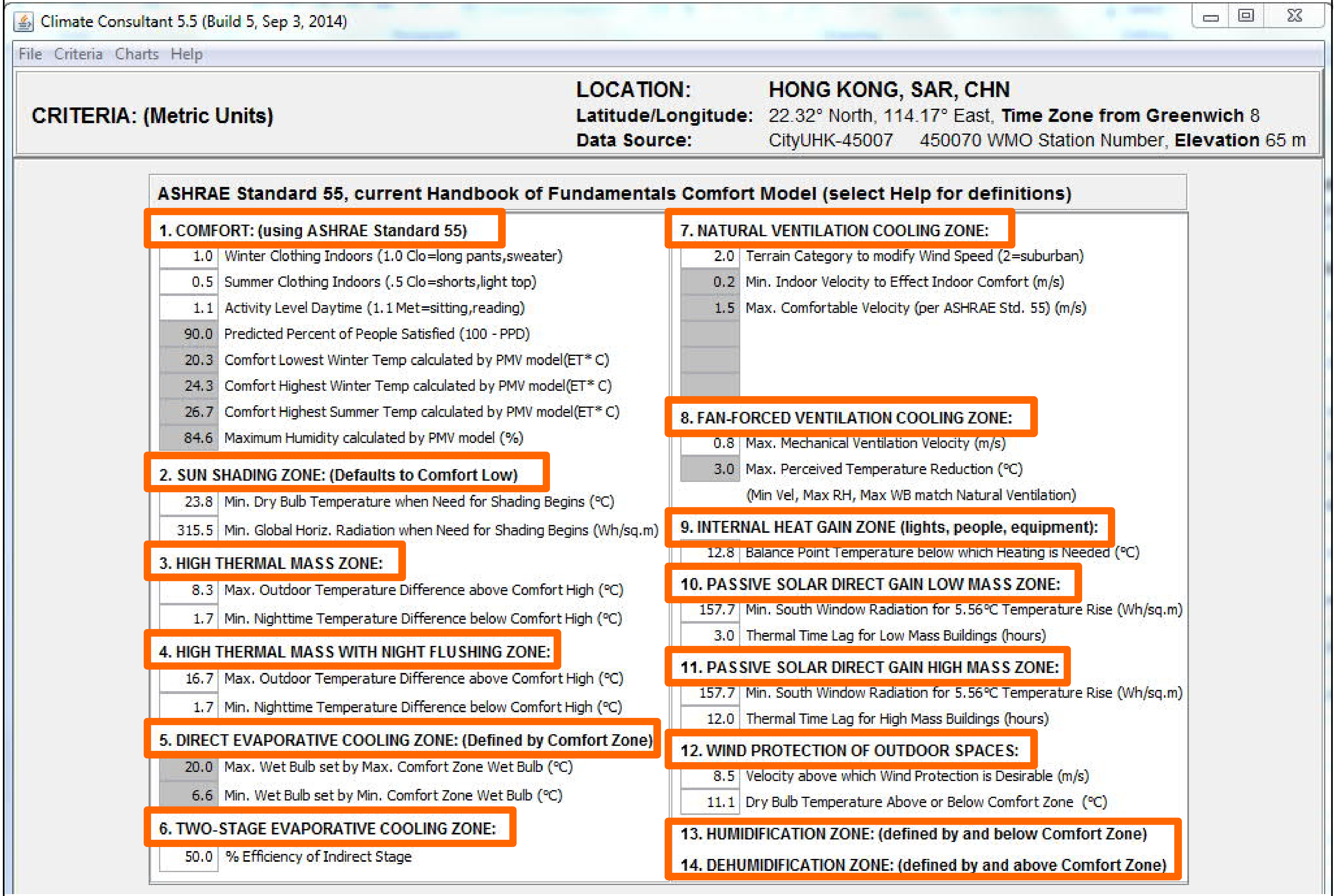
Climate Consultant 5.5 (Build 5, Sep 3, 2014)

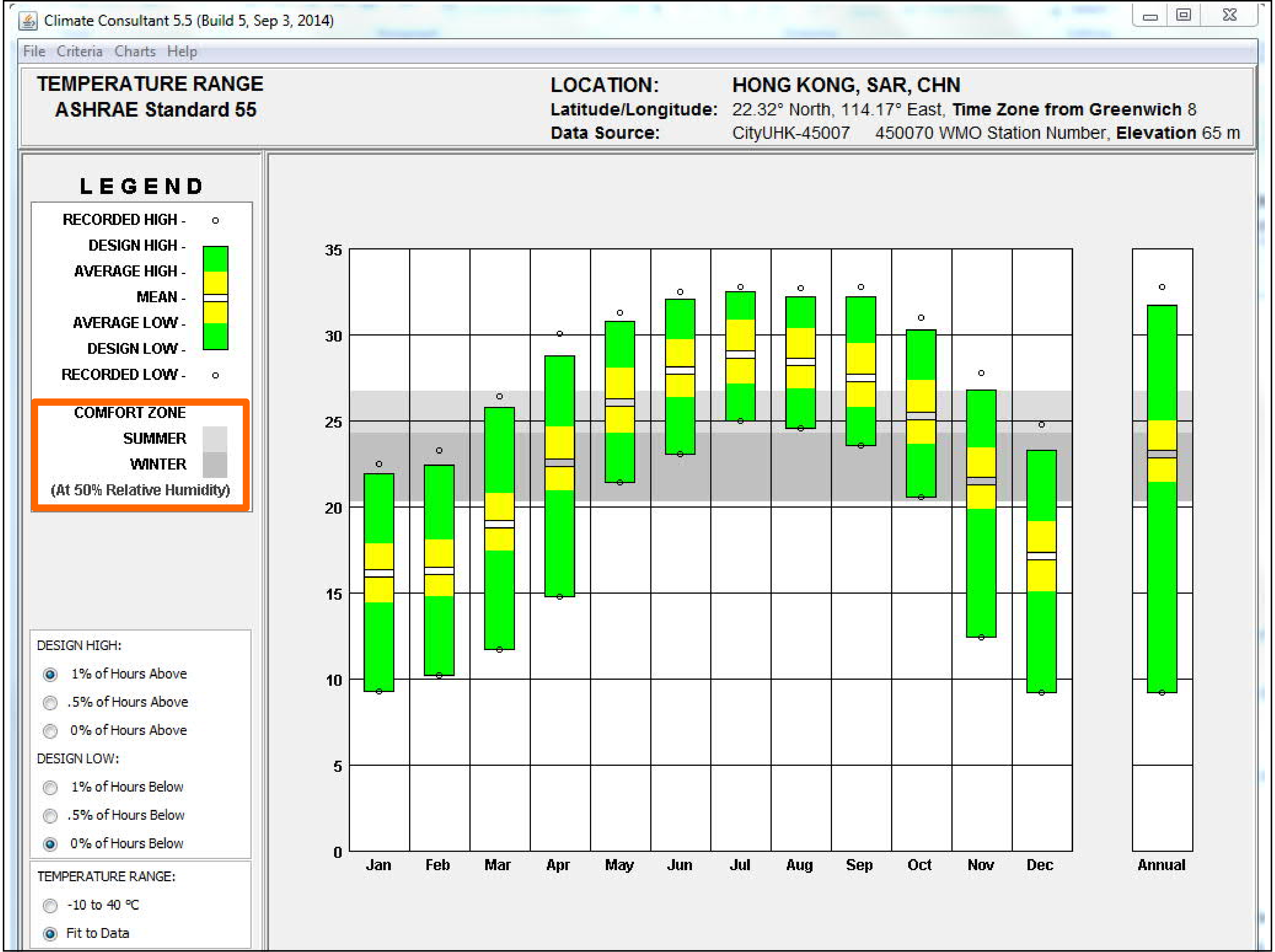
File Criteria Charts Help

WEATHER DATA SUMMARY

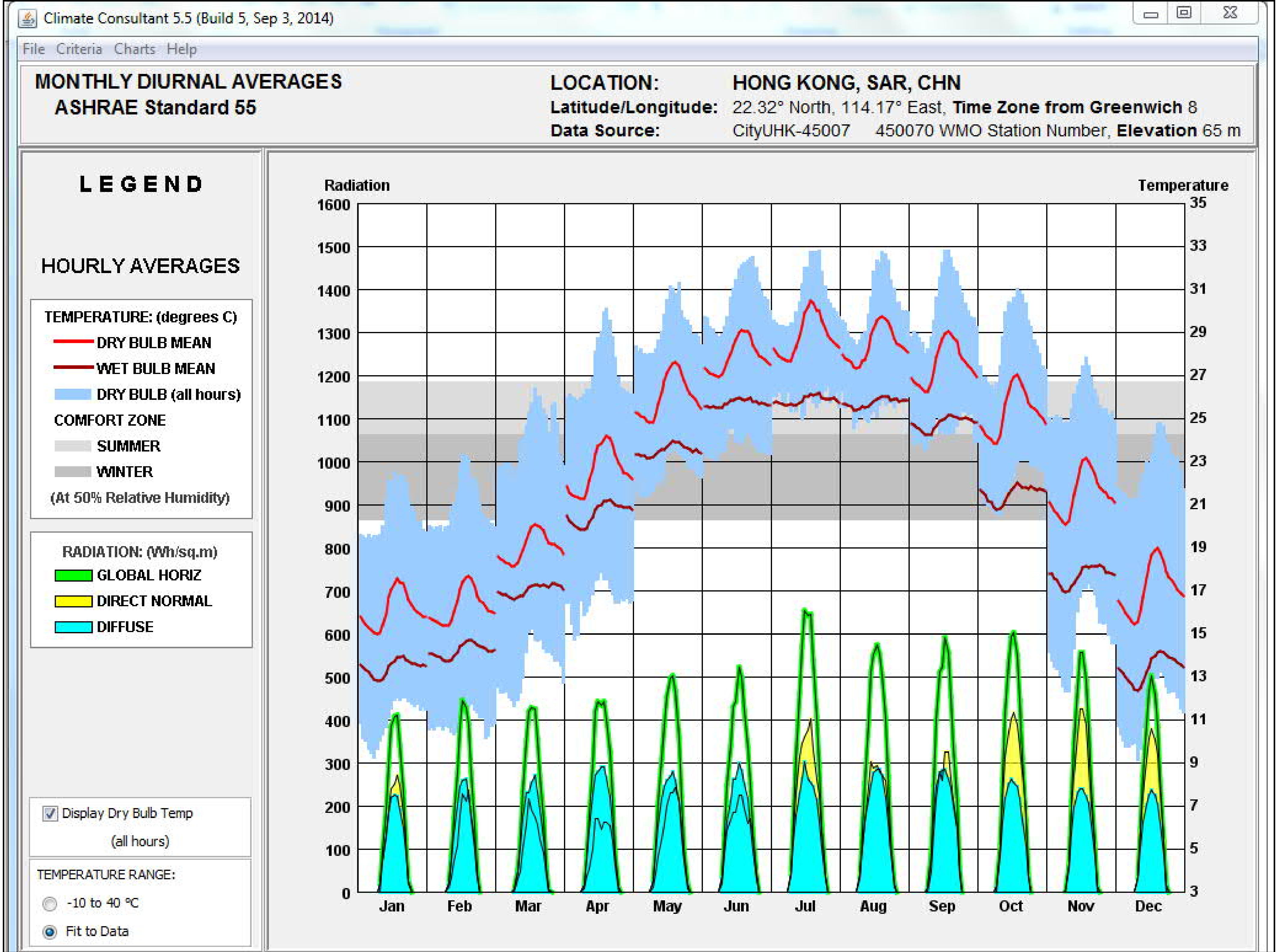
LOCATION: HONG KONG, SAR, CHN
Latitude/Longitude: 22.32° North, 114.17° East, **Time Zone from Greenwich** 8
Data Source: CityUHK-45007 450070 WMO Station Number, **Elevation** 65 m

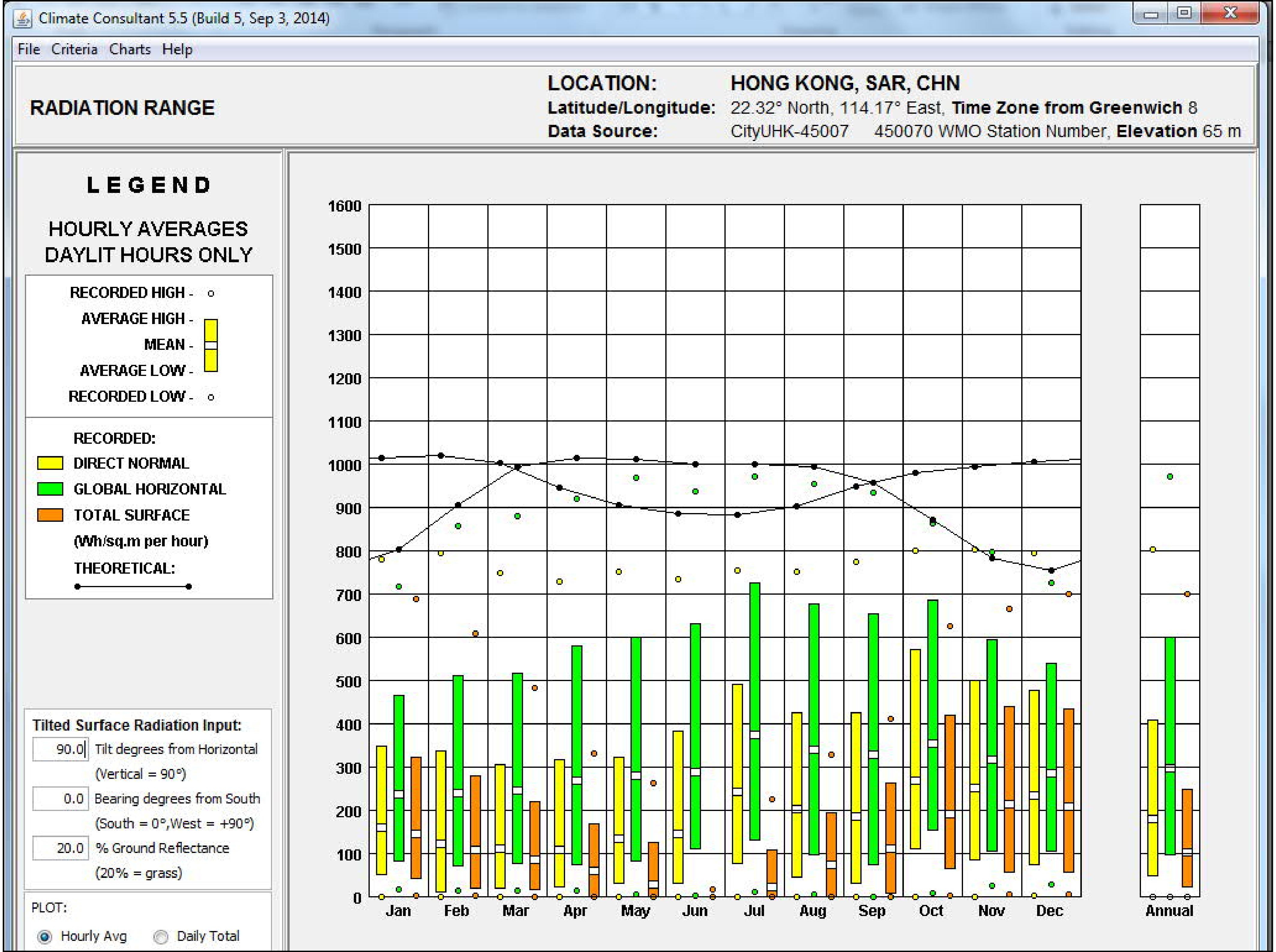
MONTHLY MEANS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Global Horiz Radiation (Avg Hourly)	235	239	244	268	280	288	373	340	329	353	316	286	Wh/sq.m
Direct Normal Radiation (Avg Hourly)	159	123	112	107	133	146	243	201	186	267	251	233	Wh/sq.m
Diffuse Radiation (Avg Hourly)	142	157	161	185	173	178	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

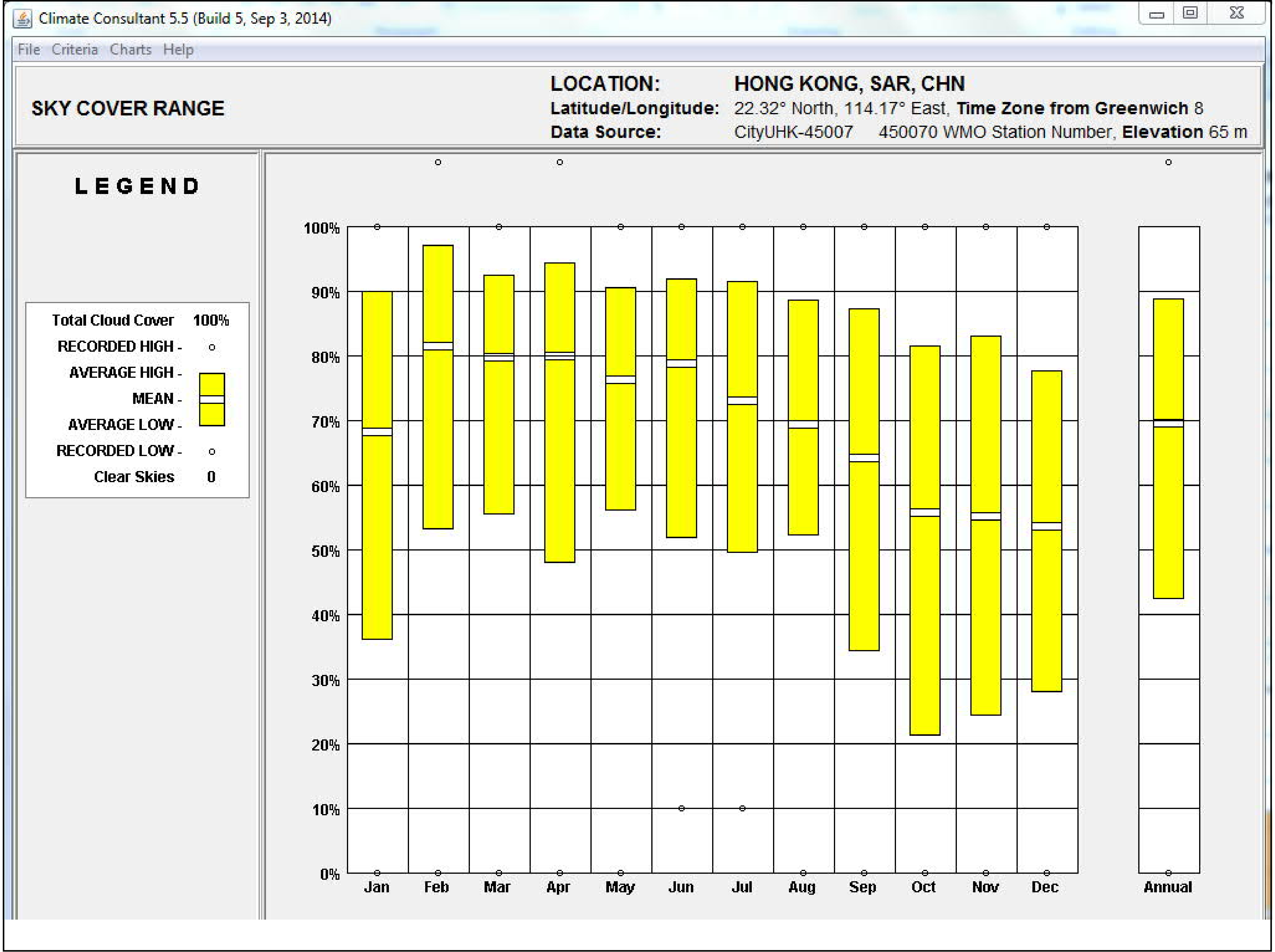

Climate Consultant 5.5 (Build 5, Sep 3, 2014)
File Criteria Charts Help
CRITERIA: (Metric Units)
LOCATION: HONG KONG, SAR, CHN
Latitude/Longitude: 22.32° North, 114.17° East, Time Zone from Greenwich 8
Data Source: CityUHK-45007 450070 WMO Station Number, Elevation 65 m
ASHRAE Standard 55, current Handbook 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)



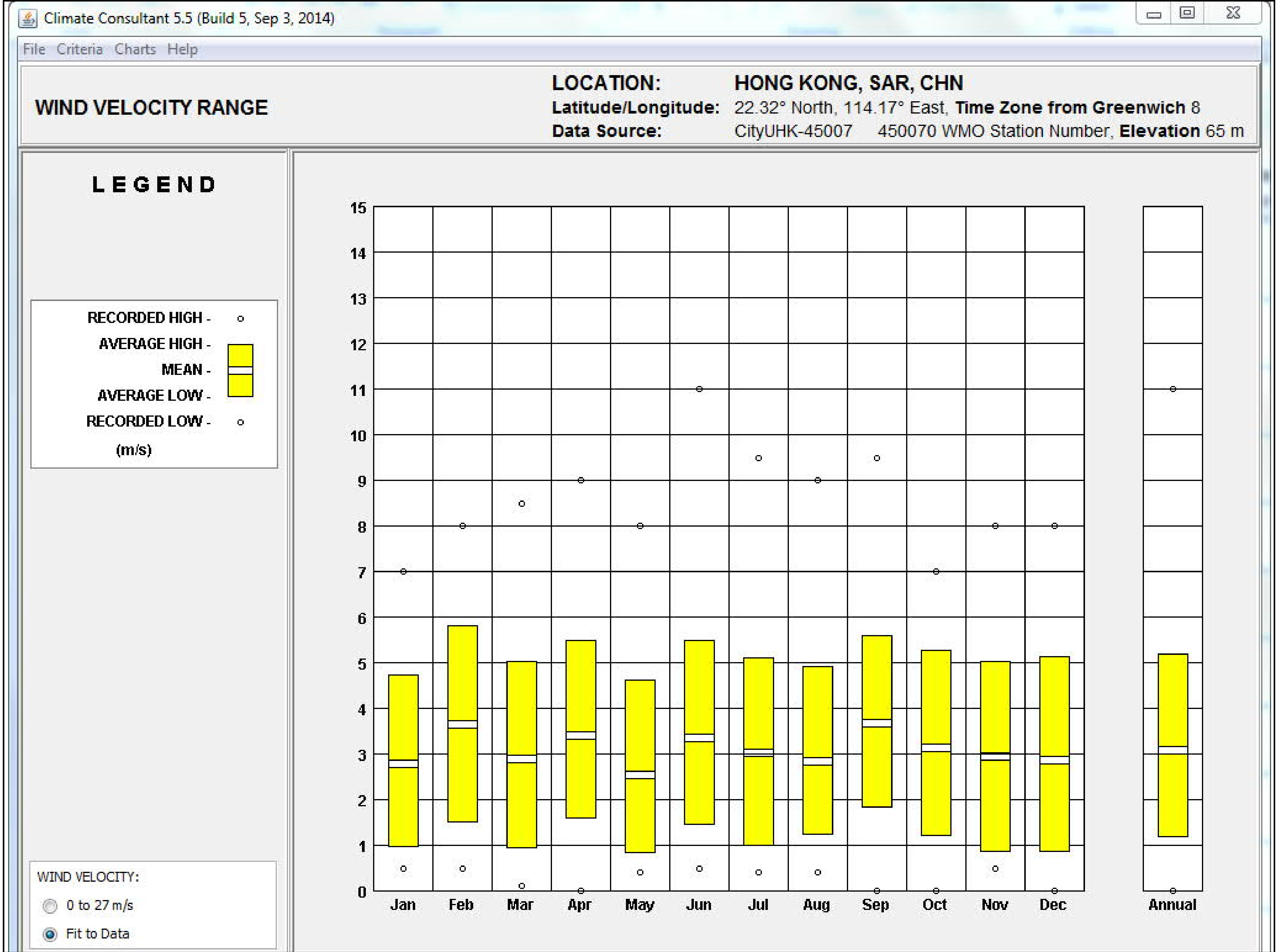
Climate Consultant 5.5 (Build 5, Sep 3, 2014)
File Criteria Charts Help
TEMPERATURE RANGE
ASHRAE Standard 55
LOCATION: HONG KONG, SAR, CHN
Latitude/Longitude: 22.32° North, 114.17° East, Time Zone from Greenwich 8
Data Source: CityUHK-45007 450070 WMO Station Number, Elevation 65 m
LEGEND
RECORDED HIGH -
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
35
30
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Annual


Climate Consultant 5.5 (Build 5, Sep 3, 2014)
File Criteria Charts Help
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
Radiation
Temperature
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
35
33
31
29
27
25
23
21
19
17
15
13
11
9
7
5
3
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

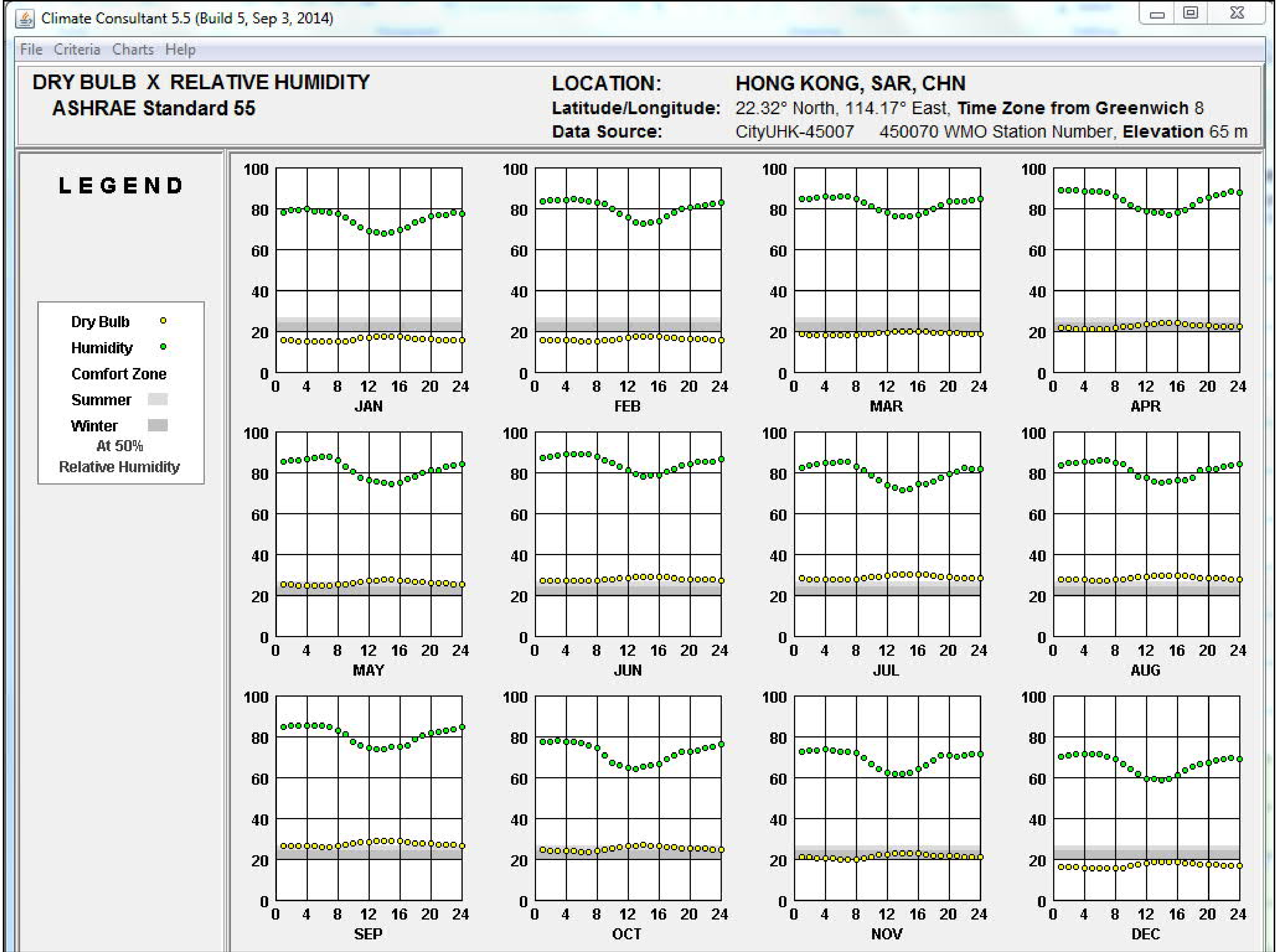

Climate Consultant 5.5 (Build 5, Sep 3, 2014)
File Criteria Charts Help
RADIATION RANGE
LOCATION: HONG KONG, SAR, CHN
Latitude/Longitude: 22.32° North, 114.17° East, Time Zone from Greenwich 8
Data Source: CityUHK-45007 450070 WMO Station Number, Elevation 65 m
LEGEND
HOURLY AVERAGES
DAYLIT HOURS ONLY
RECORDED HIGH -
AVERAGE HIGH -
MEAN -
AVERAGE LOW -
RECORDED LOW -
RECORDED:
DIRECT NORMAL
GLOBAL HORIZONTAL
TOTAL SURFACE
(Wh/sq.m per hour)
THEORETICAL:
Tilted Surface Radiation Input:
90.0 Tilt degrees from Horizontal
(Vertical = 90°)
0.0 Bearing degrees from South
(South = 0°,West = +90°)
20.0 % Ground Reflectance
(20% = grass)
PLOT:
Hourly Avg
Daily Total
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Annual



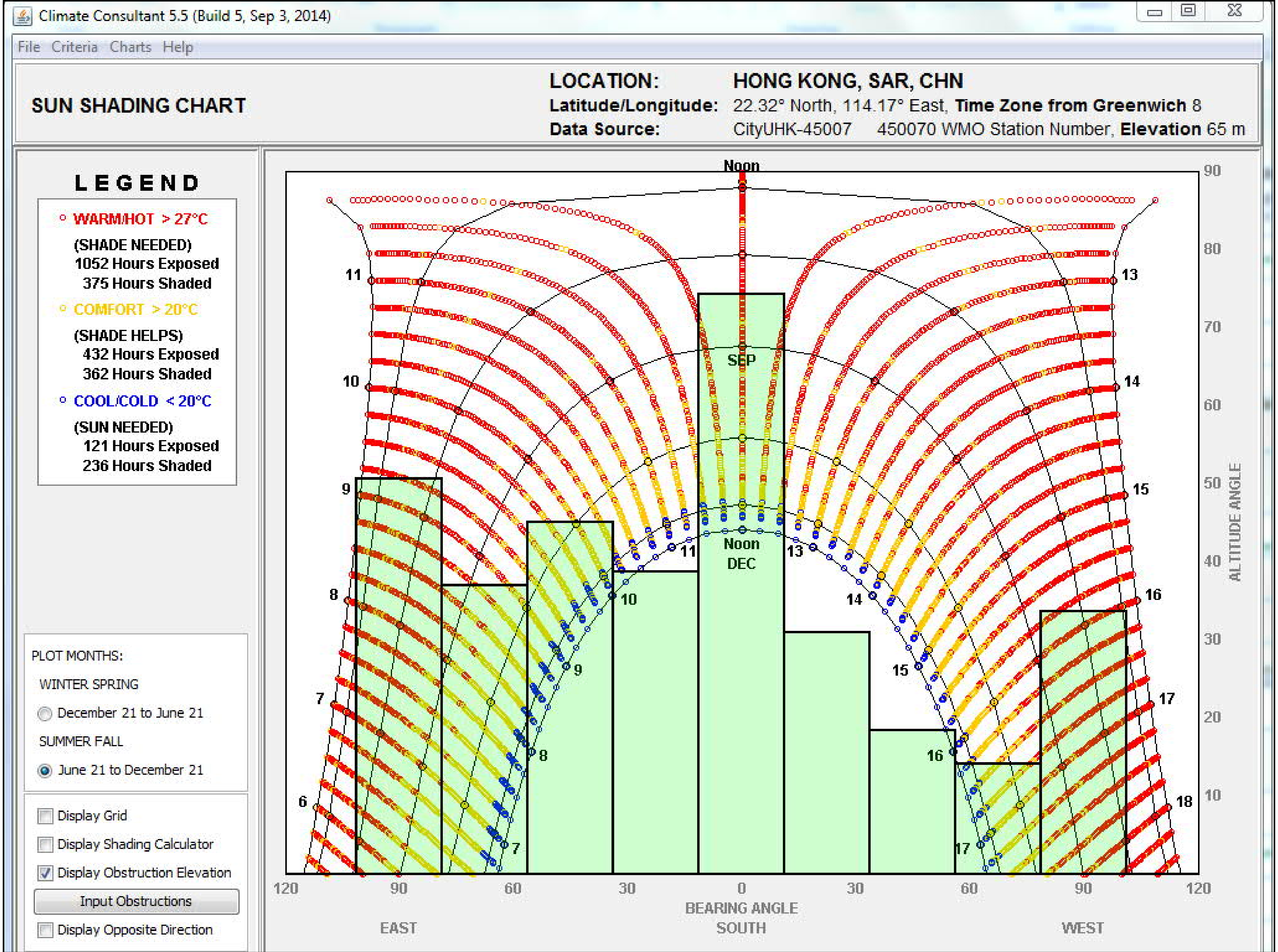
Climate Consultant 5.5 (Build 5, Sep 3, 2014)
File Criteria Charts Help
SKY COVER RANGE
LOCATION: HONG KONG, SAR, CHN
Latitude/Longitude: 22.32° North, 114.17° East, Time Zone from Greenwich 8
Data Source: CityUHK-45007 450070 WMO Station Number, Elevation 65 m
LEGEND
Total Cloud Cover 100%
RECORDED HIGH -
AVERAGE HIGH -
MEAN -
AVERAGE LOW -
RECORDED LOW -
Clear Skies 0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Annual



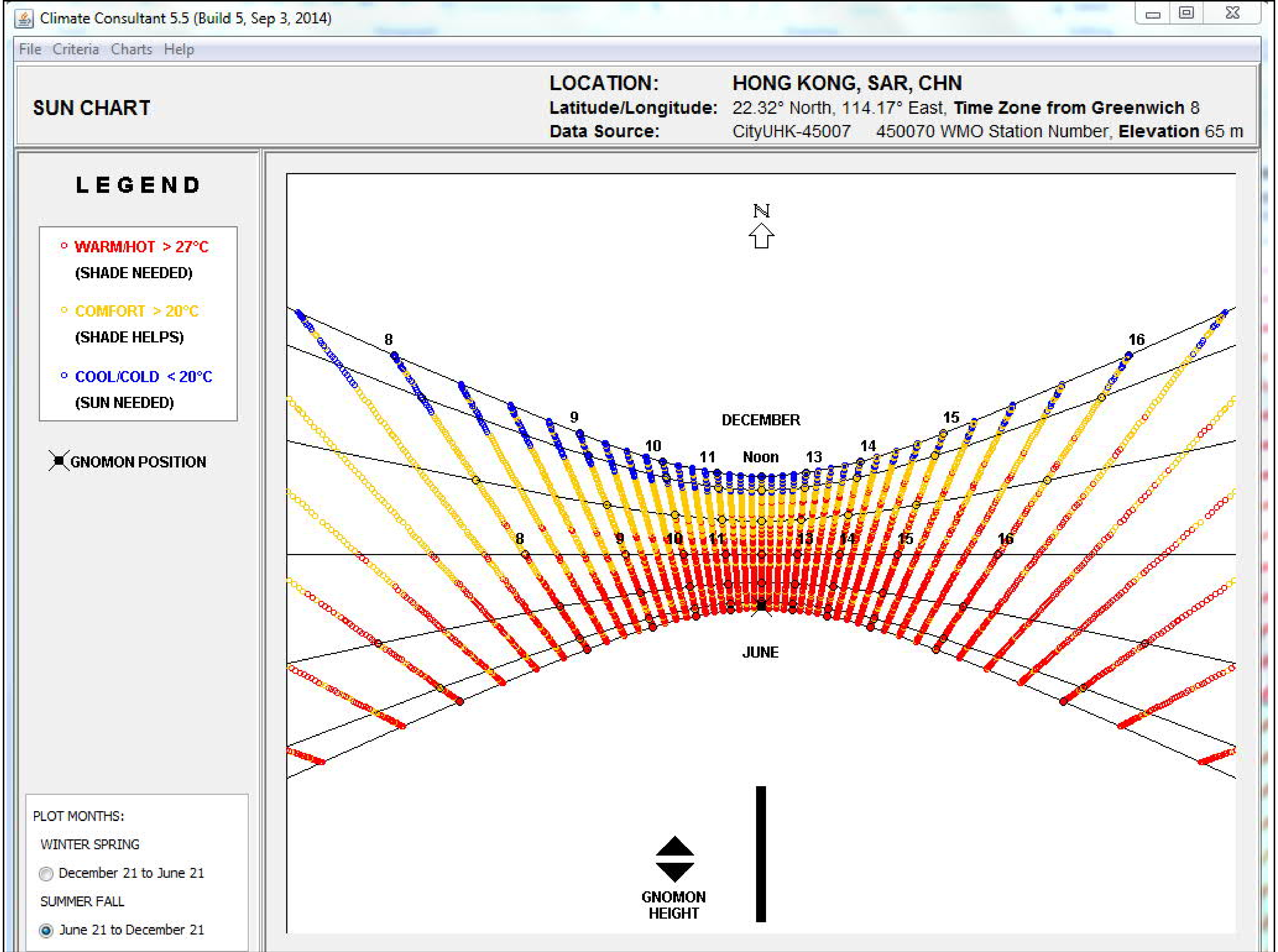
Climate Consultant 5.5 (Build 5, Sep 3, 2014)
File Criteria Charts Help
WIND VELOCITY RANGE
LOCATION: HONG KONG, SAR, CHN
Latitude/Longitude: 22.32° North, 114.17° East, Time Zone from Greenwich 8
Data Source: CityUHK-45007 450070 WMO Station Number, Elevation 65 m
LEGEND
RECORDED HIGH -
AVERAGE HIGH -
MEAN -
AVERAGE LOW -
RECORDED LOW -
(m/s)
WIND VELOCITY:
0 to 27 m/s
Fit to Data
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Annual

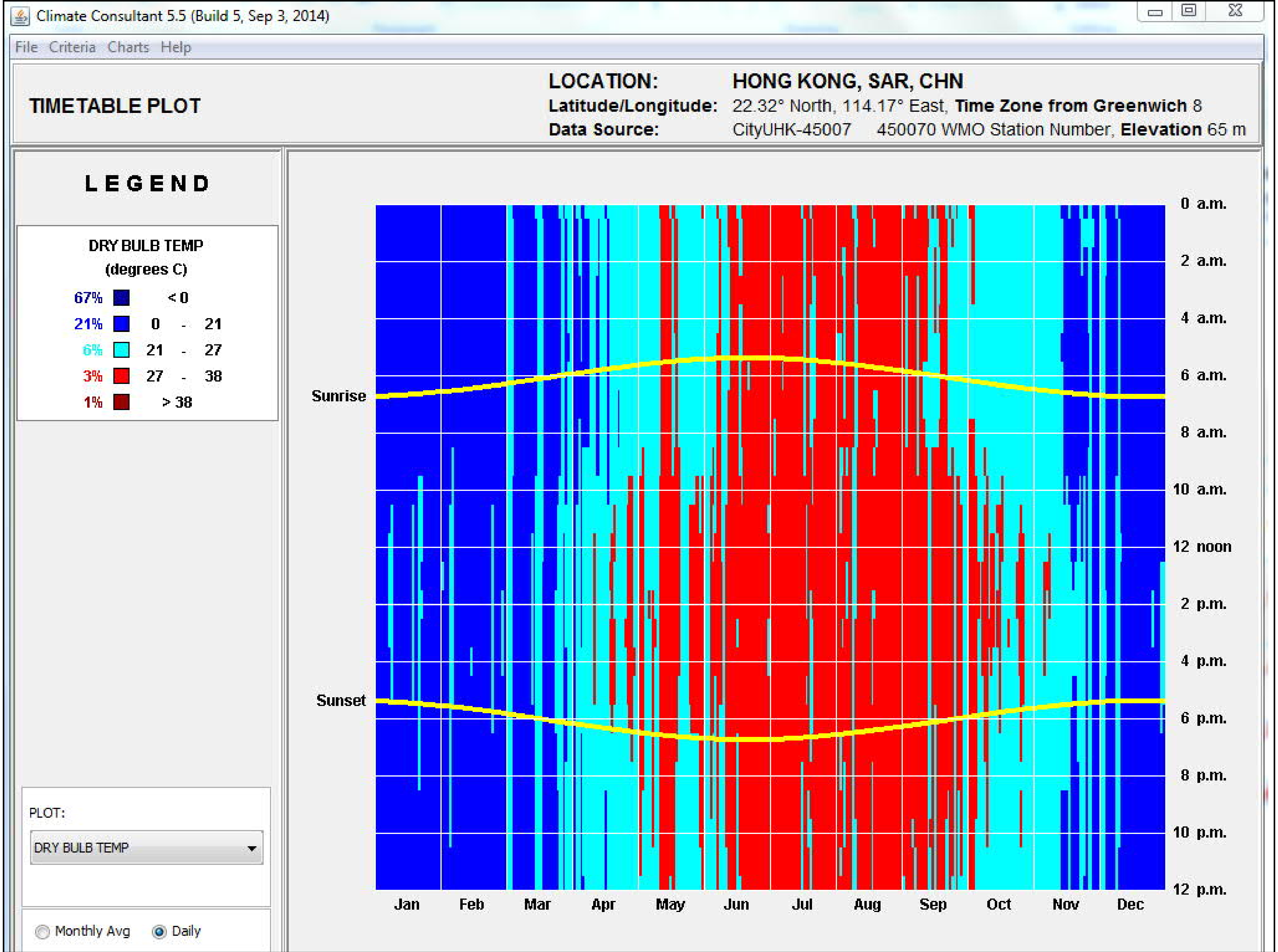


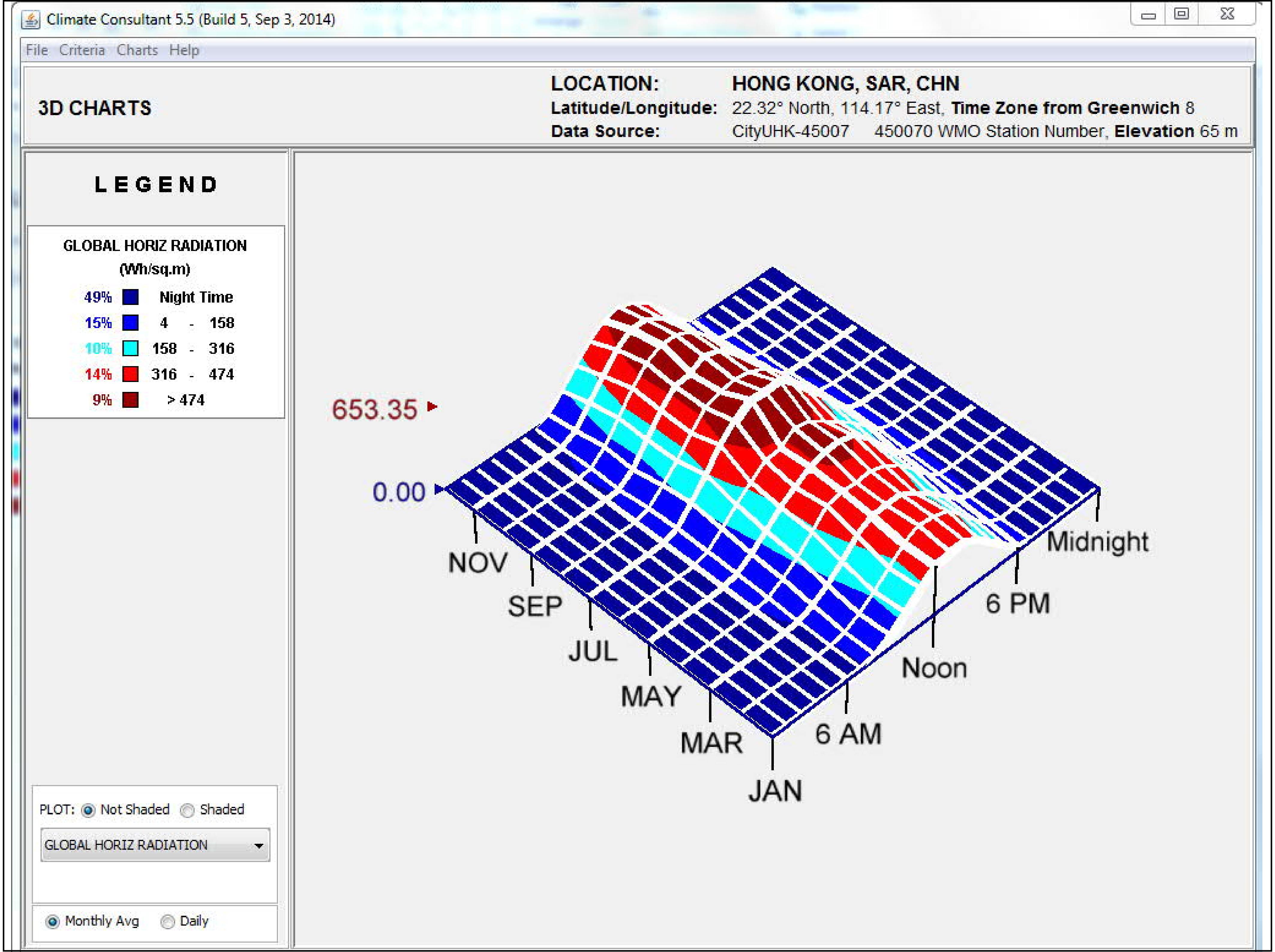
Climate Consultant 5.5 (Build 5, Sep 3, 2014)
File Criteria Charts Help
DRY BULB X RELATIVE HUMIDITY
ASHRAE Standard 55
LOCATION: HONG KONG, SAR, CHN
Latitude/Longitude: 22.32° North, 114.17° East, Time Zone from Greenwich 8
Data Source: CityUHK-45007 450070 WMO Station Number, Elevation 65 m
LEGEND
Dry Bulb
Humidity
Comfort Zone
Summer
Winter
At 50% Relative Humidity
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

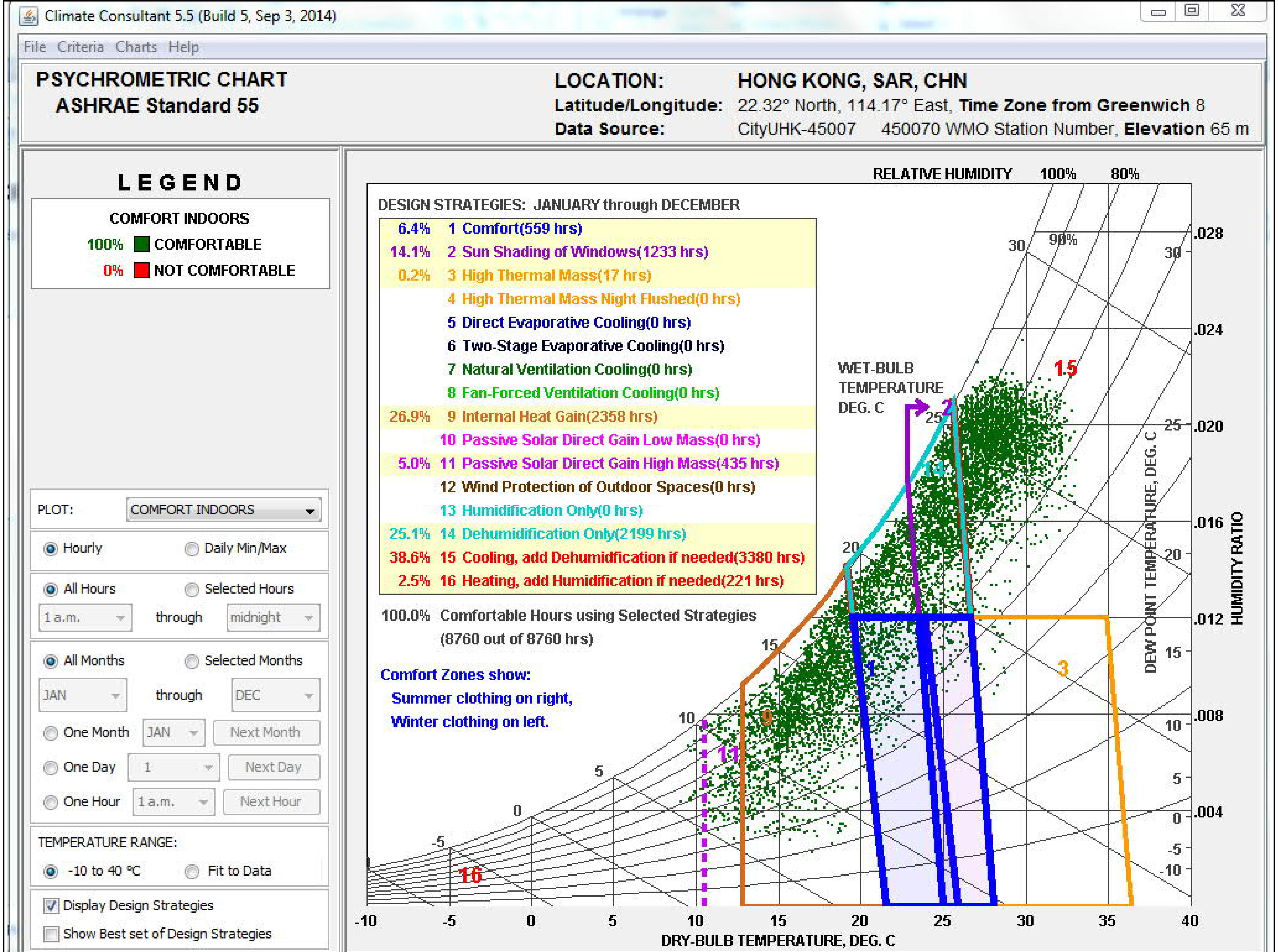


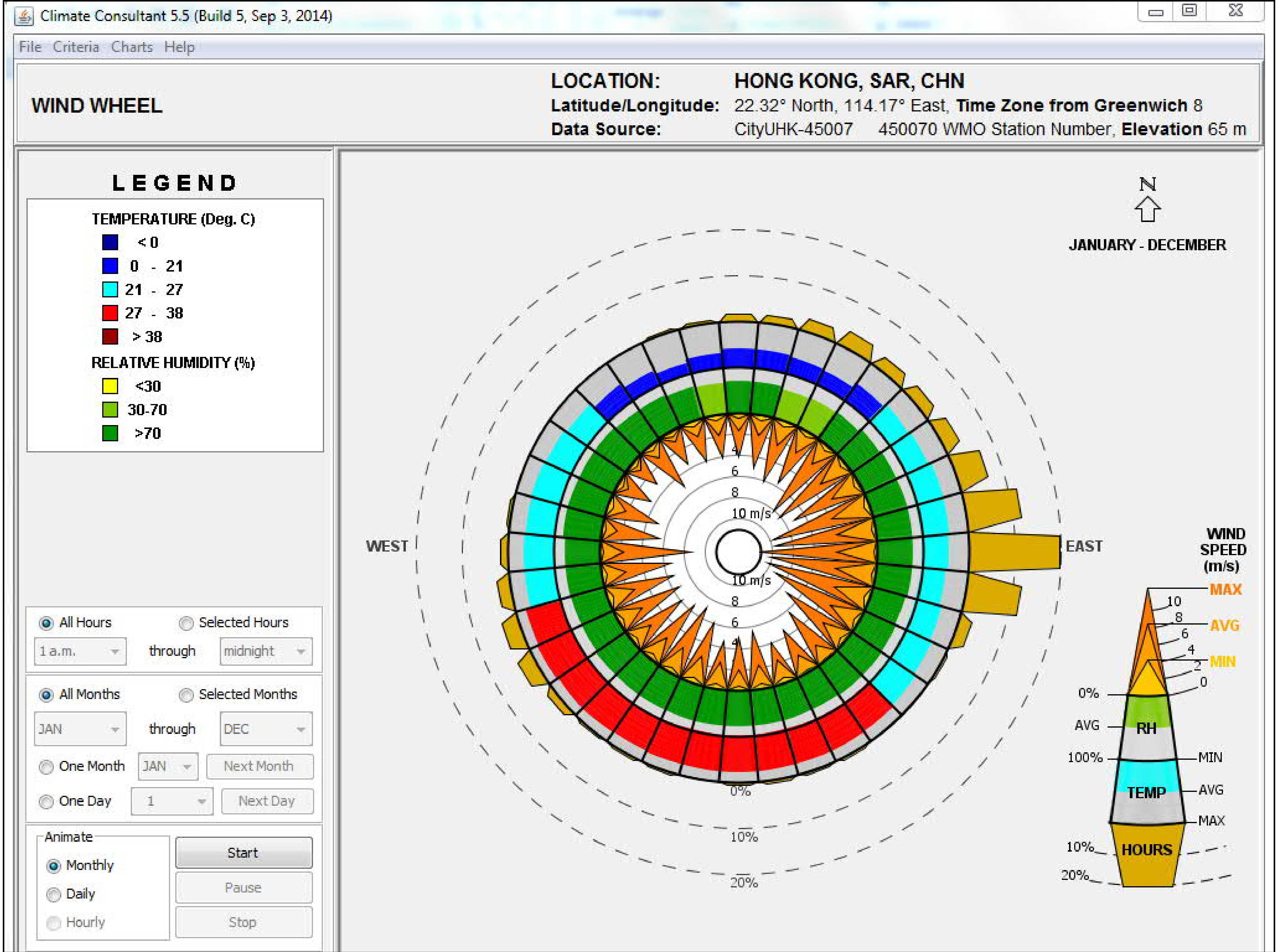
Climate Consultant 5.5 (Build 5, Sep 3, 2014)
File Criteria Charts Help
SUN SHADING CHART
LOCATION: HONG KONG, SAR, CHN
Latitude/Longitude: 22.32° North, 114.17° East, Time Zone from Greenwich 8
Data Source: CityUHK-45007 450070 WMO Station Number, Elevation 65 m
LEGEND
WARM/HOT > 27°C
(SHADE NEEDED)
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
Noon
SEP
Noon
DEC
ALTITUDE ANGLE
BEARING ANGLE
EAST
SOUTH
WEST


Climate Consultant 5.5 (Build 5, Sep 3, 2014)
File Criteria Charts Help
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
N
DECEMBER
Noon
JUNE
8
9
10
11
13
14
15
16
GNOMON
HEIGHT

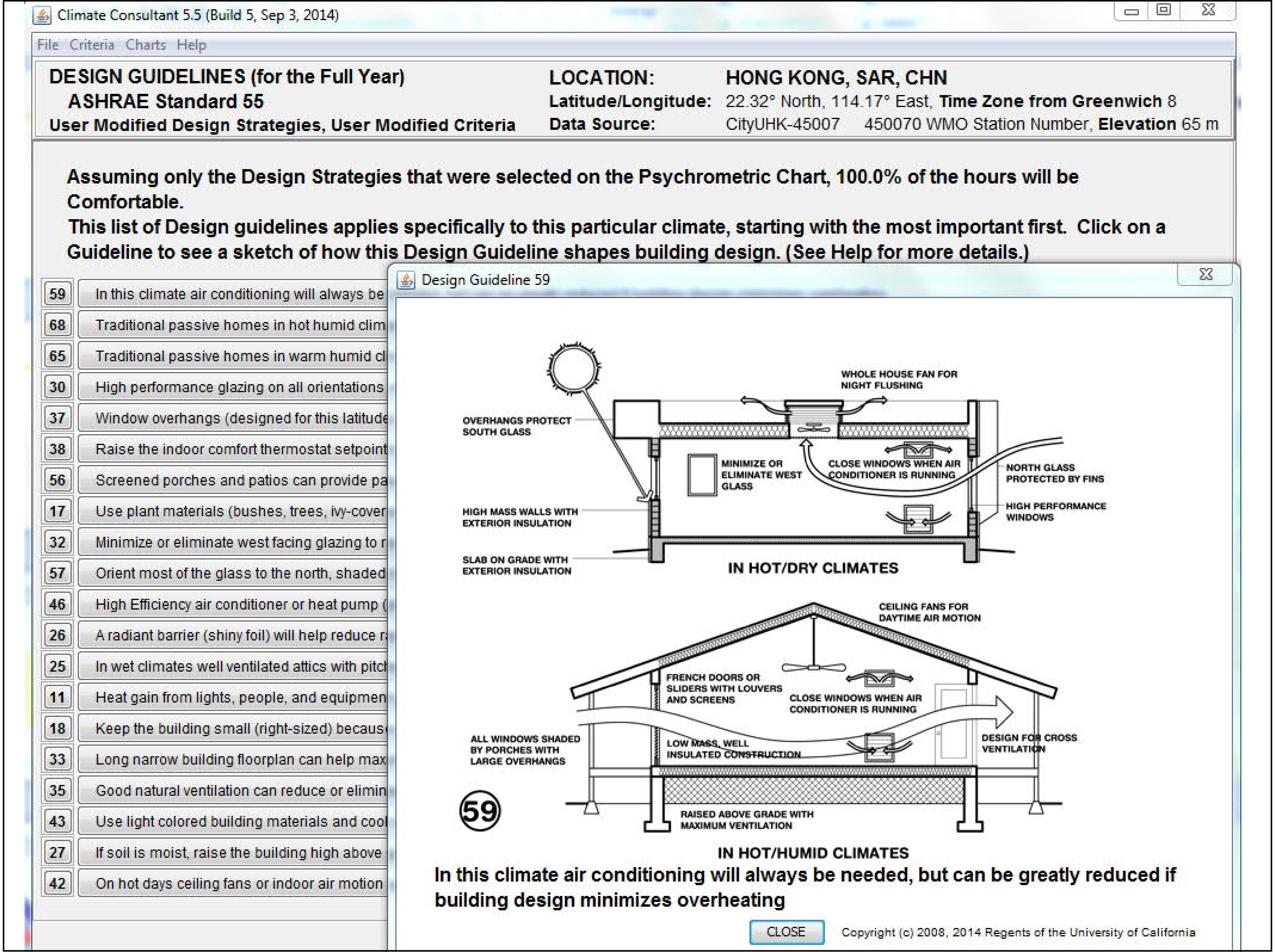

Climate Consultant 5.5 (Build 5, Sep 3, 2014)
File Criteria Charts Help
TIMETABLE PLOT
LOCATION: HONG KONG, SAR, CHN
Latitude/Longitude: 22.32° North, 114.17° East, Time Zone from Greenwich 8
Data Source: CityUHK-45007 450070 WMO Station Number, Elevation 65 m
LEGEND
DRY BULB TEMP
(degrees C)
67% < 0
21% 0 - 21
6% 21 - 27
3% 27 - 38
1% > 38
PLOT:
DRY BULB TEMP
Monthly Avg
Daily
Sunrise
Sunset
0 a.m.
2 a.m.
4 a.m.
6 a.m.
8 a.m.
10 a.m.
12 noon
2 p.m.
4 p.m.
6 p.m.
8 p.m.
10 p.m.
12 p.m.
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Climate Consultant 5.5 (Build 5, Sep 3, 2014)
File Criteria Charts Help
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
653.35
0.00
NOV
SEP
JUL
MAY
MAR
JAN
6 AM
Noon
6 PM
Midnight
PLOT: Not Shaded Shaded
GLOBAL HORIZ RADIATION
Monthly Avg Daily


Climate Consultant 5.5 (Build 5, Sep 3, 2014)
File Criteria Charts Help
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 Dehumidfication 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.
RELATIVE HUMIDITY 100% 80%
WET-BULB TEMPERATURE DEG. C
DEW POINT TEMPERATURE, DEG. C
HUMIDITY RATIO
DRY-BULB TEMPERATURE, DEG. C
-10 -5 0 5 10 15 20 25 30 35 40
.028 .024 .020 .016 .012 .008 .004



Climate Consultant 5.5 (Build 5, Sep 3, 2014)
File Criteria Charts Help
WIND WHEEL
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
TEMPERATURE (Deg. C)
< 0
0 - 21
21 - 27
27 - 38
> 38
RELATIVE HUMIDITY (%)
<30
30-70
>70
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
Animate
Monthly
Daily
Hourly
Start
Pause
Stop
N
JANUARY - DECEMBER
WEST
EAST
10 m/s
8
6
4
0%
10%
20%
WIND SPEED (m/s)
MAX
AVG
MIN
10
8
6
4
2
0
0%
AVG
RH
100%
MIN
TEMP
AVG
MAX
10%
HOURS
20%


Climate Consultant 5.5 (Build 5, Sep 3, 2014)
File Criteria Charts Help
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
68 Traditional passive homes in hot humid clim
65 Traditional passive homes in warm humid cl
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 pa
17 Use plant materials (bushes, trees, ivy-cover
32 Minimize or eliminate west facing glazing to r
57 Orient most of the glass to the north, shaded
46 High Efficiency air conditioner or heat pump (
26 A radiant barrier (shiny foil) will help reduce r
25 In wet climates well ventilated attics with pitch
11 Heat gain from lights, people, and equipmen
18 Keep the building small (right-sized) becaus
33 Long narrow building floorplan can help max
35 Good natural ventilation can reduce or elimin
43 Use light colored building materials and cool
27 If soil is moist, raise the building high above
42 On hot days ceiling fans or indoor air motion
Design Guideline 59
WHOLE HOUSE FAN FOR NIGHT FLUSHING
OVERHANGS PROTECT SOUTH GLASS
MINIMIZE OR ELIMINATE WEST GLASS
CLOSE WINDOWS WHEN AIR CONDITIONER IS RUNNING
NORTH GLASS PROTECTED BY FINS
HIGH MASS WALLS WITH EXTERIOR INSULATION
HIGH PERFORMANCE WINDOWS
SLAB ON GRADE WITH EXTERIOR INSULATION
IN HOT/DRY CLIMATES
CEILING FANS FOR DAYTIME AIR MOTION
FRENCH DOORS OR SLIDERS WITH LOUVERS AND SCREENS
CLOSE WINDOWS WHEN AIR CONDITIONER IS RUNNING
ALL WINDOWS SHADED BY PORCHES WITH LARGE OVERHANGS
LOW MASS, WELL INSULATED CONSTRUCTION
DESIGN FOR CROSS VENTILATION
59
RAISED ABOVE GRADE WITH MAXIMUM VENTILATION
IN HOT/HUMID CLIMATES
In this climate air conditioning will always be needed, but can be greatly reduced if building design minimizes overheating
CLOSE
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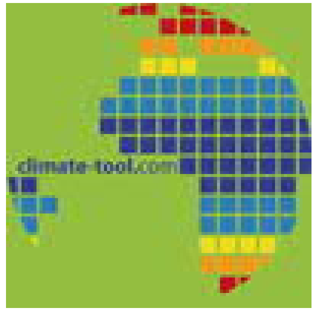
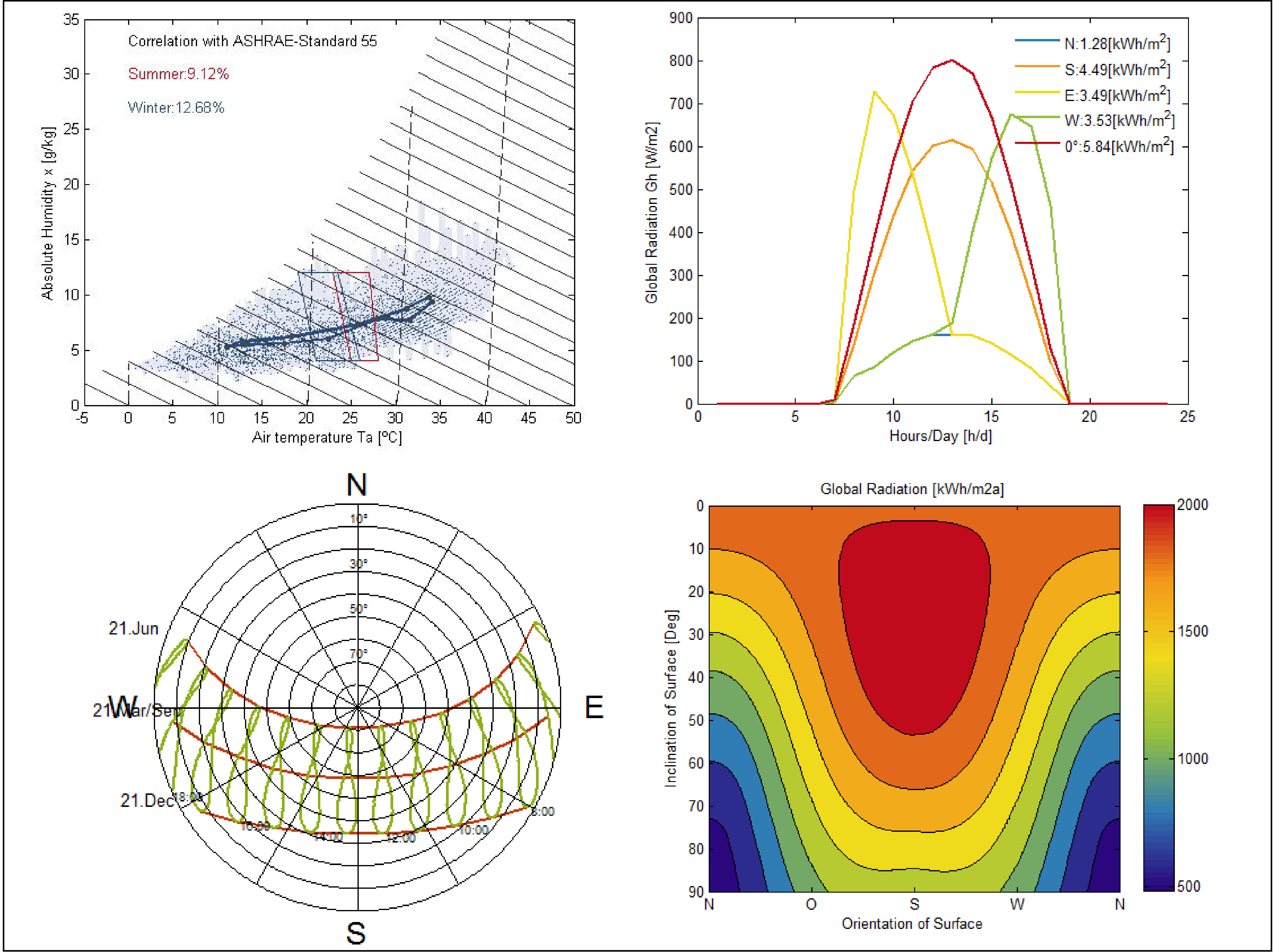
Climate analysis examples

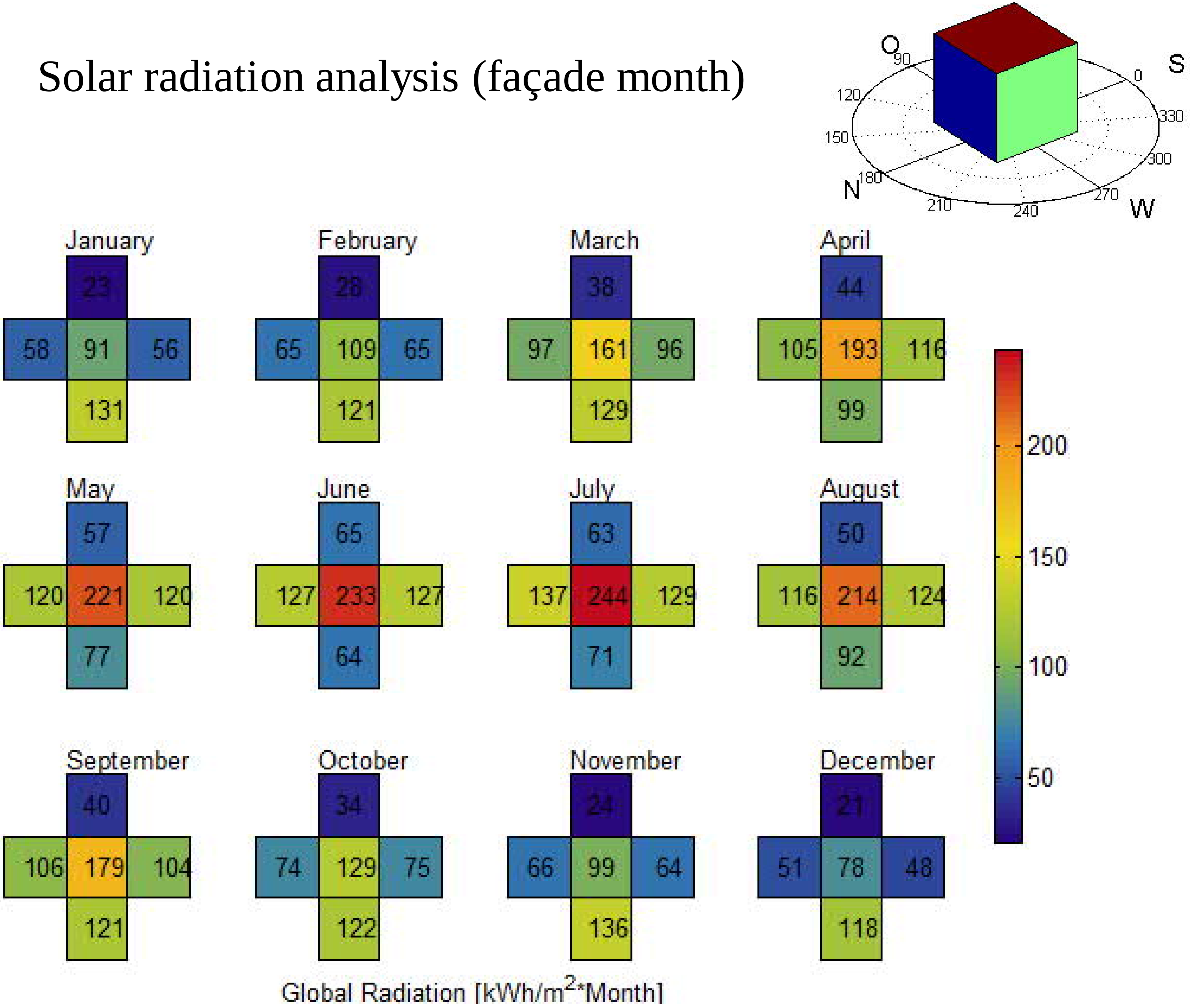


- ClimateTool Version 5.10
  - http://www.climate-tool.com
  - Analysis of the climate relevant aspects in planning (e.g. temperature, humidity, solar radiation, light and wind)
  - Climate Tool
    - http://www.climate-tool.com/en/climatetool.html
  - Climate Classification
    - http://www.climate-tool.com/en/climate-classification.html



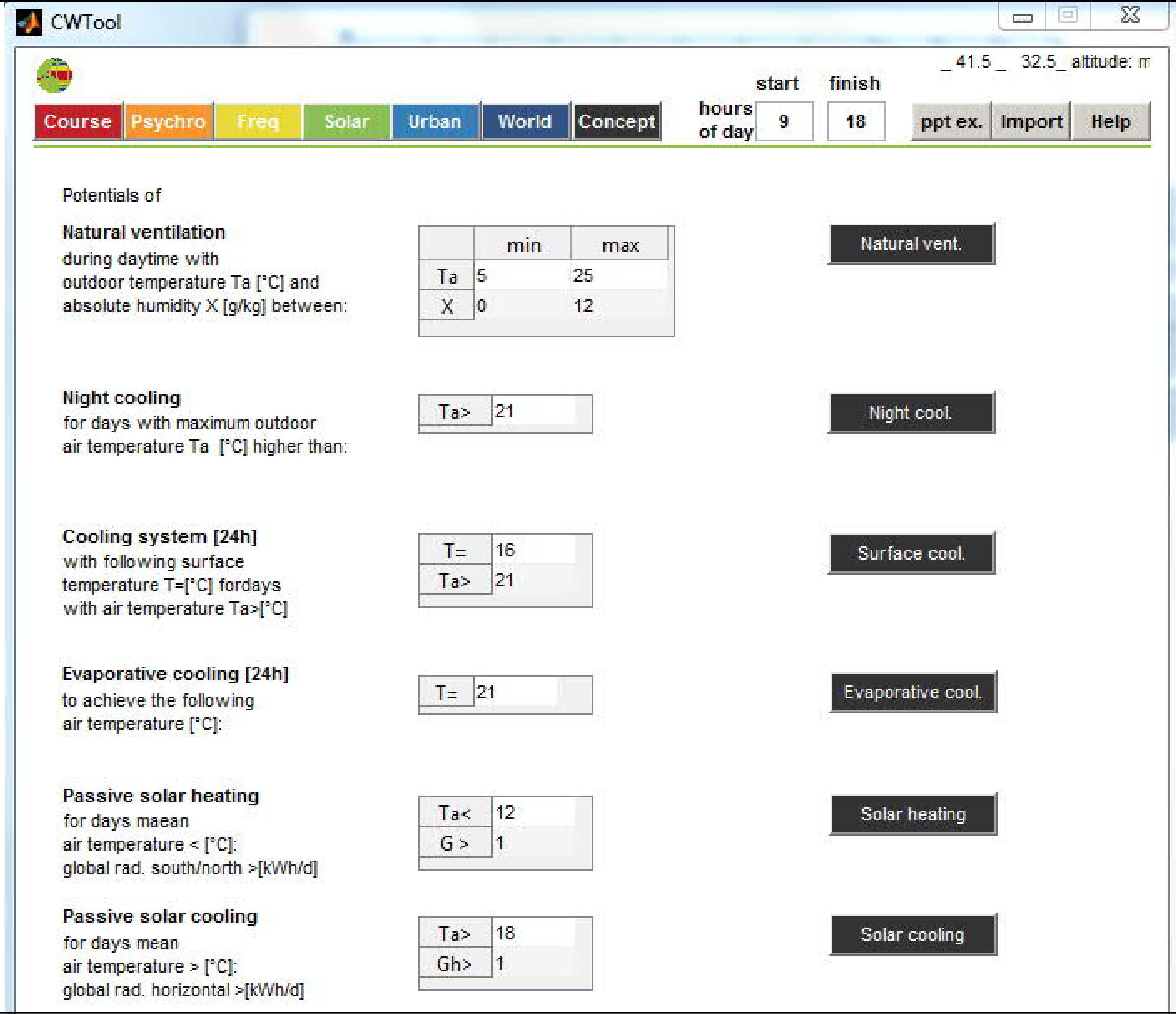
Correlation with ASHRAE-Standard 55
Summer:9.12%
Winter:12.68%
Absolute Humidity x [g/kg]
Air temperature Ta [ºC]
N:1.28[kWh/m2]
S:4.49[kWh/m2]
E:3.49[kWh/m2]
W:3.53[kWh/m2]
0°:5.84[kWh/m2]
Global Radiation Gh [W/m2]
Hours/Day [h/d]
N
S
W
E
21.Jun
21.Mar/Sep
21.Dec
Global Radiation [kWh/m2a]
Inclination of Surface [Deg]
Orientation of Surface

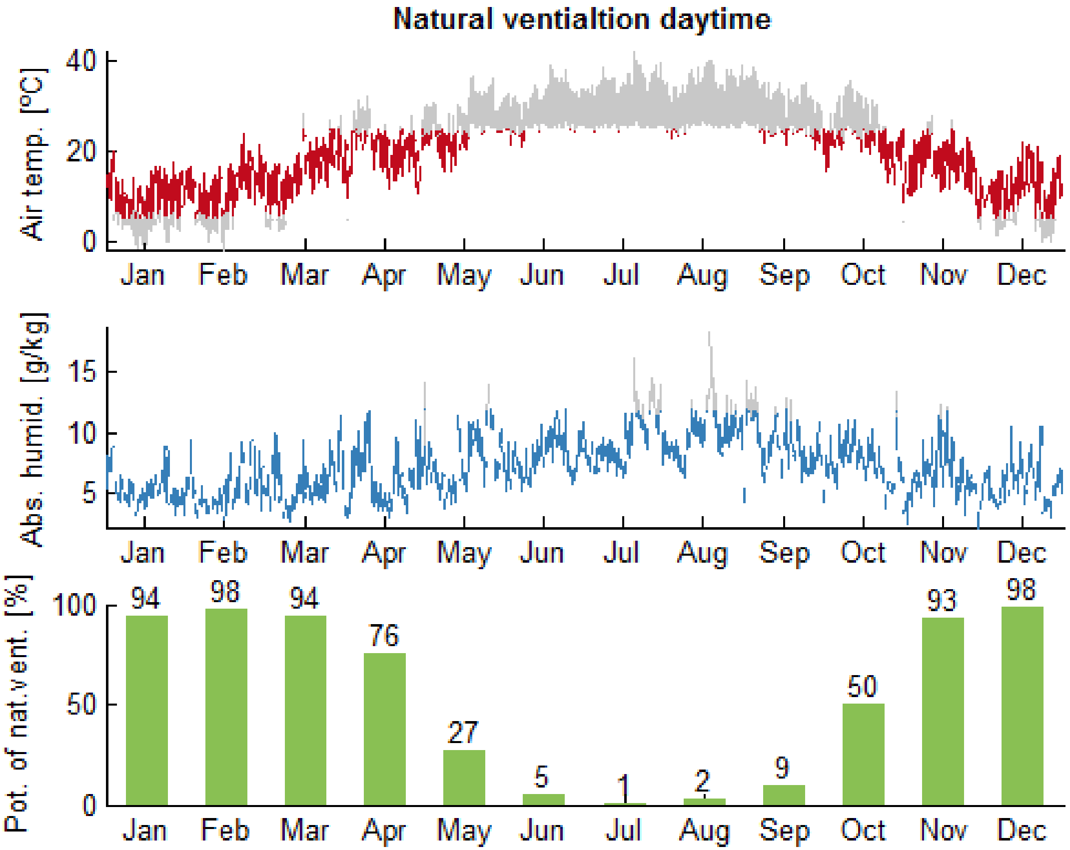
Solar radiation analysis (façade month)



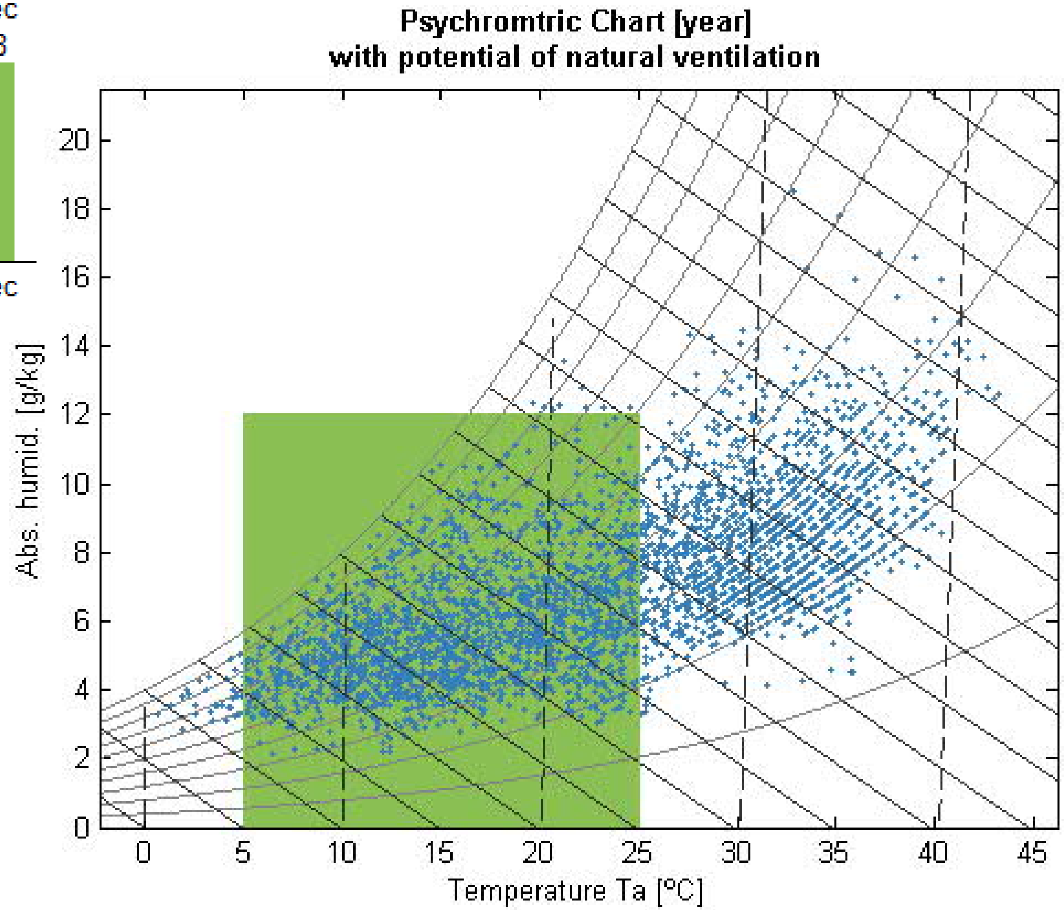
Climate analysis examples

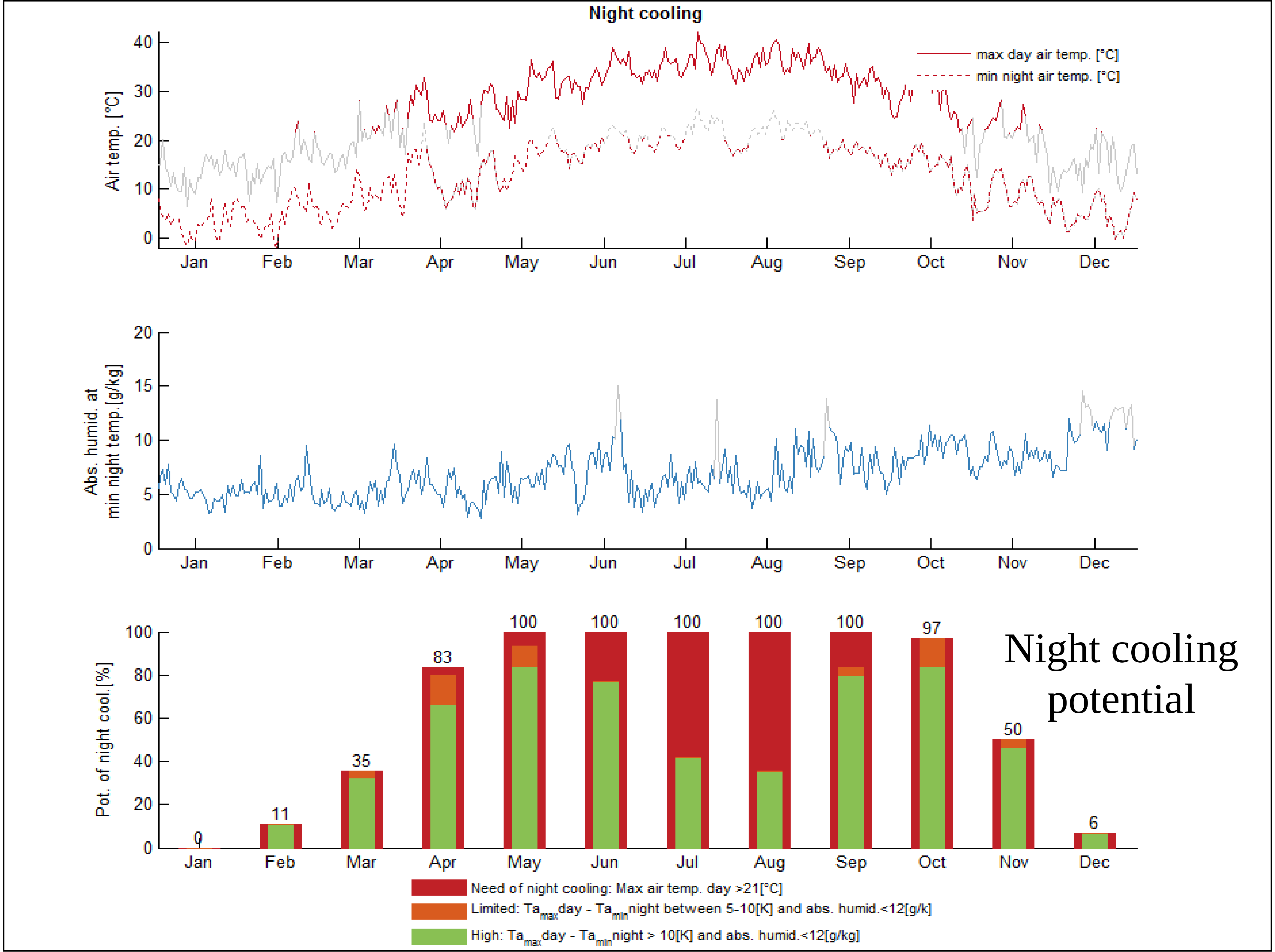
- Climate Tool – potential analysis of:
  - Natural ventilation
  - Night cooling
  - (Surface) cooling system
  - Evaporative cooling
  - Passive solar heating
  - Passive solar cooling


CWTool
_ 41.5 _ 32.5_ altitude: m
start
finish
hours of day
9
18
Course
Psychro
Freq
Solar
Urban
World
Concept
ppt ex.
Import
Help
Potentials of
Natural ventilation
during daytime with
outdoor temperature Ta [°C] and
absolute humidity X [g/kg] between:
min
max
Ta 5 25
X 0 12
Natural vent.
Night cooling
for days with maximum outdoor
air temperature Ta [°C] higher than:
Ta> 21
Night cool.
Cooling system [24h]
with following surface
temperature T=[°C] fordays
with air temperature Ta>[°C]
T= 16
Ta> 21
Surface cool.
Evaporative cooling [24h]
to achieve the following
air temperature [°C]:
T= 21
Evaporative cool.
Passive solar heating
for days maean
air temperature < [°C]:
global rad. south/north >[kWh/d]
Ta< 12
G > 1
Solar heating
Passive solar cooling
for days mean
air temperature > [°C]:
global rad. horizontal >[kWh/d]
Ta> 18
Gh> 1
Solar cooling

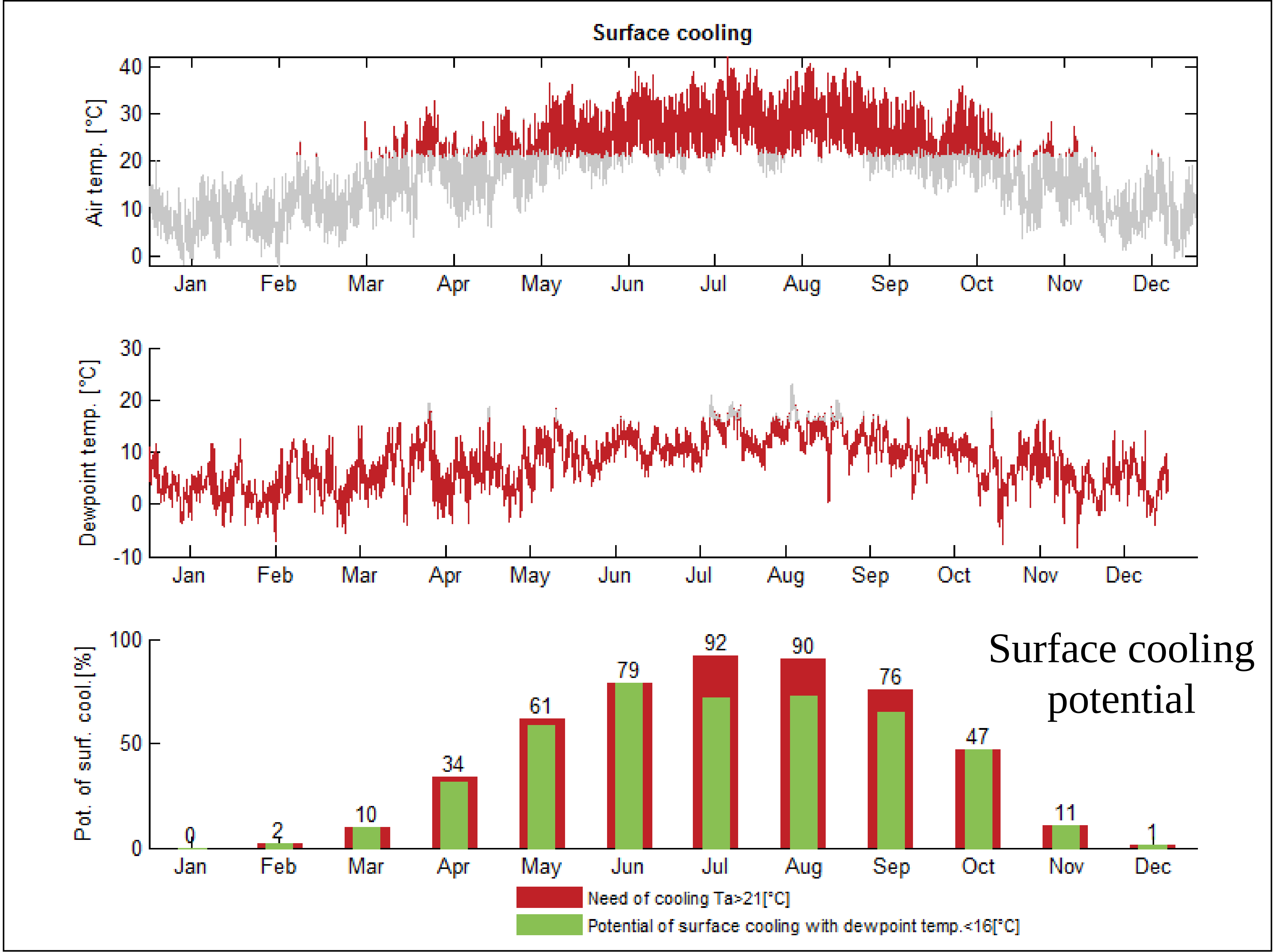


Analysis of natural ventilation potential

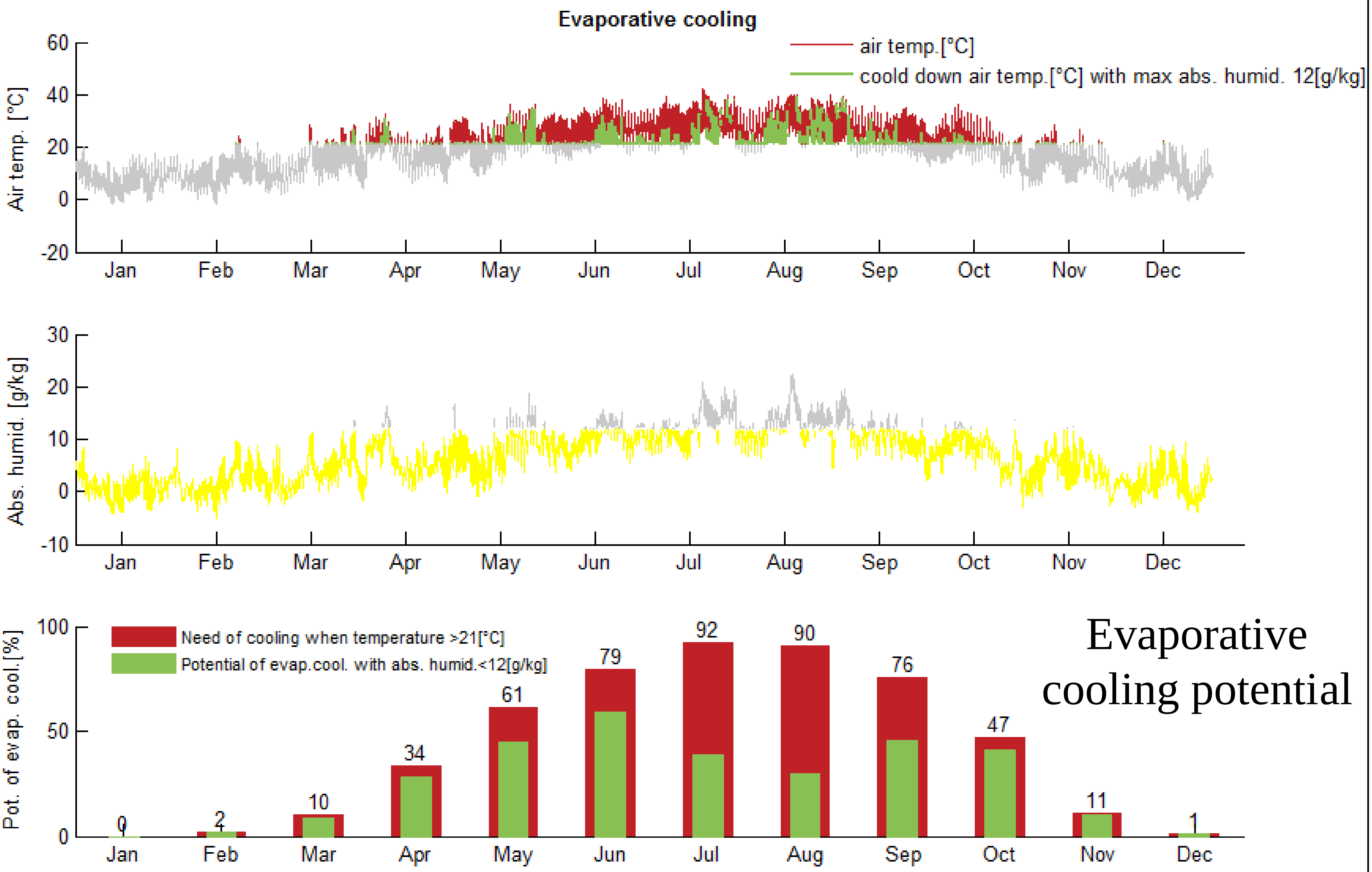


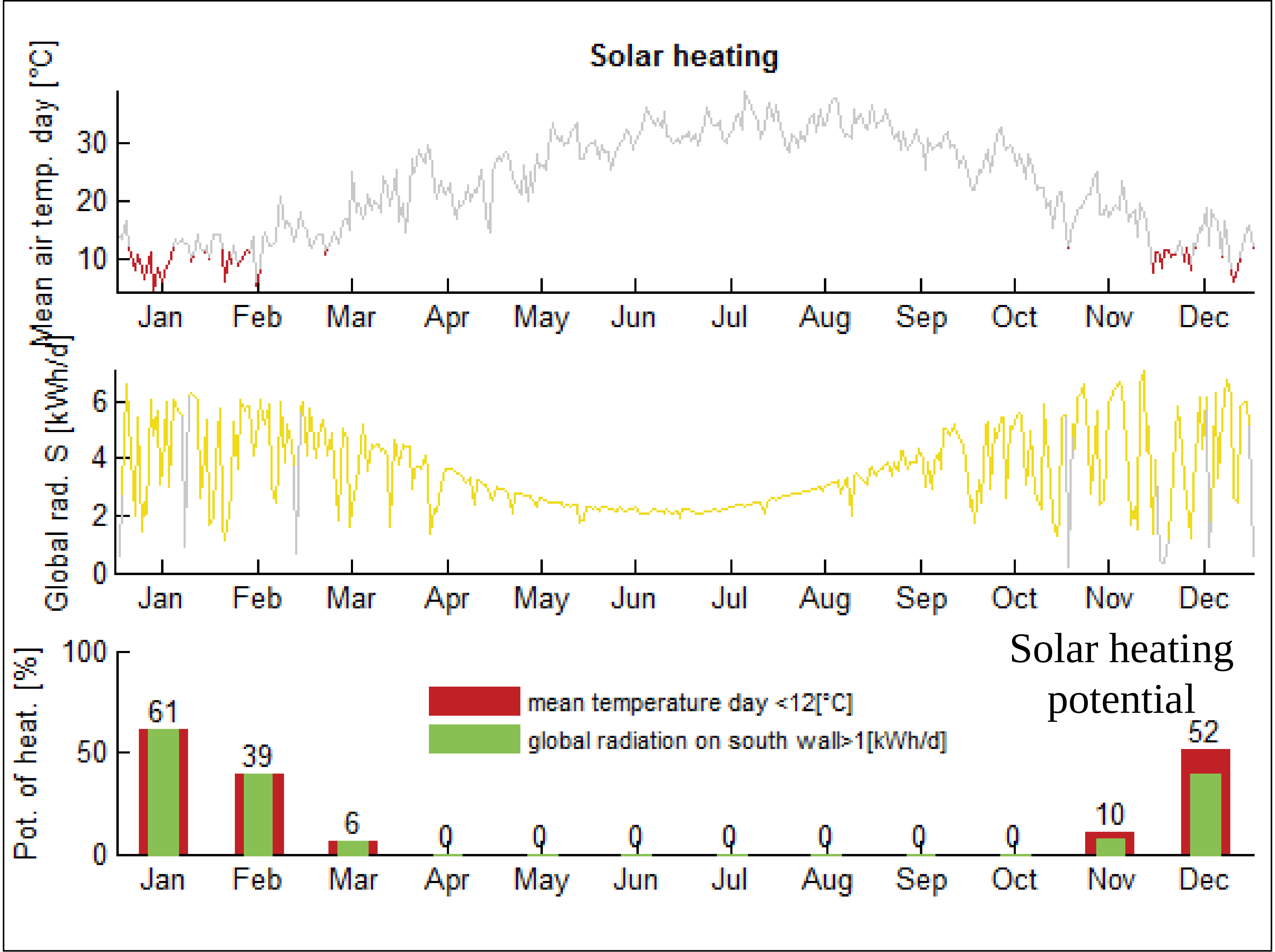


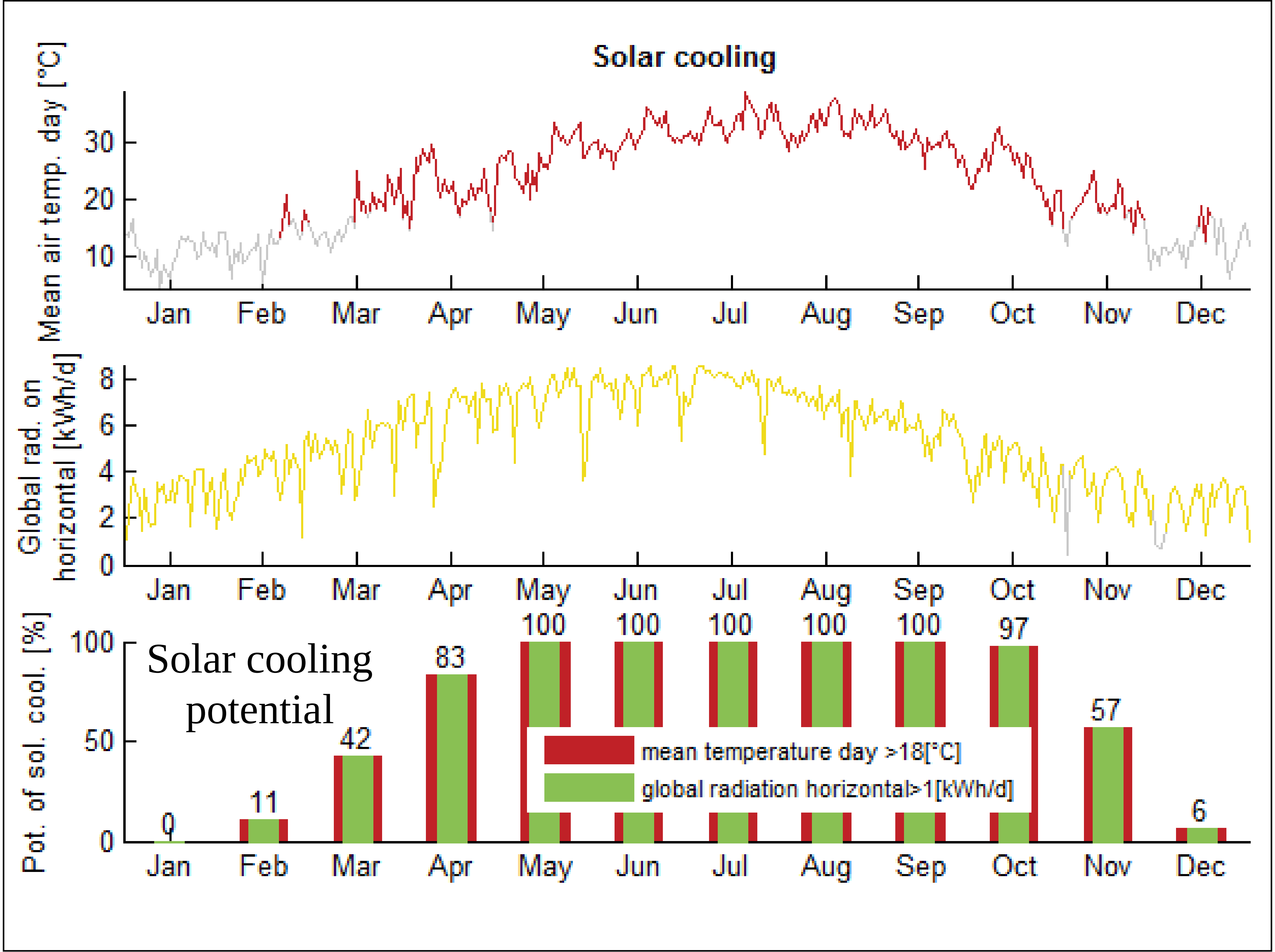
Night cooling potential


Surface cooling
Air temp. [°C]
Dewpoint temp. [°C]
Pot. of surf. cool.[%]
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
0 2 10 34 61 79 92 90 76 47 11 1
Surface cooling potential
Need of cooling Ta>21[°C]
Potential of surface cooling with dewpoint temp.<16[°C]

Evaporative cooling potential




Solar heating
Mean air temp. day [°C]
30
20
10
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Global rad. S [kWh/d]
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Solar heating potential
Pot. of heat. [%]
100
50
0
mean temperature day <12[°C]
global radiation on south wall>1[kWh/d]
61
39
6
0
0
0
0
0
0
0
10
52
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

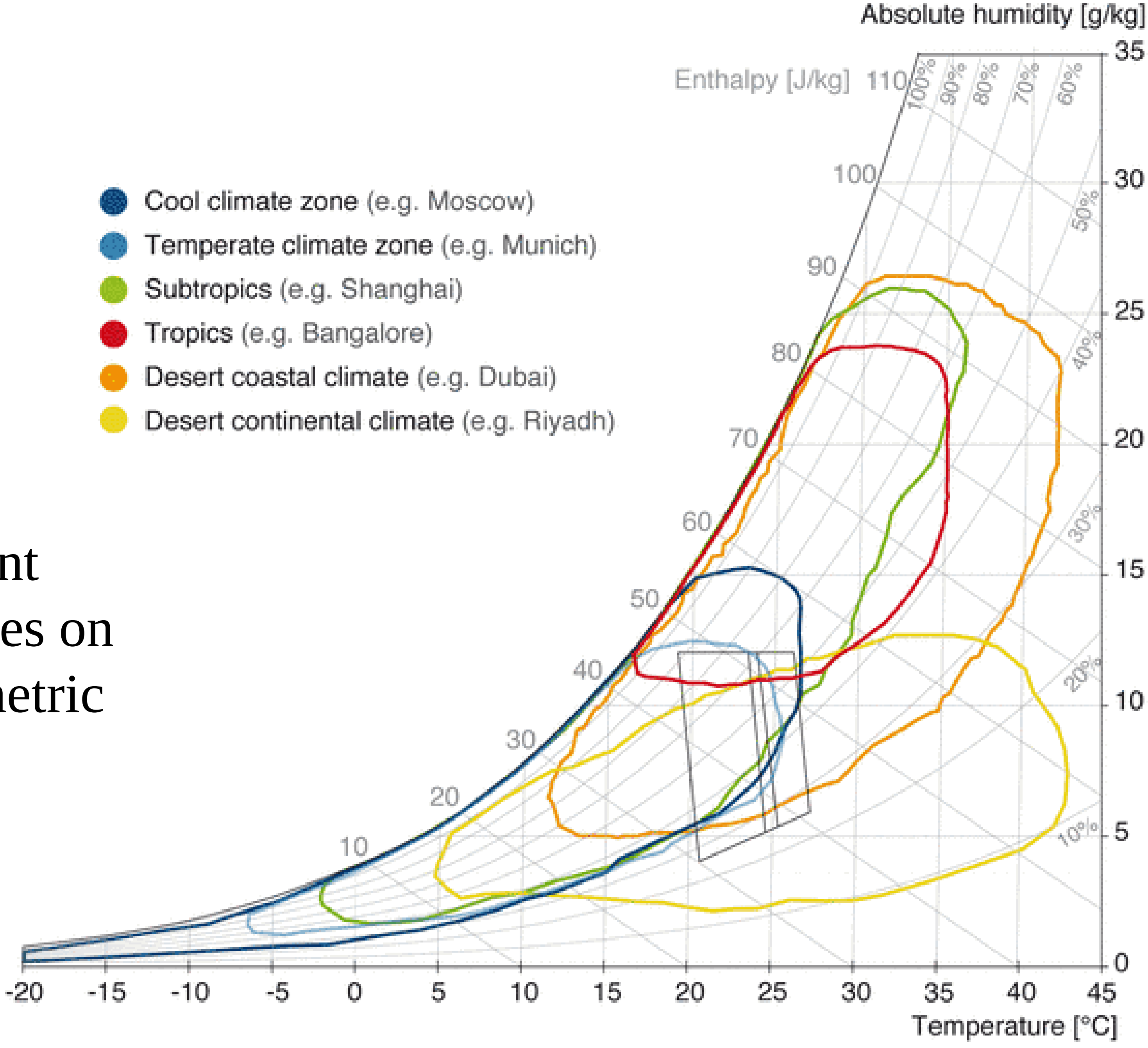


Solar cooling
Mean air temp. day [°C]
30
20
10
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Global rad. on horizontal [kWh/d]
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Pot. of sol. cool. [%]
100
50
0
Solar cooling potential
0
11
42
83
100
100
100
100
100
97
57
6
mean temperature day >18[°C]
global radiation horizontal>1[kWh/d]
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Climate analysis

- Climate Classification
  - Climate zones according to temperature and rainfall may not allow clear conclusions regarding room conditioning measures
  - Common climate diagrams cannot show all the climate differences
  - Climate data evaluation of outdoor temperatures and absolute humidity is needed for studying building climatology

Represent climate zones on a psychrometric chart



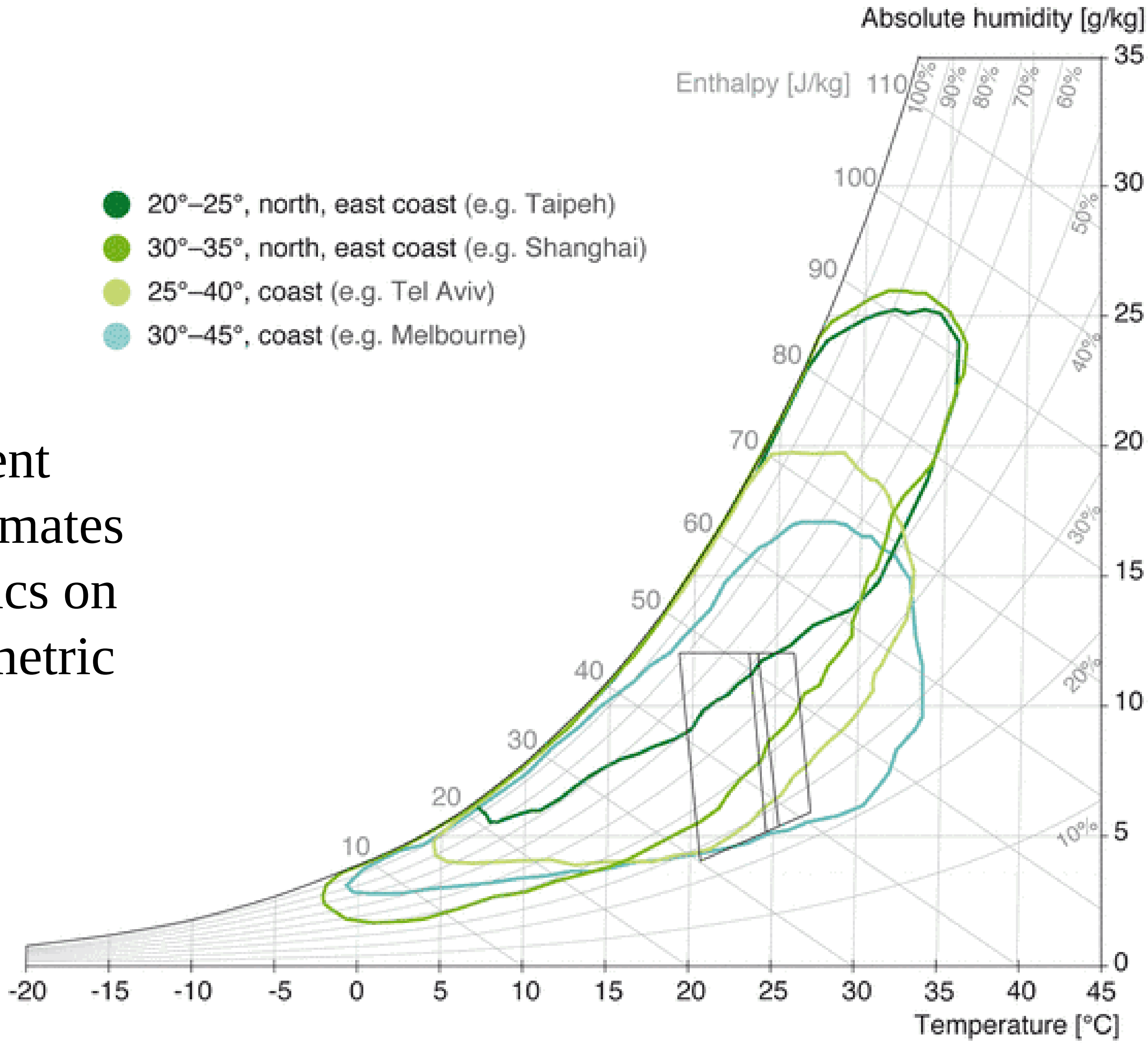
Representatives of climate zones acc. to building specific climate classification

Evaluation: ClimateTool, database: Meteonorm

Liedl, 2011

www.climate-tool.com

Represent specific climates of subtropics on a psychrometric chart

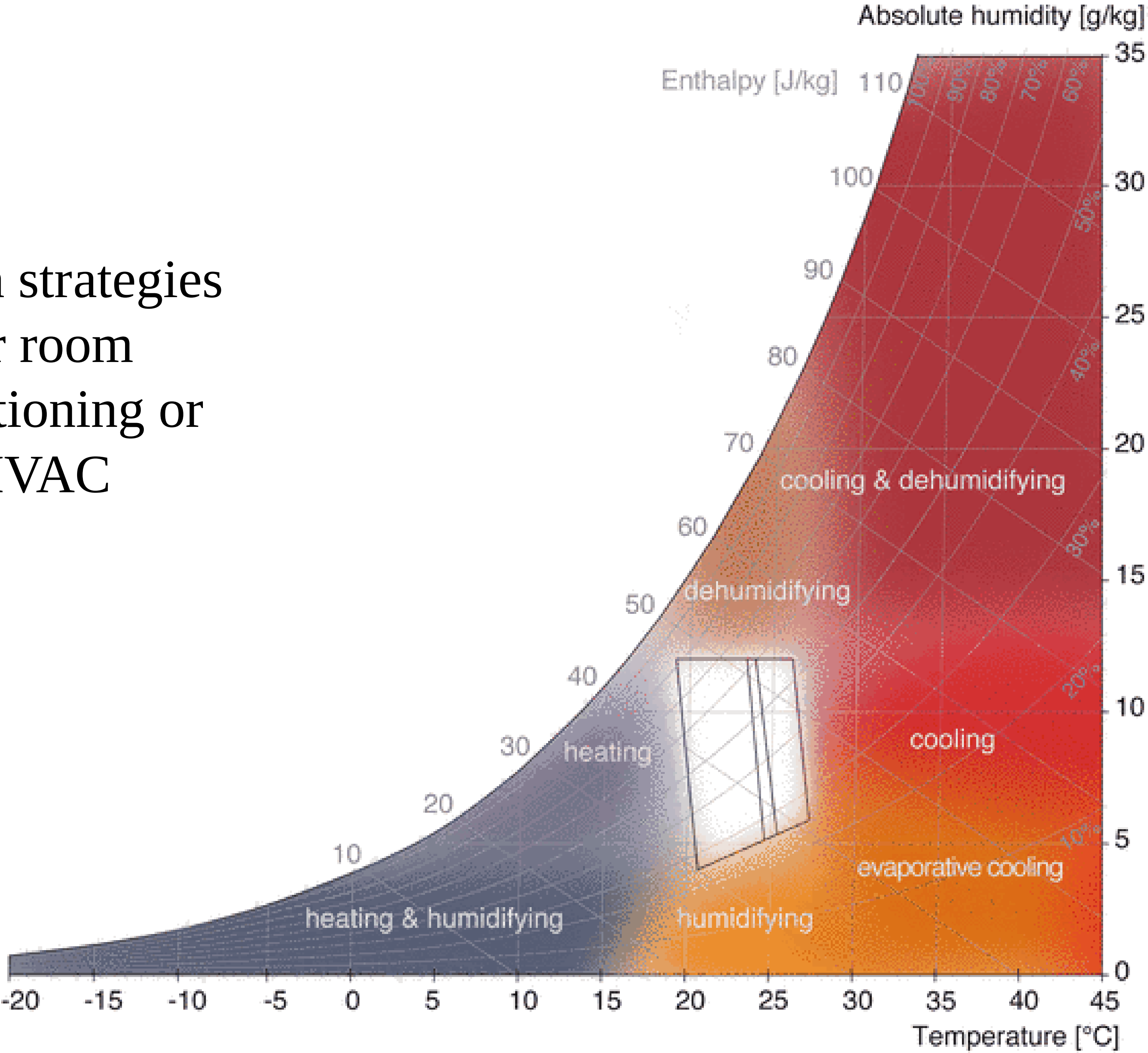


Representatives of Subtropics according to building spefic climate classification

Evaluation: ClimateTool, database: Meteonorm

Liedl, 2011
www.climate-tool.com

Design strategies for room conditioning or HVAC

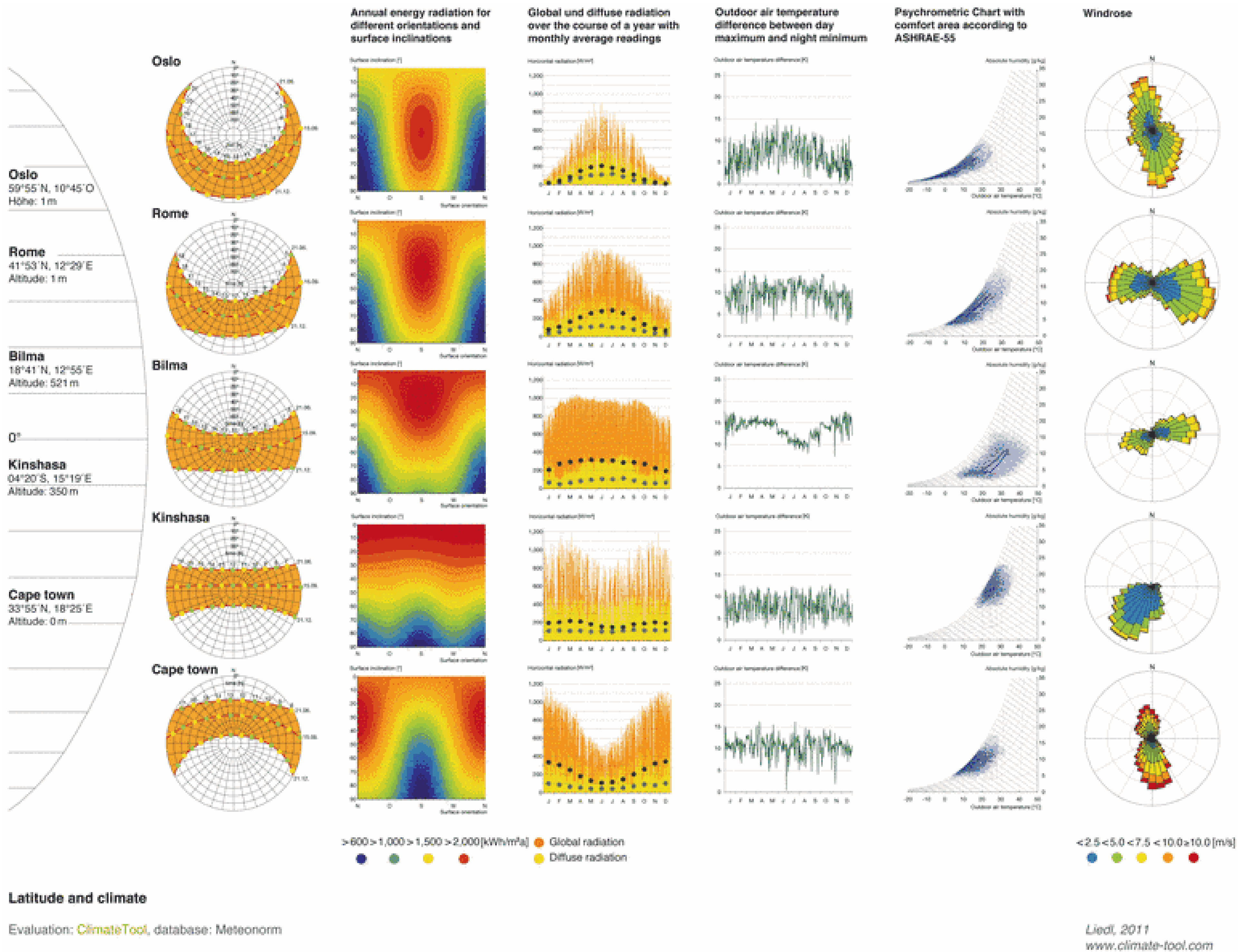


Room conditioning according to the outdoor climate shown in psychometric chart (cf. Olgay, 1963)

Liedl, 2011

www.climate-tool.com

Climate and latitude

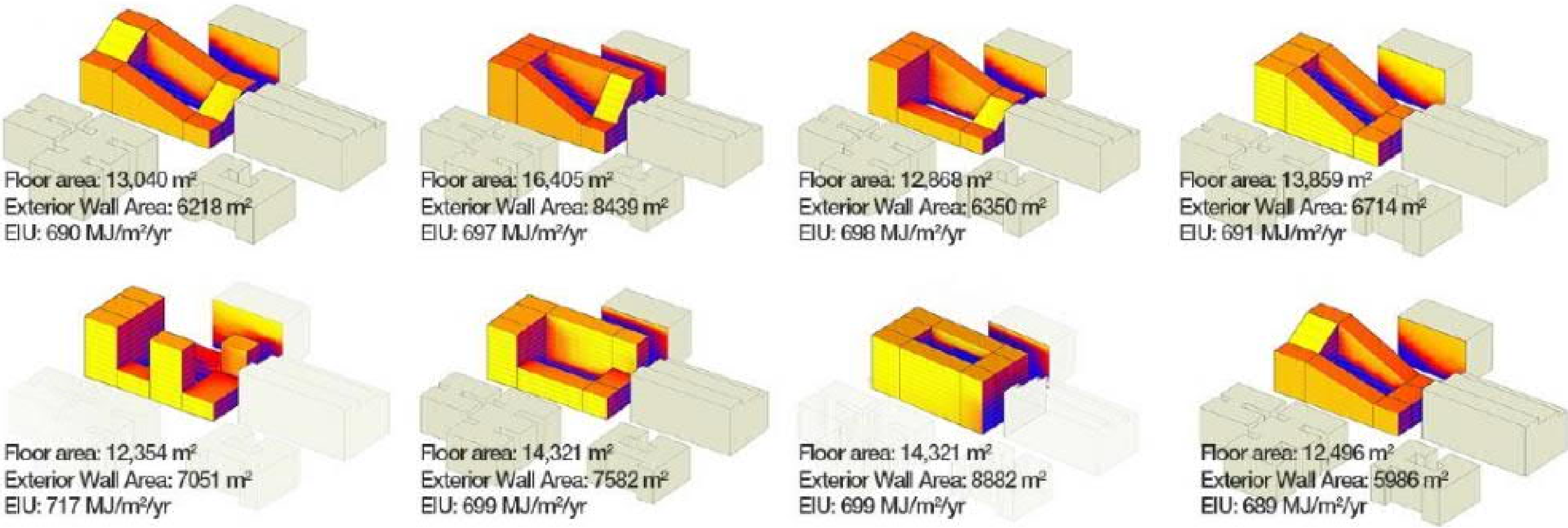


Building design examples

- Building Design Examples (1)
  - http://sustainabilityworkshop.autodesk.com/building-design/examples
  - Hunts Point Revival: Example of Climate Analysis and Adaptive Re-Use
    - http://sustainabilityworkshop.autodesk.com/project-gallery/hunts-point-revival-example-climate-analysis-and-adaptive-re-use

Autodesk Vasari

COURTYARD STUDY

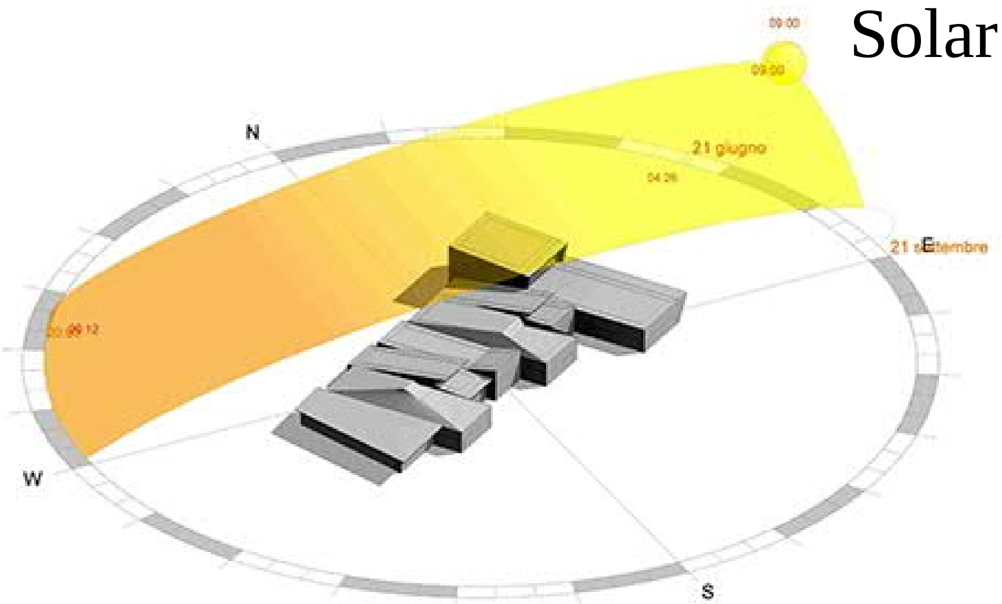


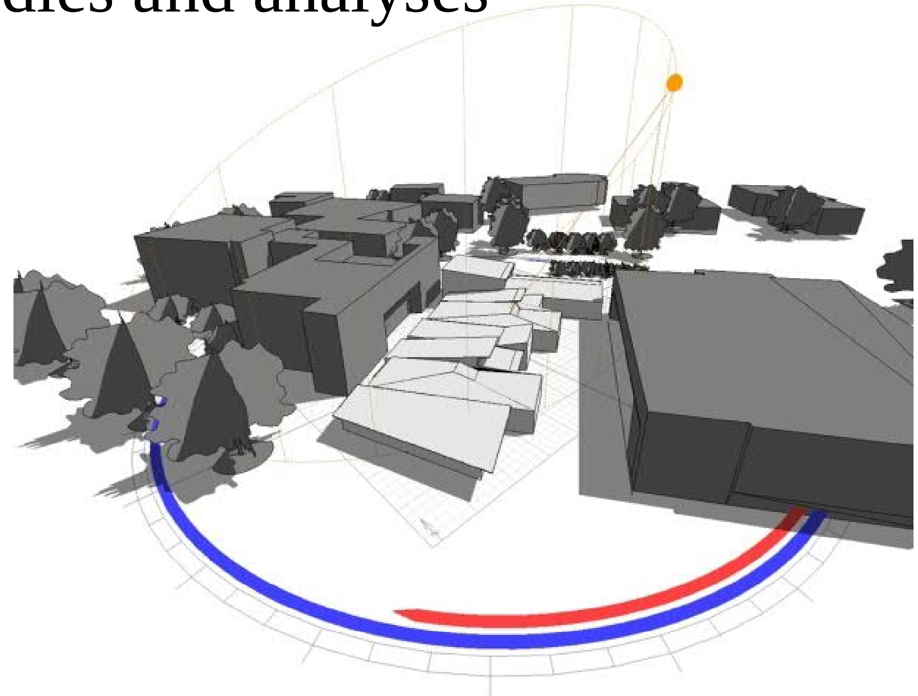
(Source: Autodesk)

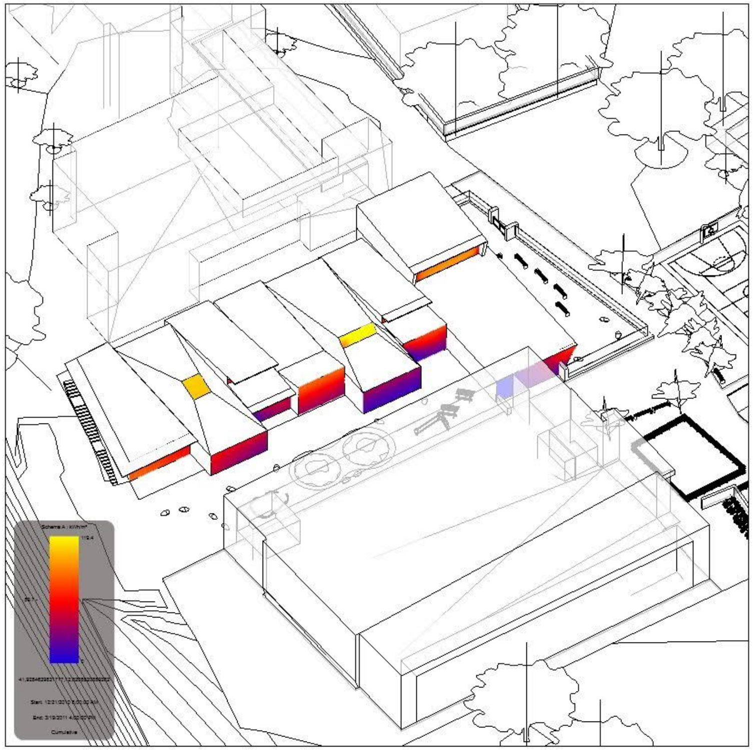
Building design examples

- Building Design Examples (2)
  - http://sustainabilityworkshop.autodesk.com/building-design/examples
  - Italian Nursery School: Conceptual Design Analysis
    - http://sustainabilityworkshop.autodesk.com/project-gallery/italian-nursery-school-conceptual-design-analysis

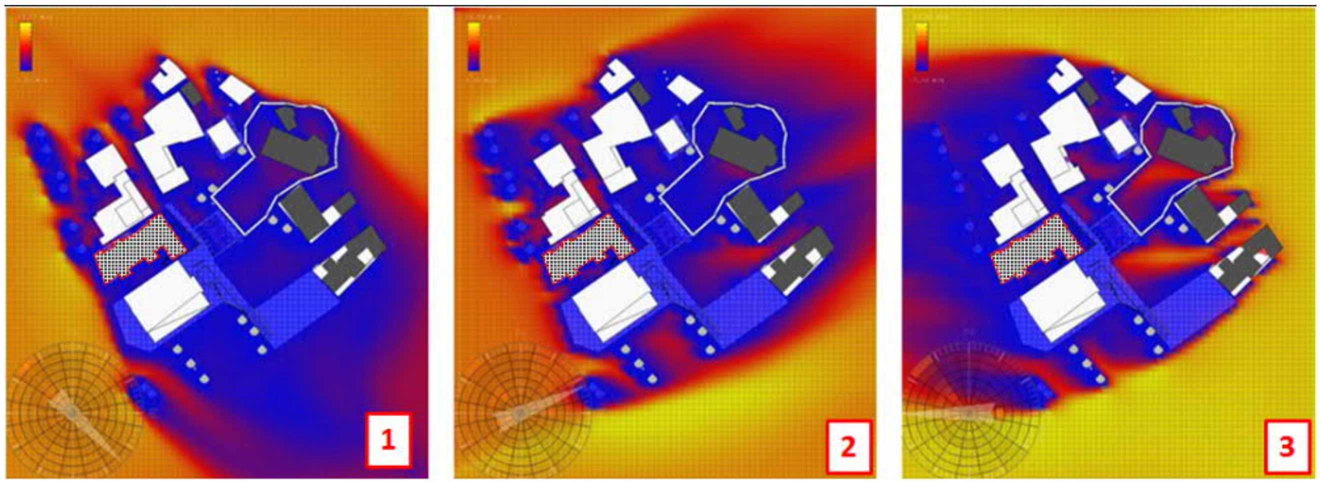
Solar studies and analyses







Solar insolation



Wind tunnel analysis

(Source: Autodesk)