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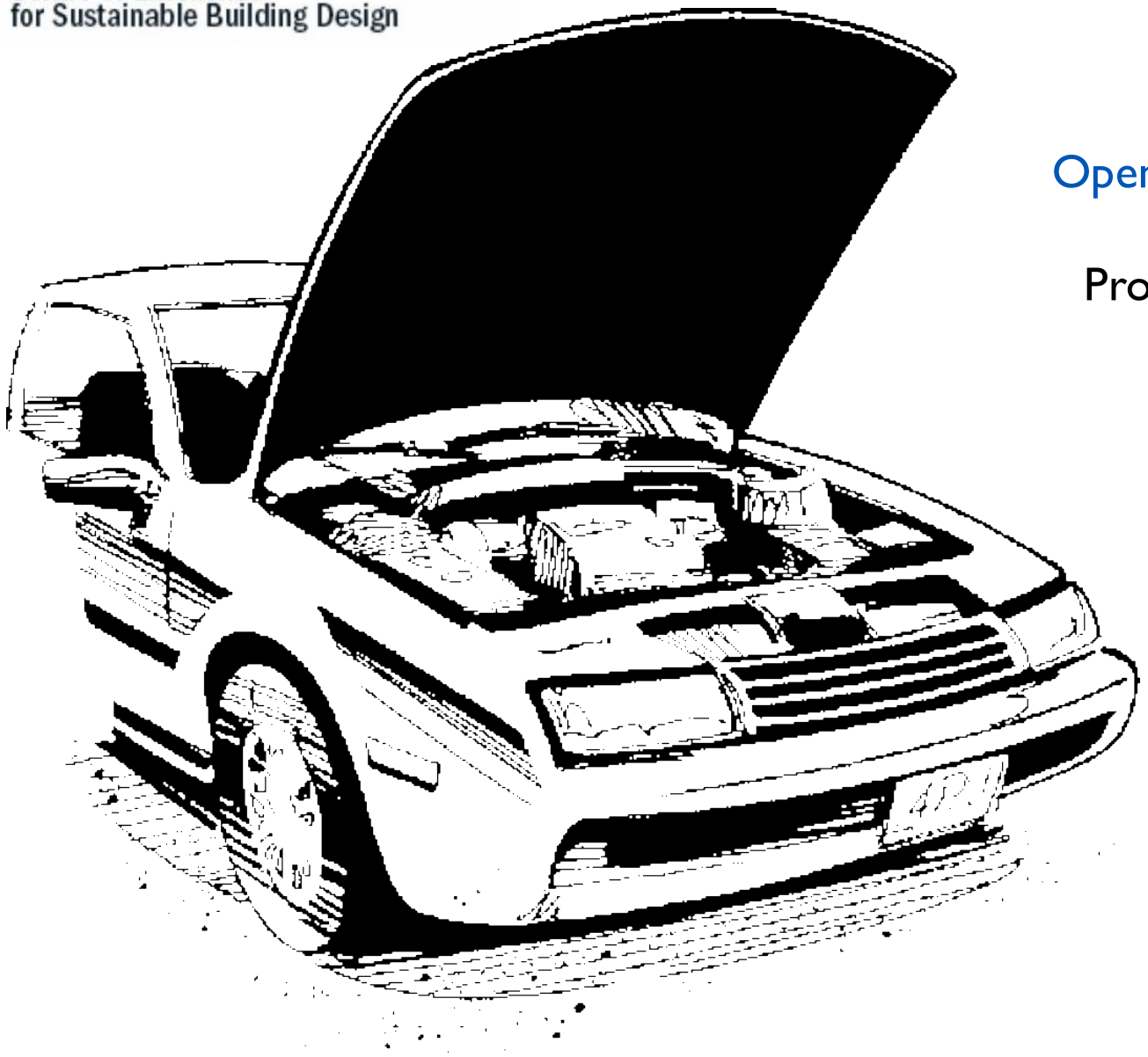
Voted England's Best Student Experience for six years running *Times Higher Education*

ROYAL ACADEMY OF ENGINEERING

Centre of Excellence for Sustainable Building Design

HOARE LEA



Opening the Bonnet

Prof Darren Woolf

Loughborough University

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WYSINWYG – What You See Is NOT What You Get: Looking inside the Pandora's Box

Prof Darren Woolf

WYSIWYG

implies a user interface that allows the user to view something very similar to the end result

What You See – Simulation Outputs

What You Get – Real Performance

WYSIMOLWYG

what you see is more or less what you get - recognizing that most implementations are imperfect

WYSYHYG

what you see you hope you get

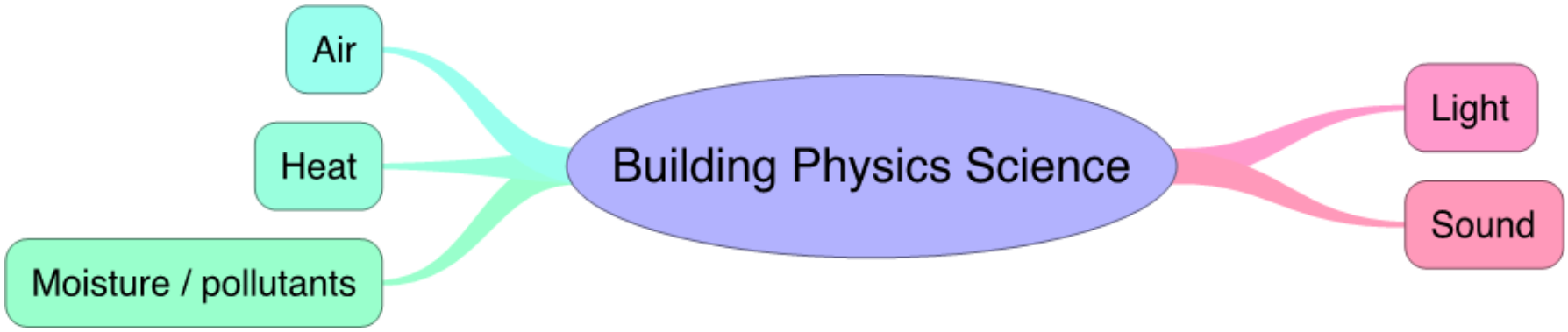
YAFIYGI

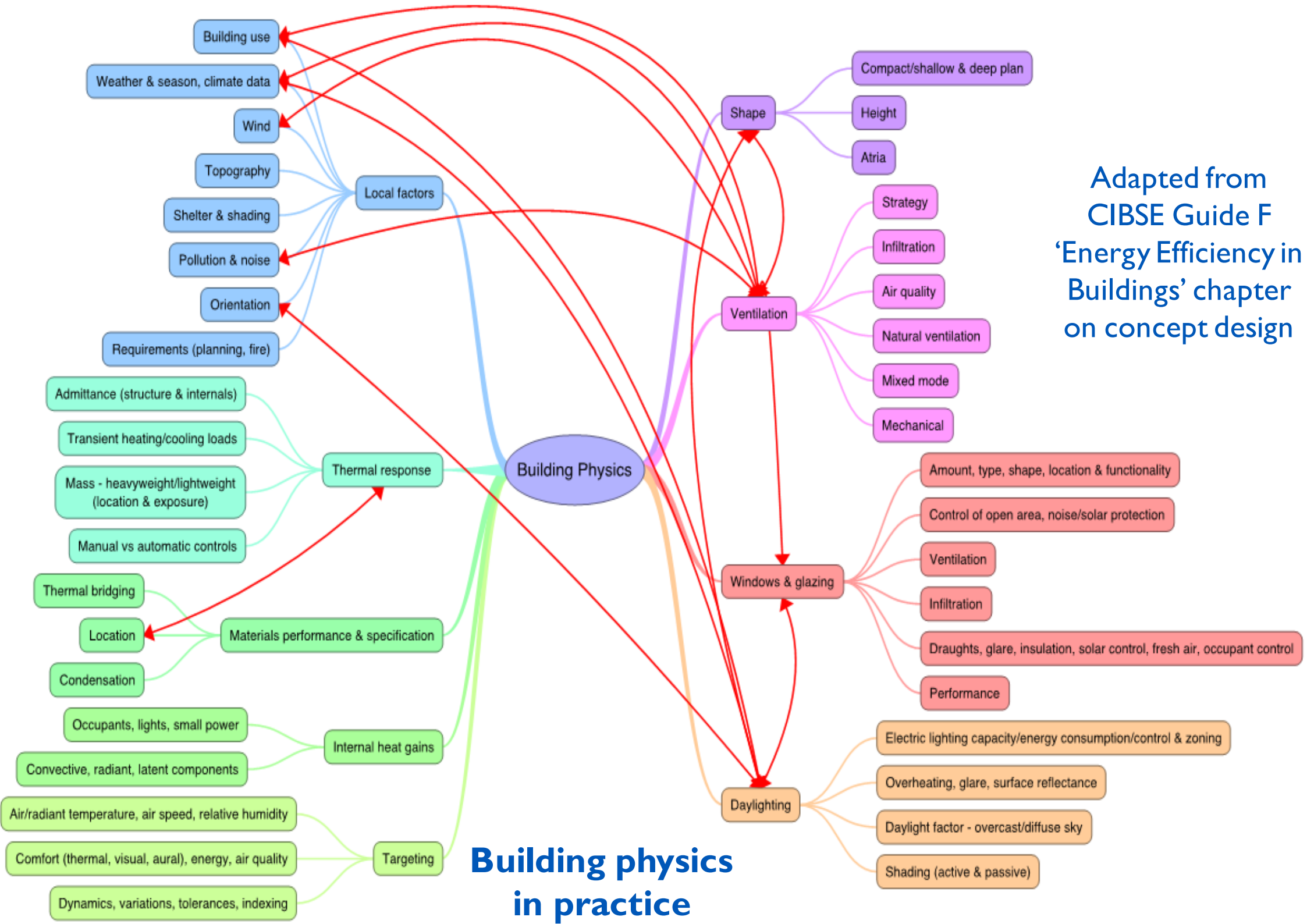
you asked for it you got it

CONTENTS

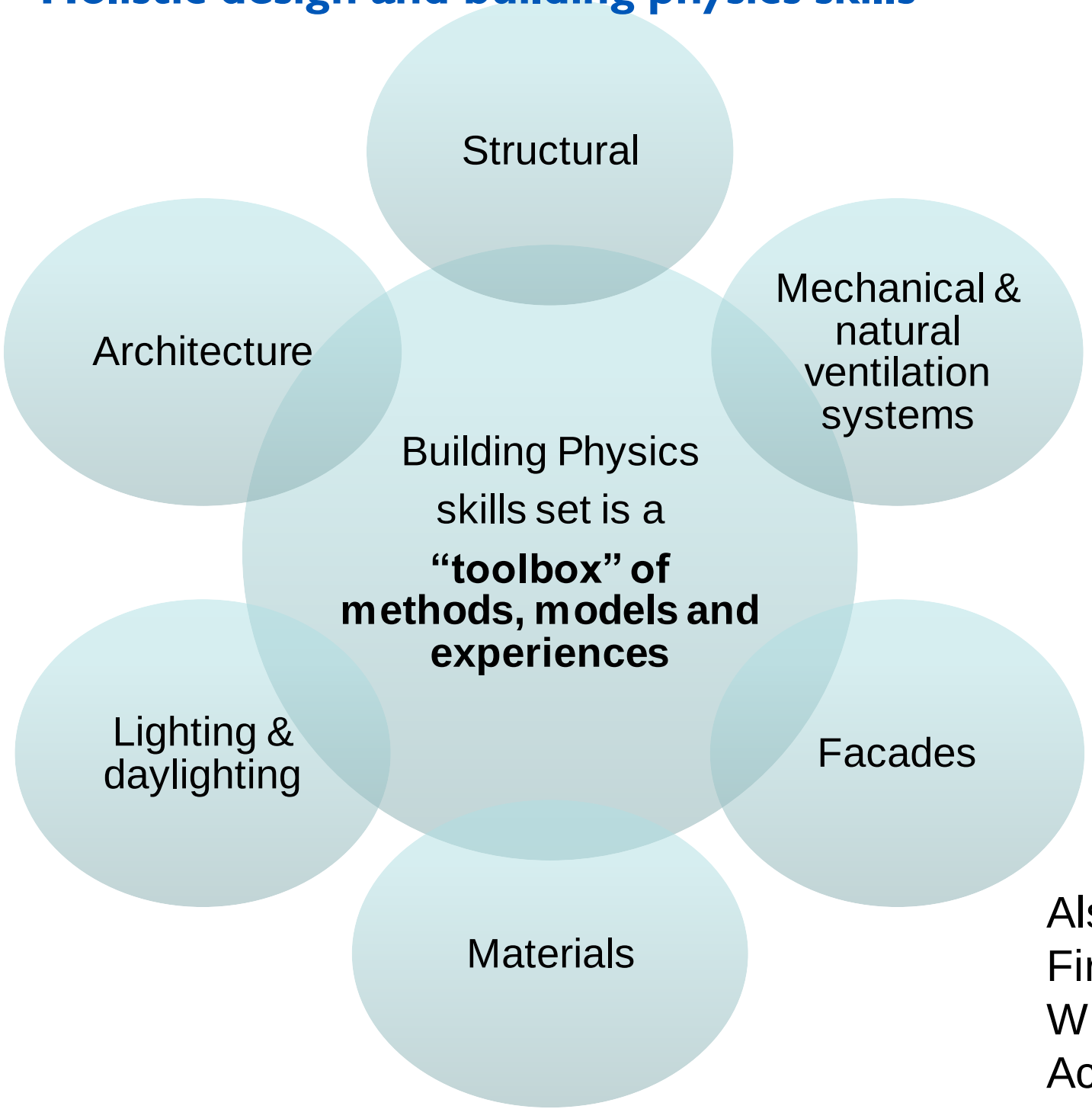
- Width and depth of building simulation studies
- Their impact within and on the design process
- Case studies covering
    - Complexities of building physics within simulation
    - Need for planning, attention to detail, scrutiny
    - Good communication supporting an appropriate message

Building Physics: The engineering sciences




Building use
Weather & season, climate data
Wind
Topography
Shelter & shading
Pollution & noise
Orientation
Requirements (planning, fire)
Local factors
Admittance (structure & internals)
Transient heating/cooling loads
Mass - heavyweight/lightweight (location & exposure)
Manual vs automatic controls
Thermal response
Thermal bridging
Location
Condensation
Materials performance & specification
Occupants, lights, small power
Convective, radiant, latent components
Internal heat gains
Air/radiant temperature, air speed, relative humidity
Comfort (thermal, visual, aural), energy, air quality
Dynamics, variations, tolerances, indexing
Targeting
Building Physics
Shape
Compact/shallow & deep plan
Height
Atria
Ventilation
Strategy
Infiltration
Air quality
Natural ventilation
Mixed mode
Mechanical
Windows & glazing
Amount, type, shape, location & functionality
Control of open area, noise/solar protection
Ventilation
Infiltration
Draughts, glare, insulation, solar control, fresh air, occupant control
Performance
Daylighting
Electric lighting capacity/energy consumption/control & zoning
Overheating, glare, surface reflectance
Daylight factor - overcast/diffuse sky
Shading (active & passive)
Adapted from CIBSE Guide F 'Energy Efficiency in Buildings' chapter on concept design
Building physics in practice

Holistic design and building physics skills



Also:
Fire
Wind
Acoustics

Defining your building simulation services

Performance based design for indoor and outdoor spaces

- Low energy, high comfort levels, high air quality

Environmental modelling

- Dynamic thermal modelling, CFD, daylight

Façade analysis

- Moisture, condensation, thermal bridging, glass performance

Mechanical and natural ventilation systems

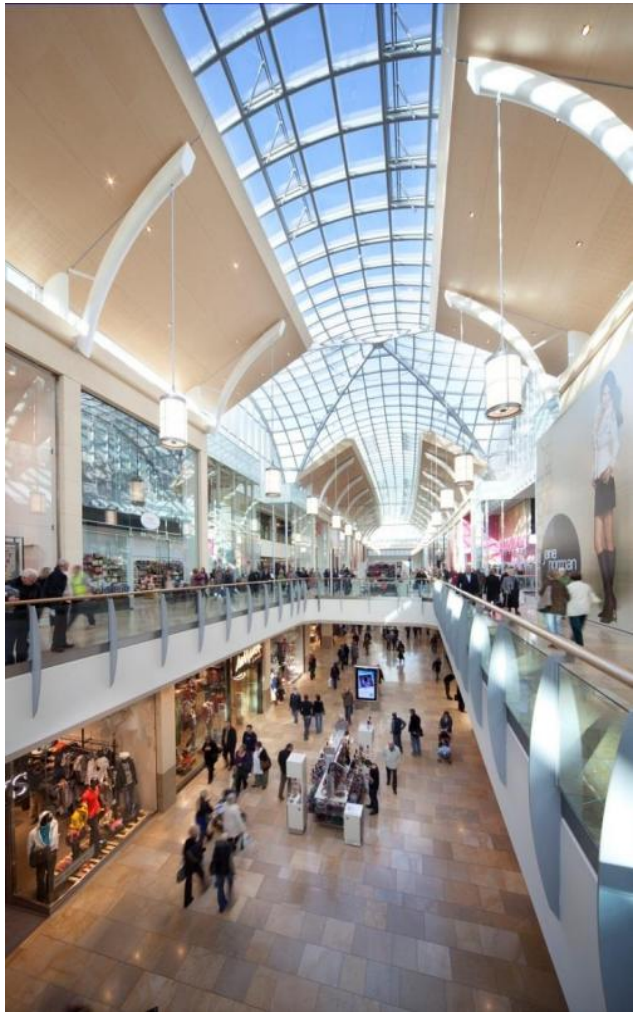
- Supply and extract air conditions / configuration
- Configuration and size of openings

Building envelope performance

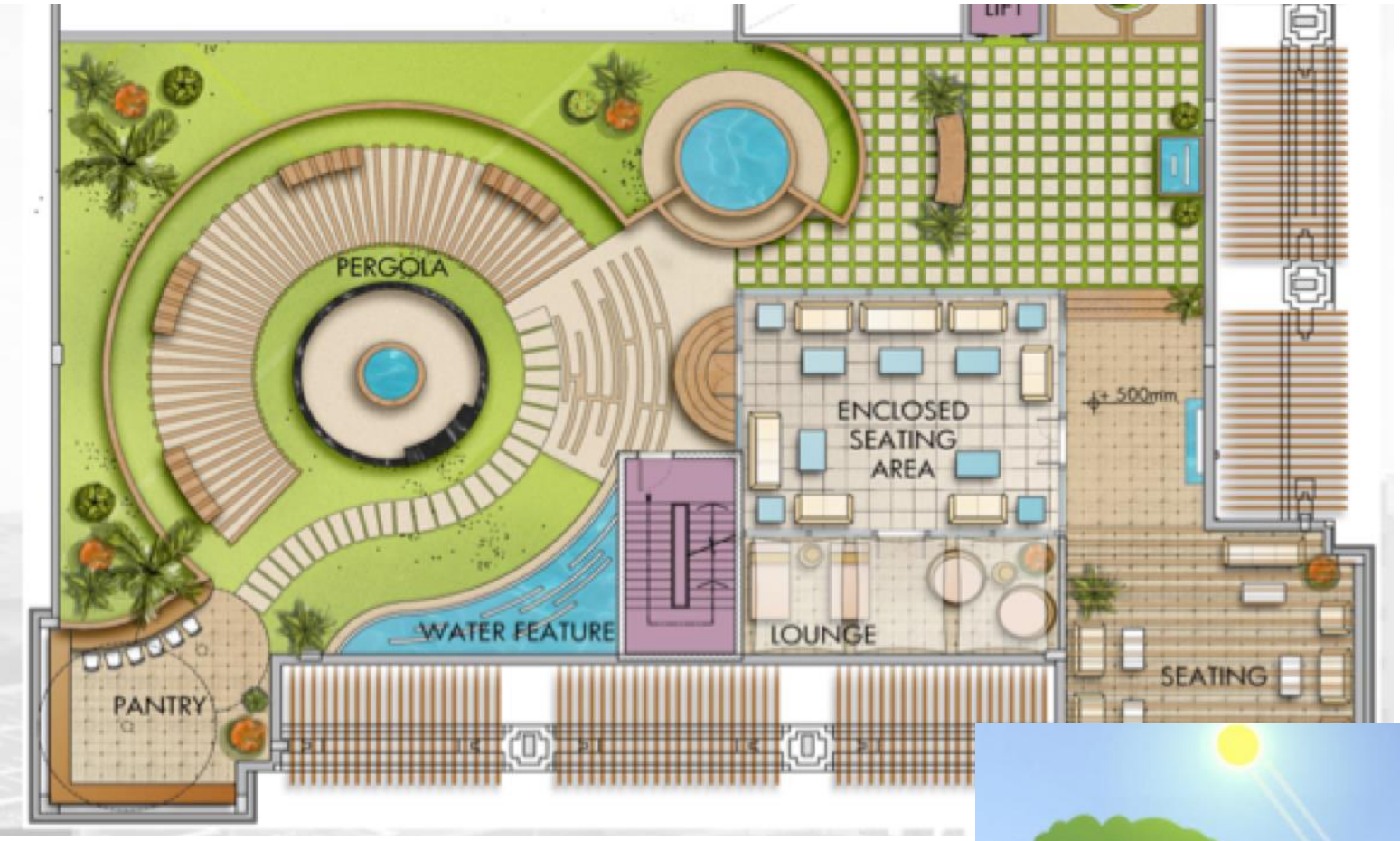
- Down draughts, overheating risk

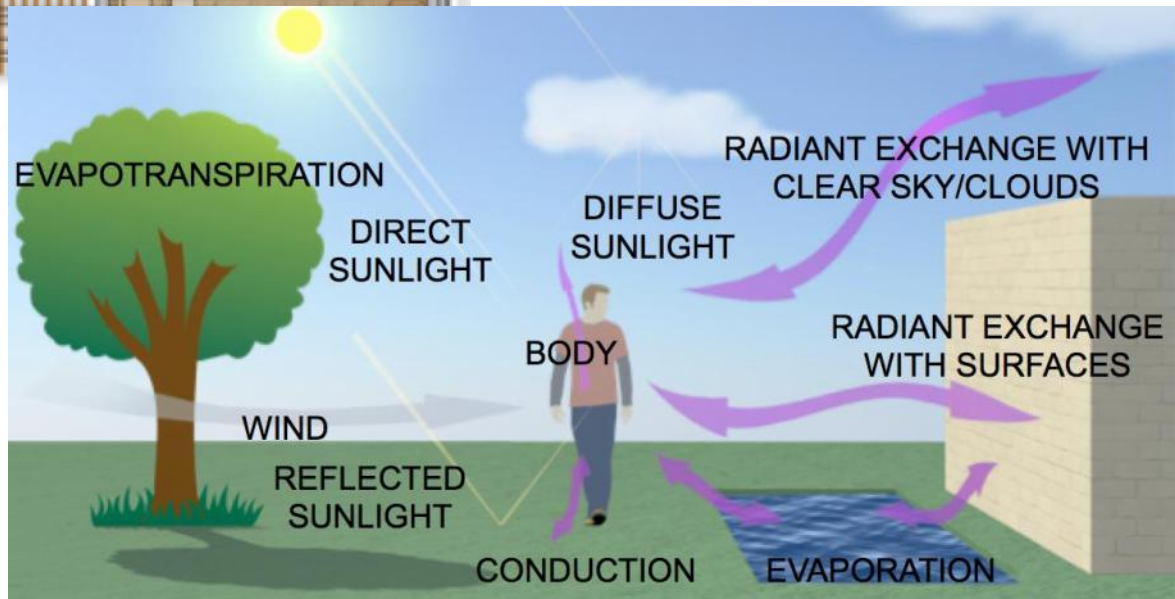
EIA, ES

- Wind, sunlight

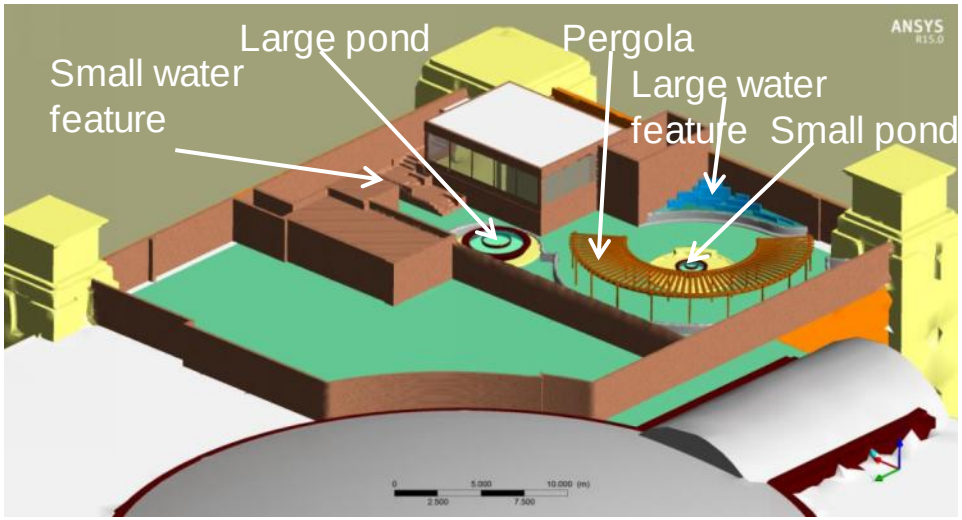


Bounding your model: Defining geometry and physics





Understanding the relationship between environmental variables



Effect of air temperatures on:

- **Thermal comfort**
- **Surface temperatures**

Effect of humidity levels on:

- **Evaporative cooling performance of still ponds and water features**
- **Thermal comfort**

Effect of wind on:

- **Local air movement within the garden – effect of walls and terrace lounge**
- **Air temperatures (mixing)**
- **Evaporative cooling off water surfaces and features**

Effect of the sun on:

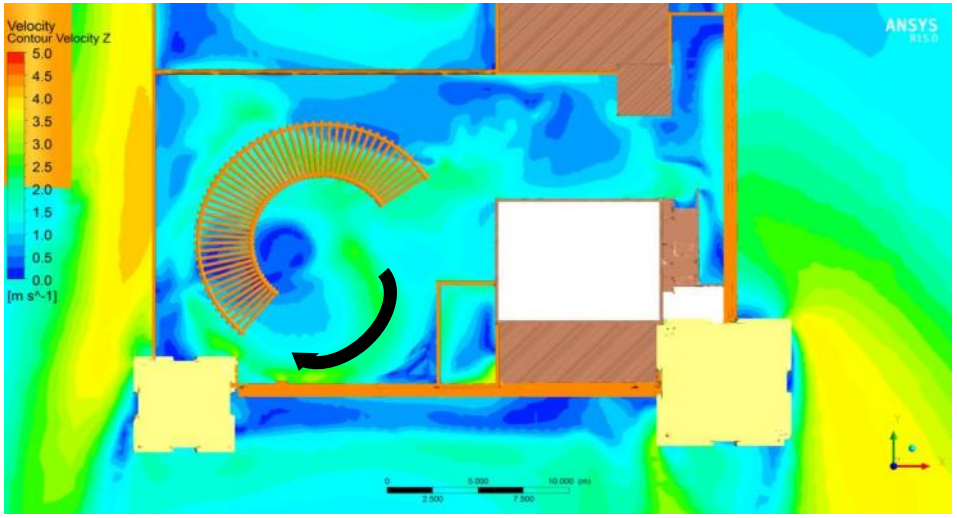
- **Shading performance**
- **Surface temperatures – potential radiant effects of surfaces on thermal comfort**
- **Air temperatures within the roof garden from heated surfaces**

Using indexes to explain / combine your environmental variables, not bury them

March 1pm: 27°C dry bulb, 51% RH, NW wind

Air temperatures

Air velocities



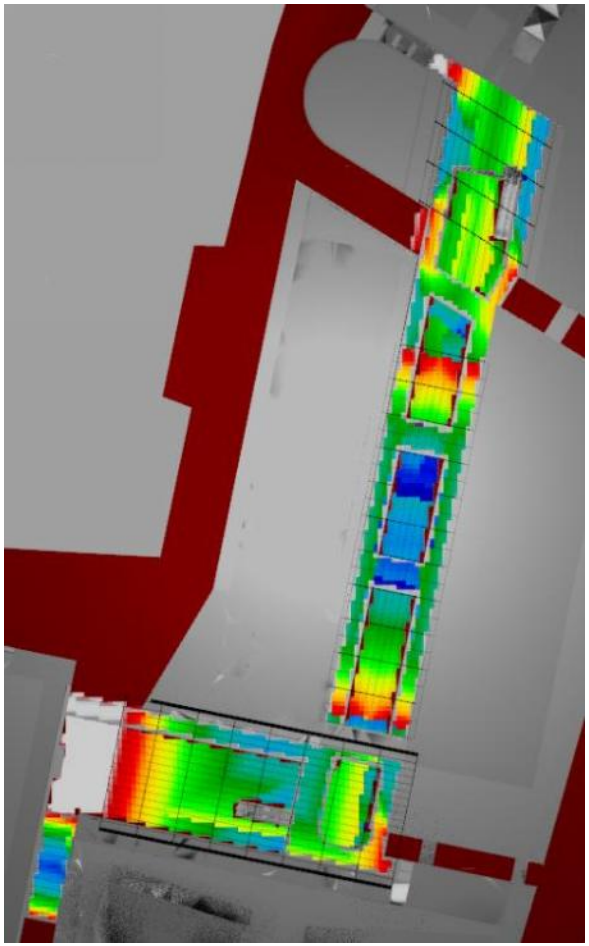
Sense of thermal comfort:

- Very hot:
- Hot:
- Warm:
- Slightly Warm:
- Neutral:
- Slightly Cool:

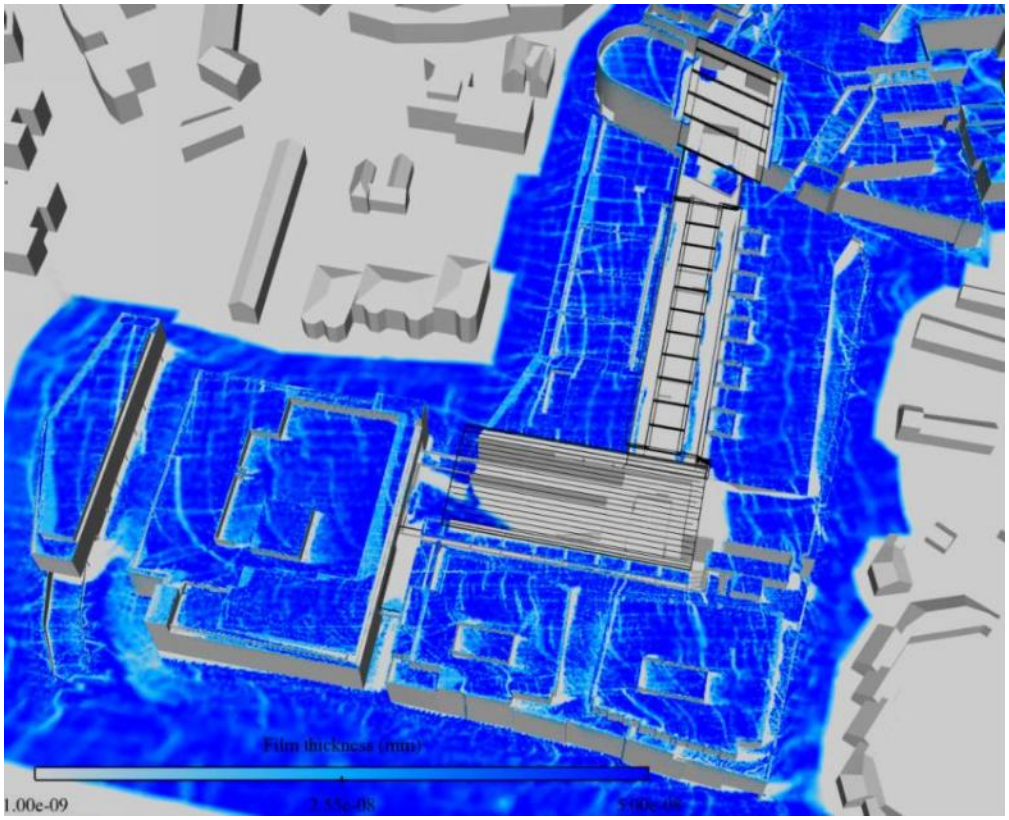
Index limits?

Increasing complexity through the design stages

Simple geometric model (Concept)
Light–ray tracing (Radiance)



Advanced droplet model (Scheme)
CFD



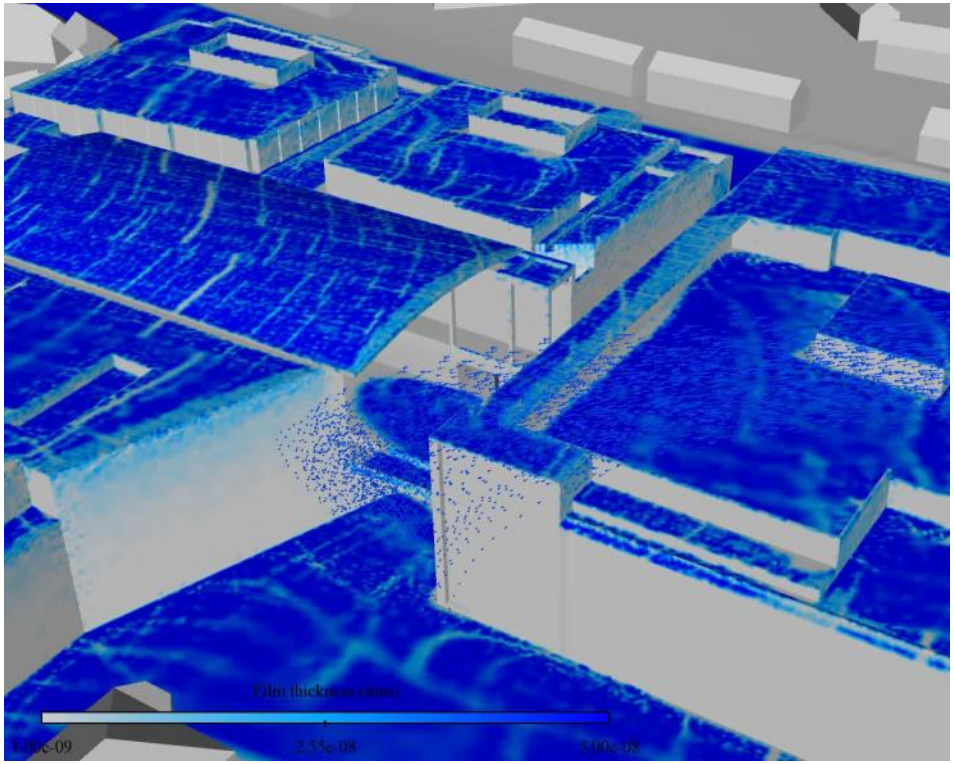
Understanding risk

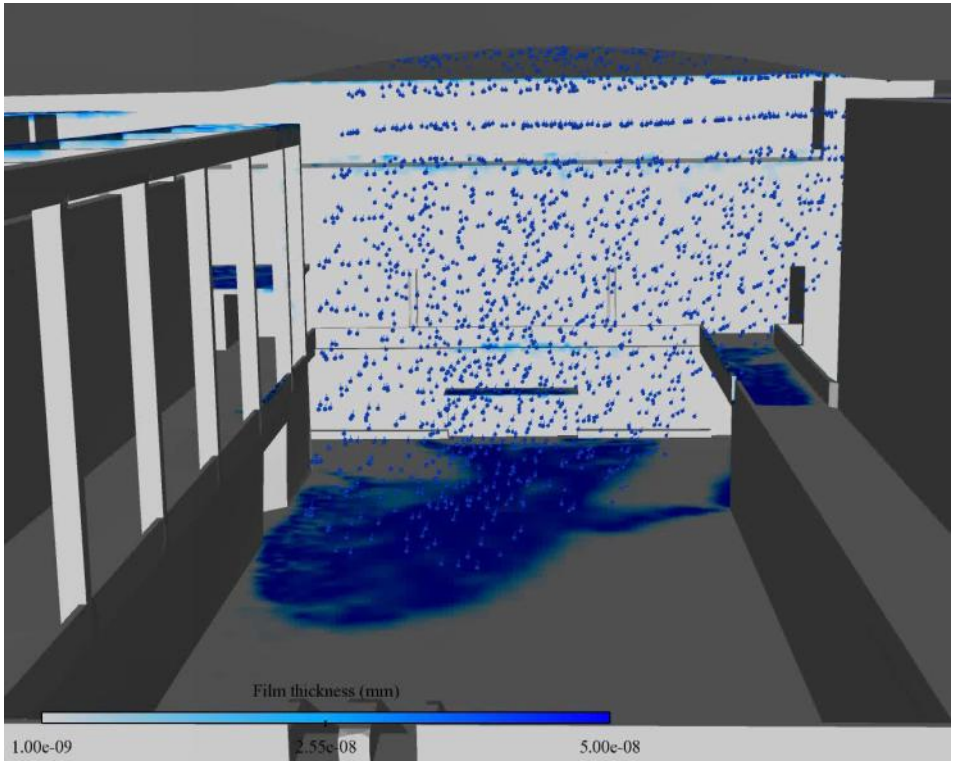
Advanced droplet model

CFD using a droplet model representing light, medium and heavy rain

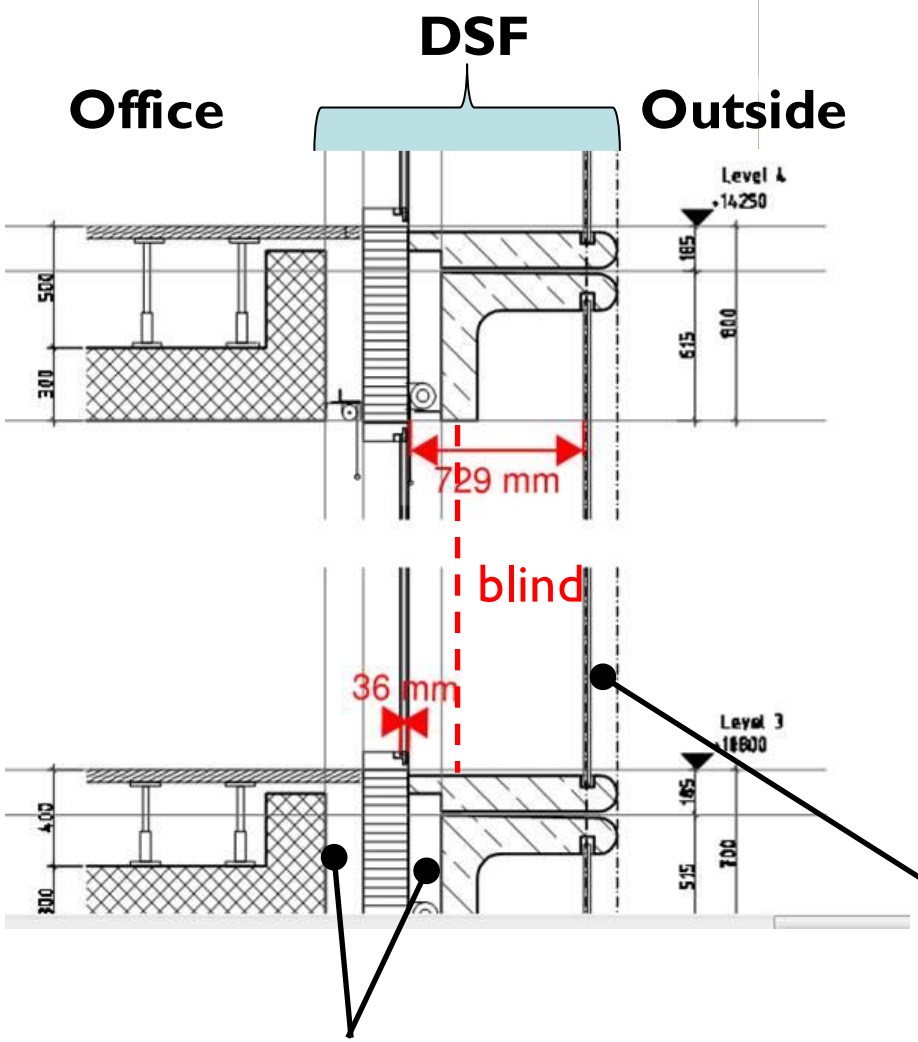
Capture of local wind and surface film effects including secondary transport

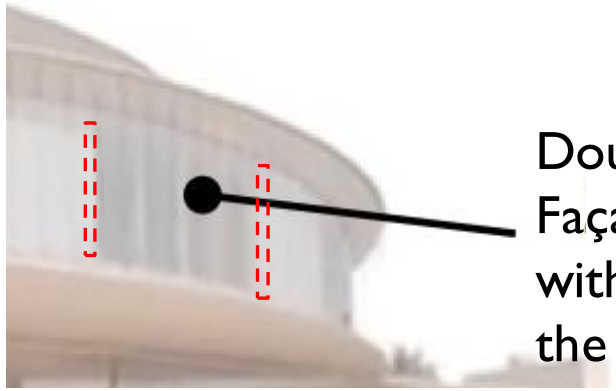
Improved roof canopy design (integrating performance analysis into design cycle)



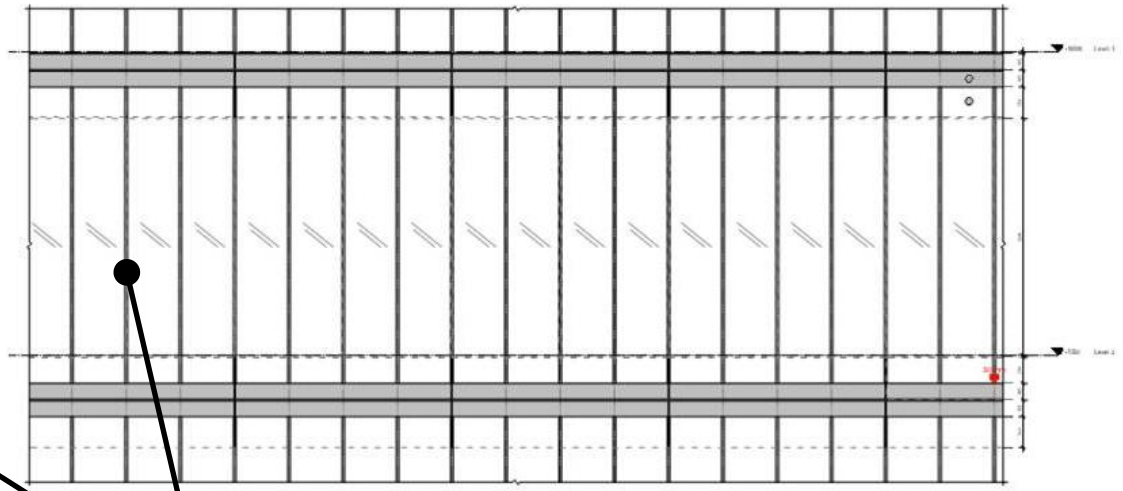


Complex facades





Double Skin Façade (DSF) with vents to the side



Double Glazed Unit (DGU) with air vents to each side (between DSF and office)

Single Glazed Unit (SGU) with 30mm vertical gaps (apertures between DSF and outside)

Using gut feeling / experienced judgements

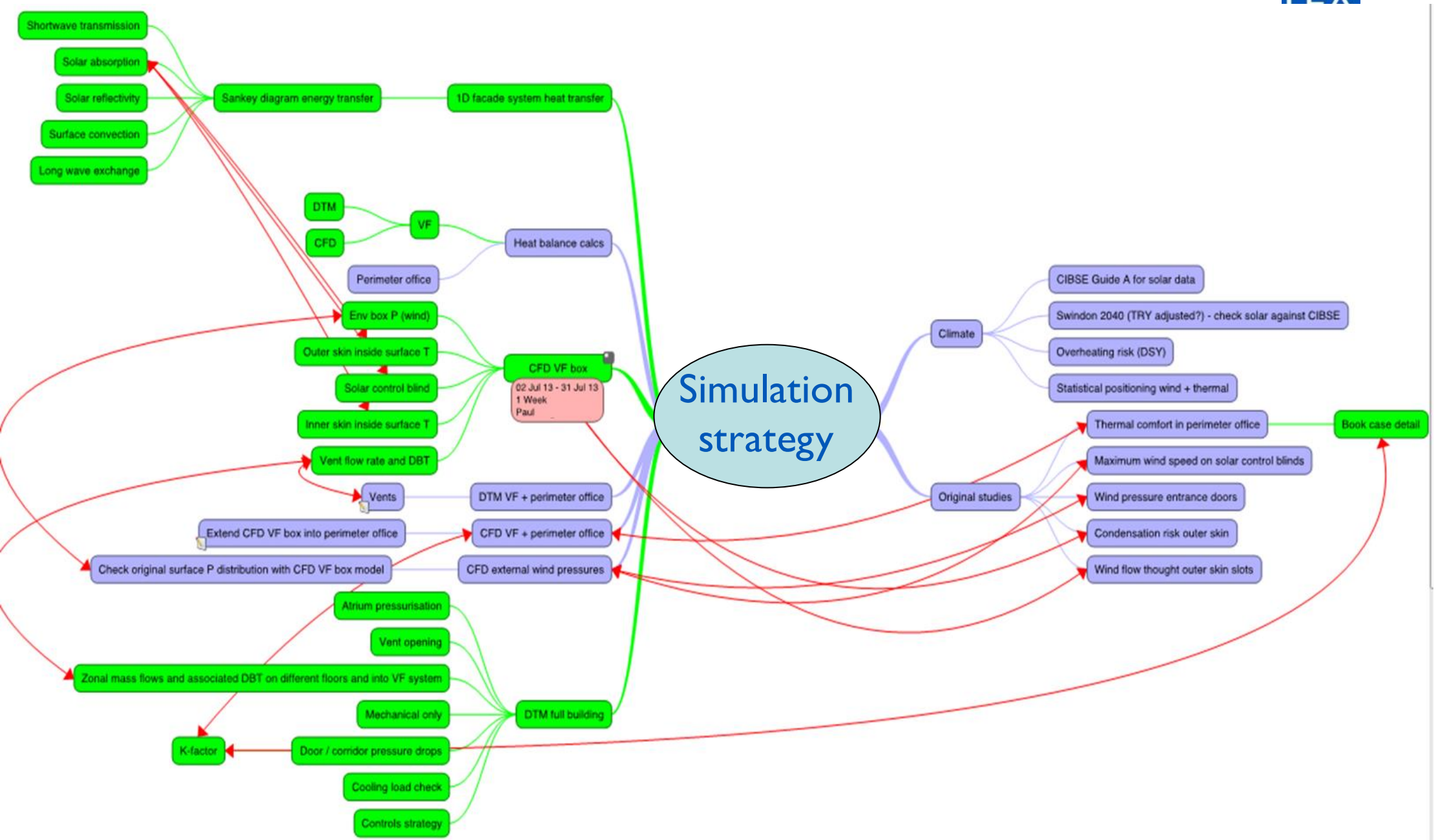
External Conditions					
Dry-bulb T (° C)	Wet-bulb T (° C)	Wind speed (m/s)	Direct rad (W/m²)	Diffuse rad (W/m²)	Global rad (W/m²)

DSF Conditions					
SGU surface T (° C)	DGU surface T (° C)	External Air Change Rate (l/s)	Dry-bulb T (° C)	Mean radiant T (° C)	Operative T (° C)

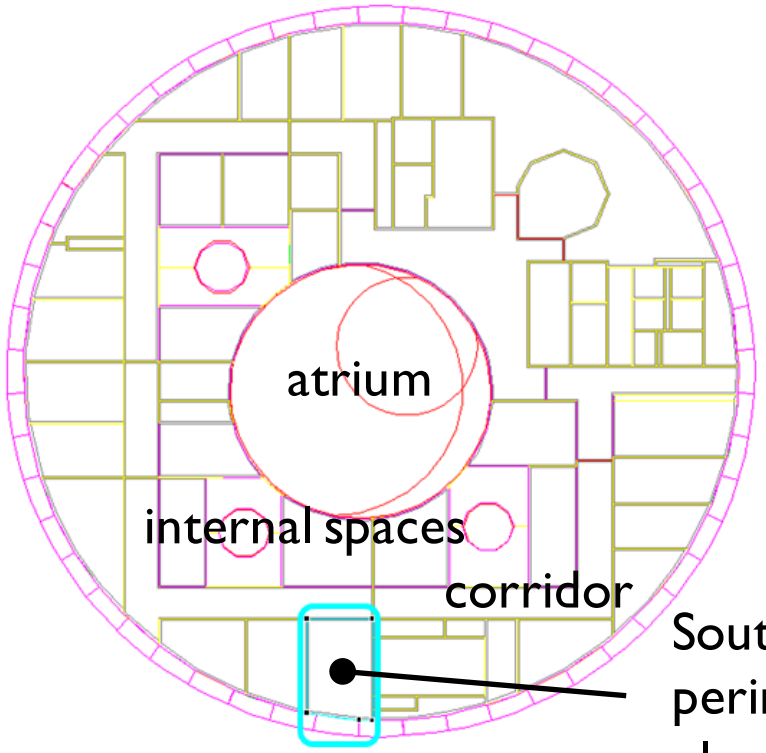
Room Conditions						
Dry-bulb T (° C)	Mean radiant T (° C)	Operative T (° C)	Nat Vent Rate (l/s)	Mech Vent Rate (l/s)	Flowrate out of room through rear transfer grille (l/s)	Flowrate into room through rear transfer grille (l/s)

early observations very small ΔT
south-facing DSF, afternoon in July

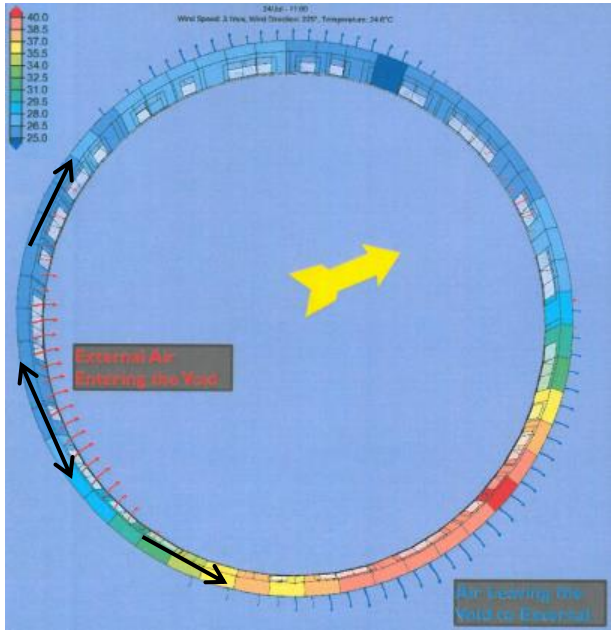
Devising a simulation strategy



Closer scrutiny using sub-models



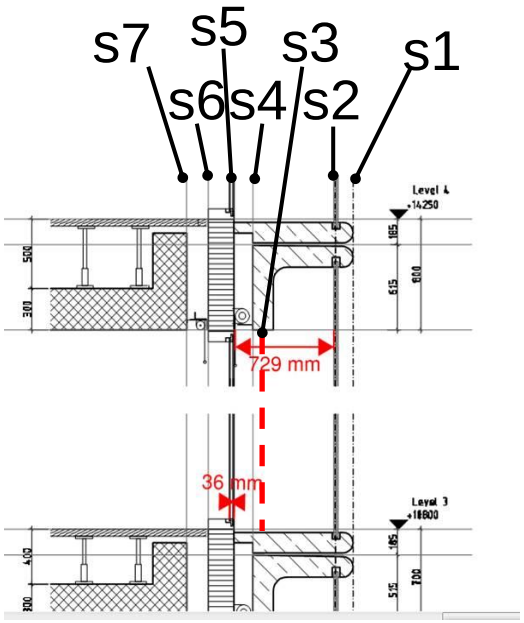
Original DTM of 3rd floor

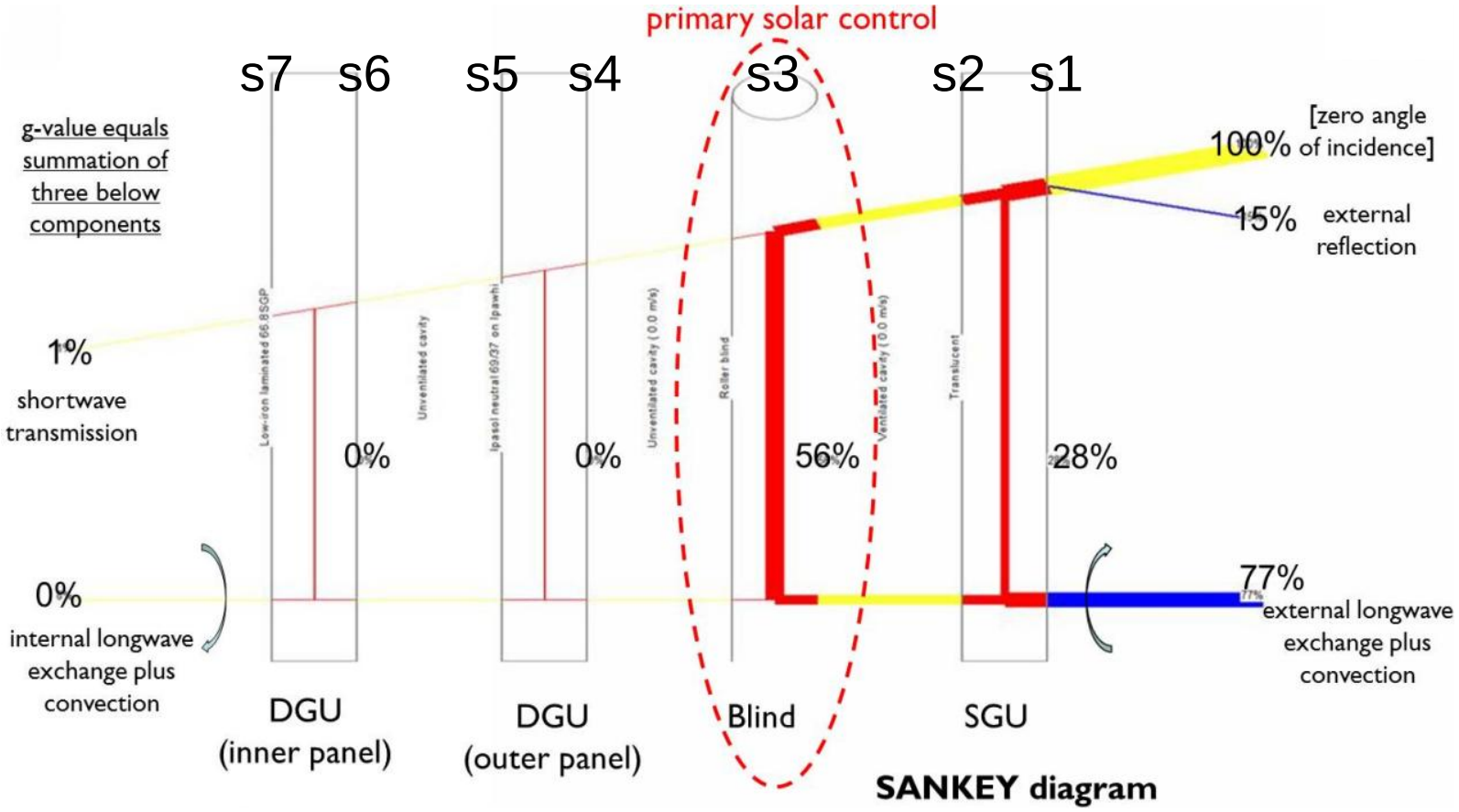


Checking sub model (annulus flow)
- operative temperature and flow directions

- Extremely complex model with many variables
- High uncertainty with wind, solar-heat distributions, DSF performance, air movement between internal and external zones

Understanding heat transfer detail within solar transmission

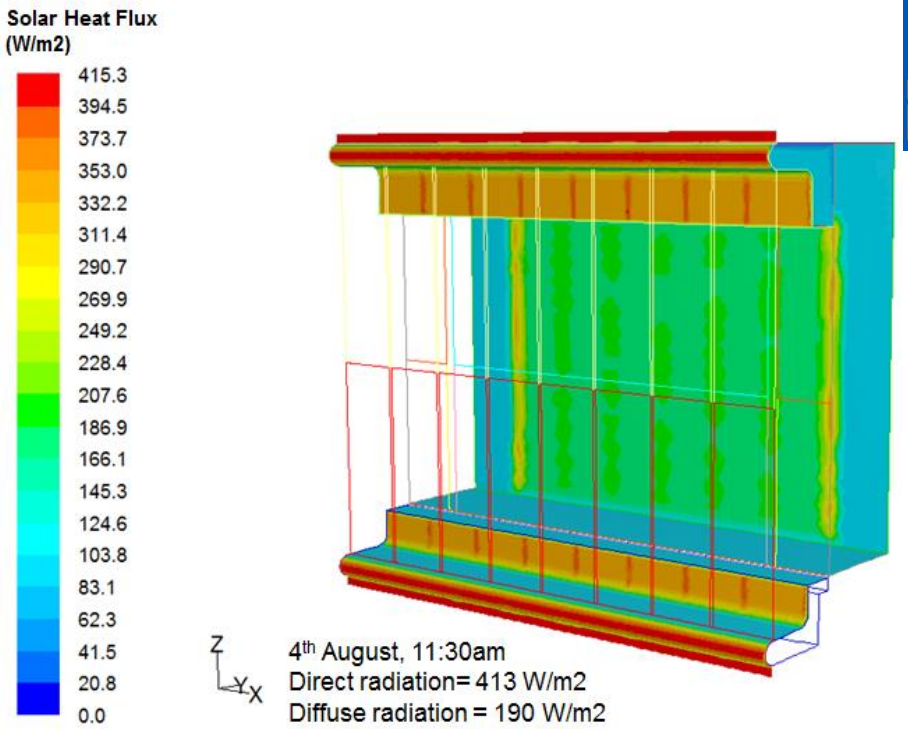


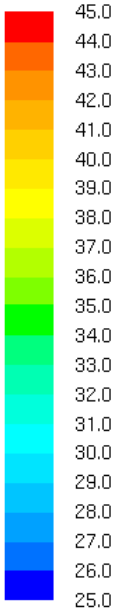


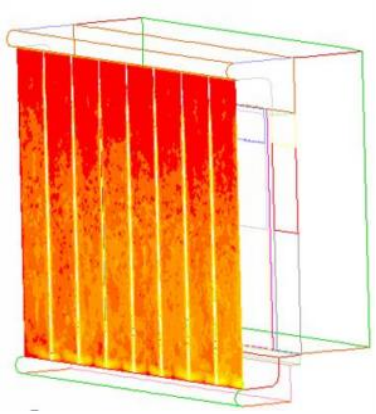
- Relative importance of different elements – contribution to overall heat distribution

Understanding surface detail within the heat distribution

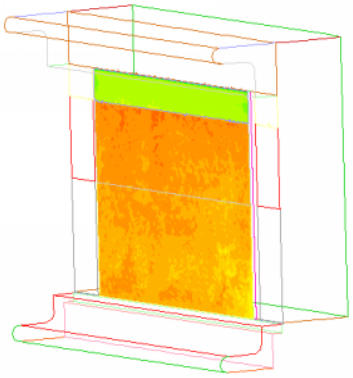
- Each surface has two sides (two sets of surface properties)
- Some surfaces have only incident diffuse radiation (shaded from direct sun), some have direct plus diffuse (in sun patch)



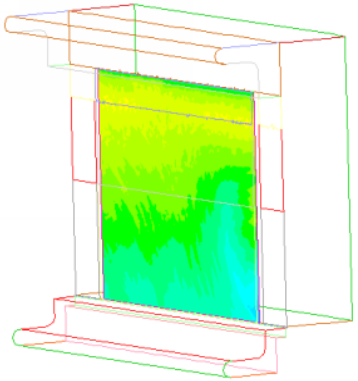




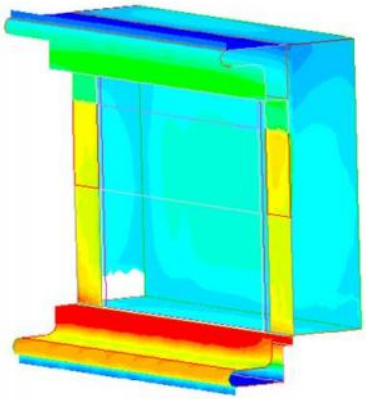
SGU (outer)



Blind (outer)

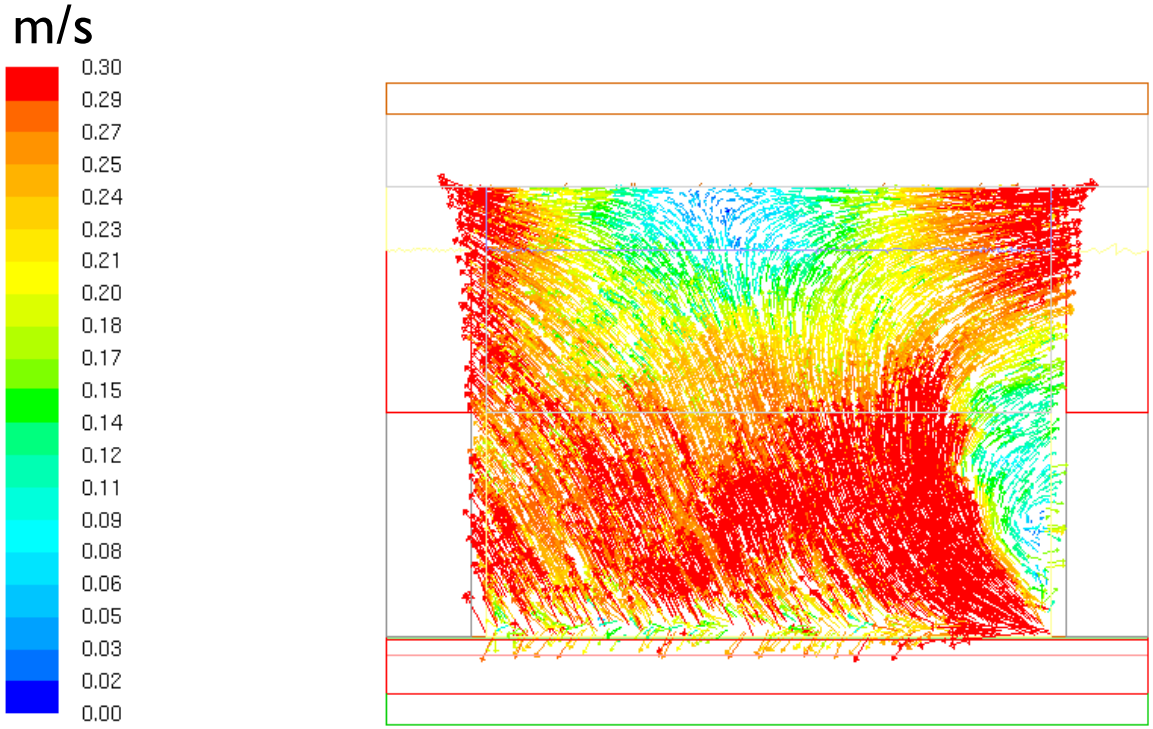


DGU (outer)



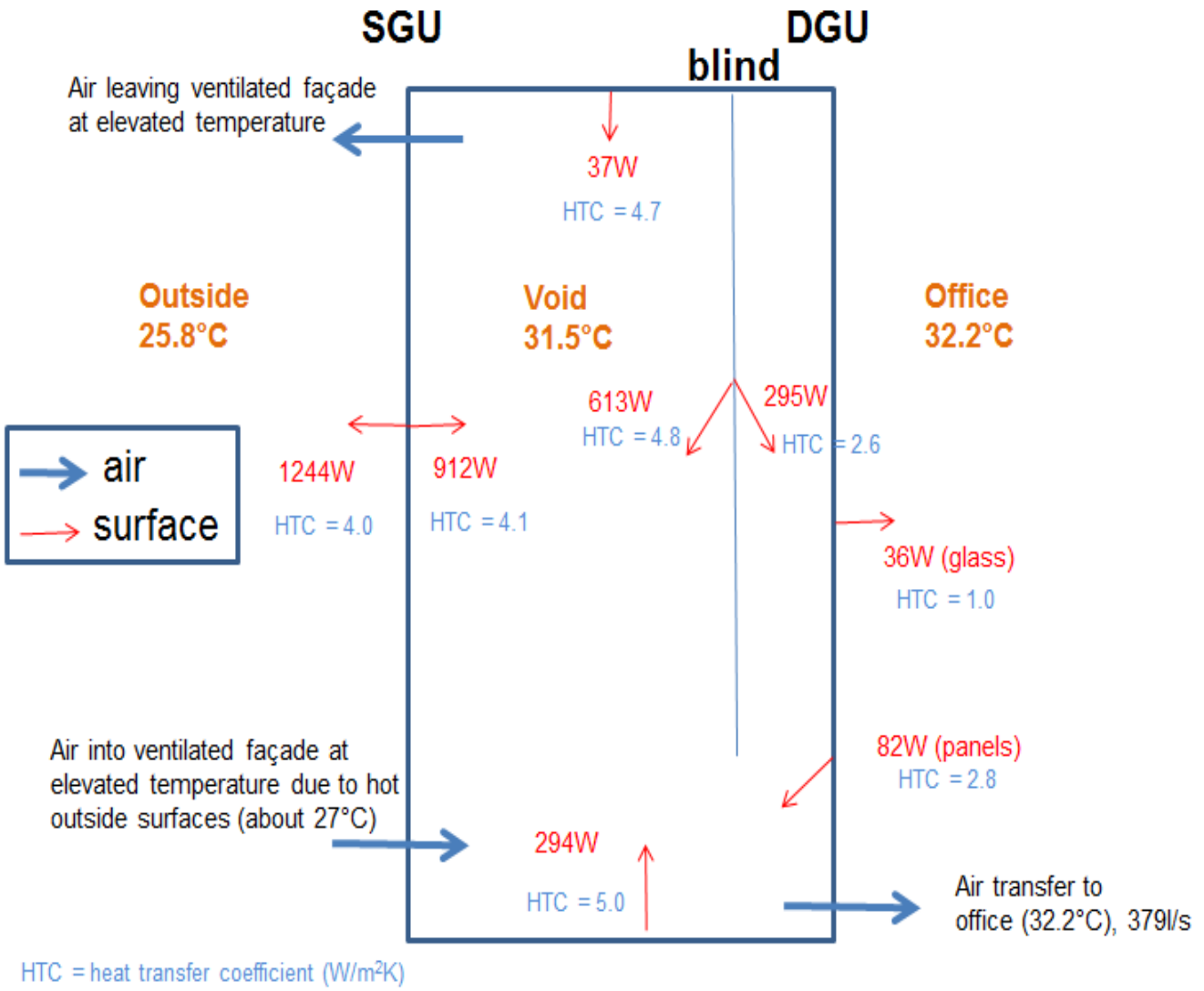
Solid surfaces

How were the blinds influencing the 3D heat transfer?



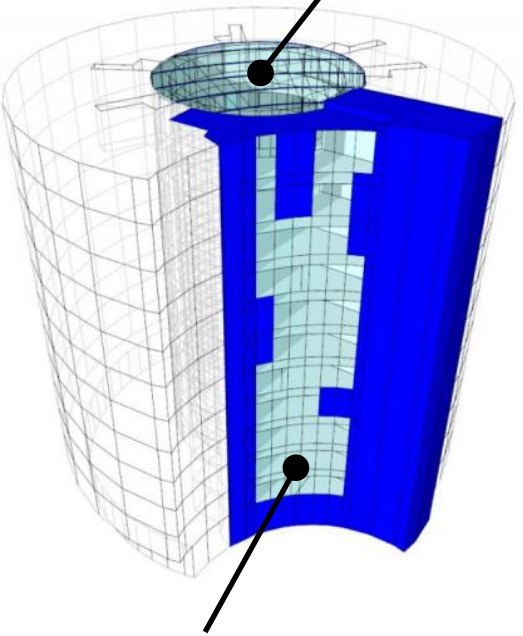
- Vertically upward movement in gap between blind and DGU in CFD (not recirculating between these surfaces)
- Limitations of DTM, e.g. only able to attach blind to inside of SGU, HTC?
- How does the heat transfer through a closely coupled blind differ from a far coupled one?

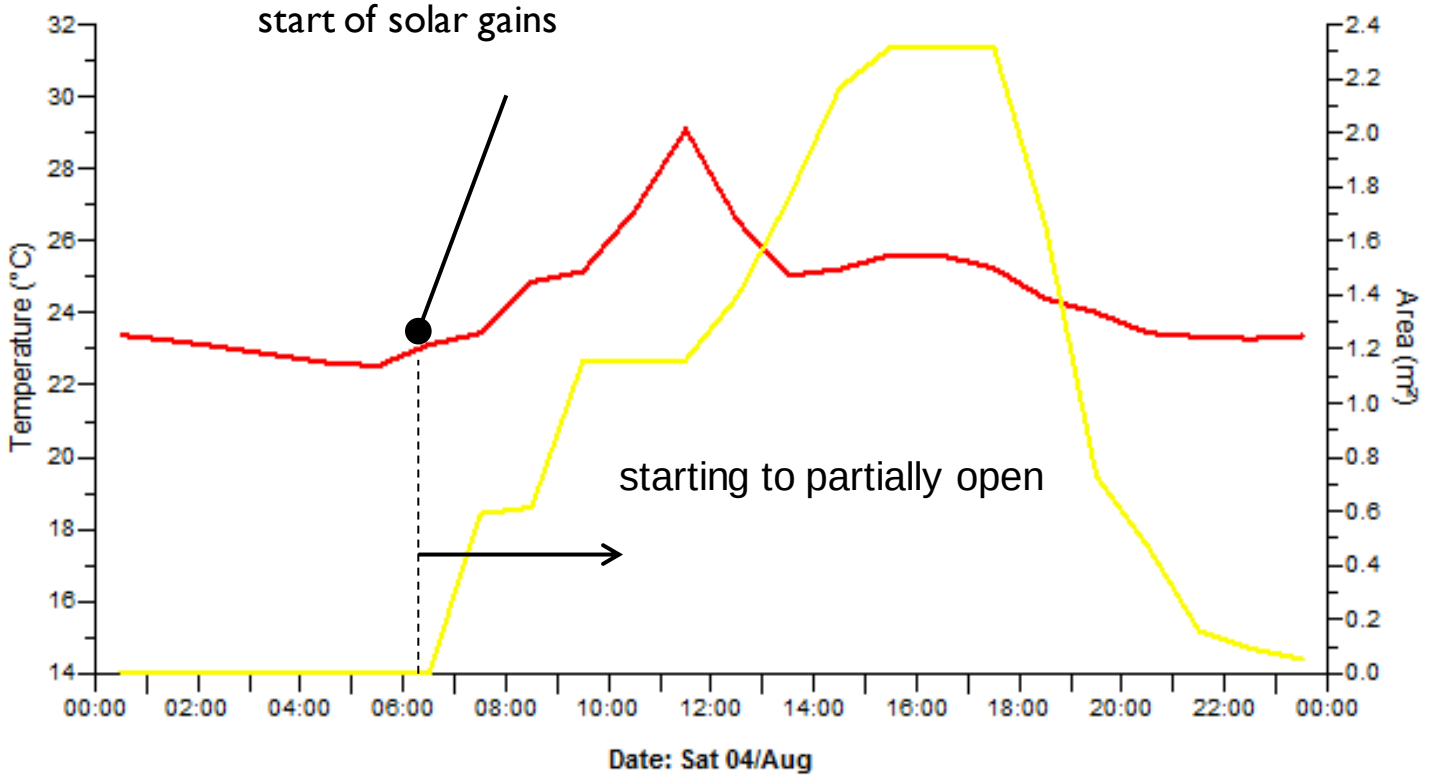
Extracting data to simplify understanding



- Hand calculations provided an 'offset' to better assess predictions and increase confidence overall

Controlling performance



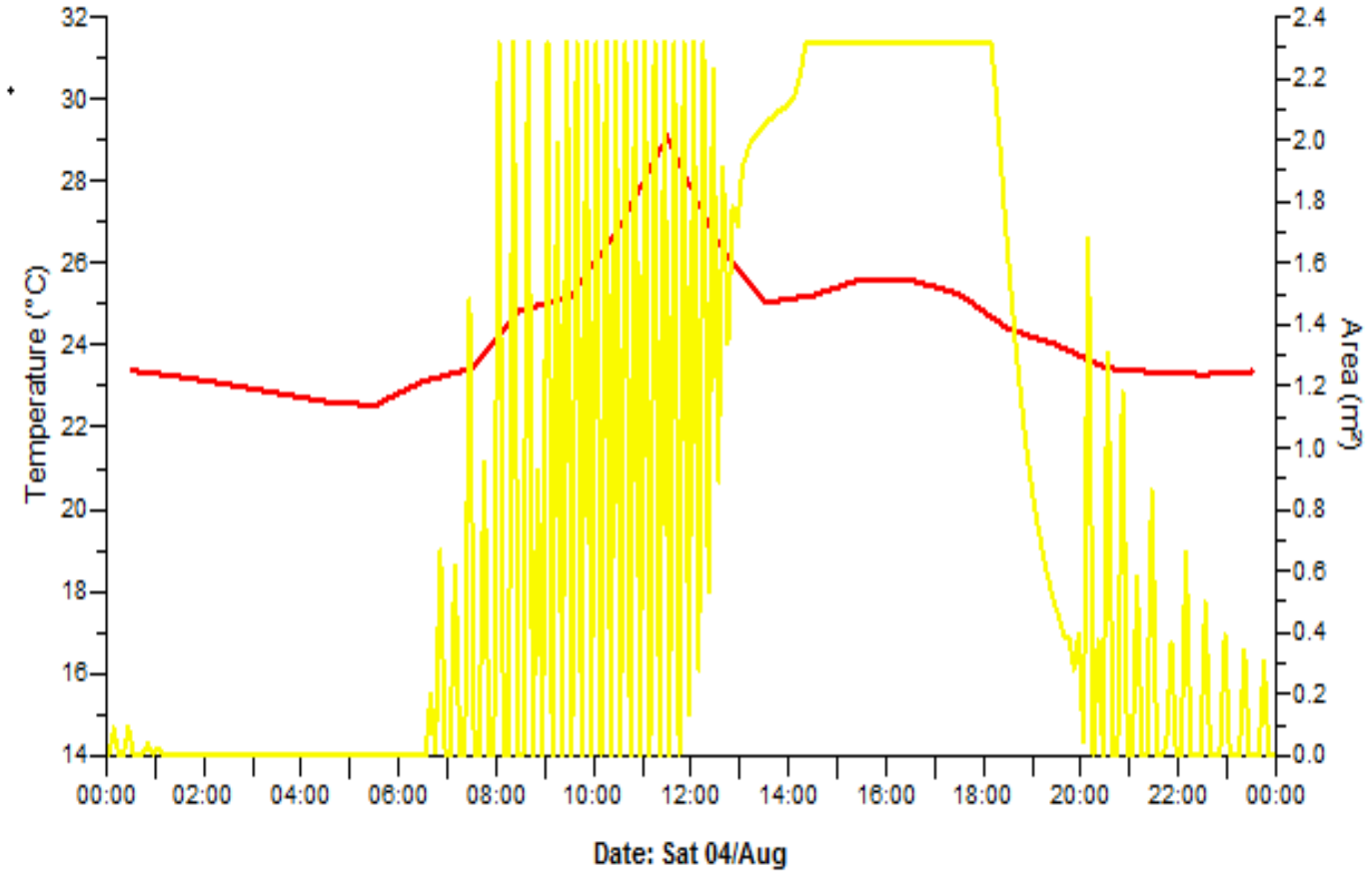


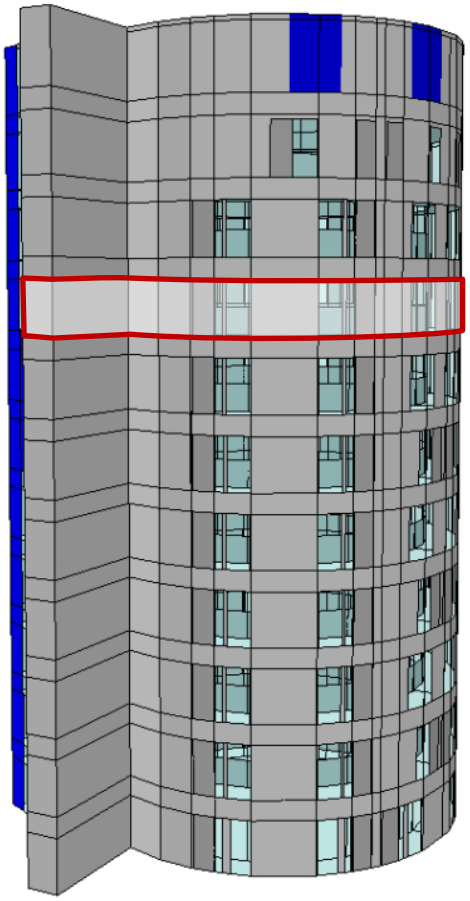
air T just below roof vents

open area

10 min time step recording at hourly intervals

Controlling defaults and time steps

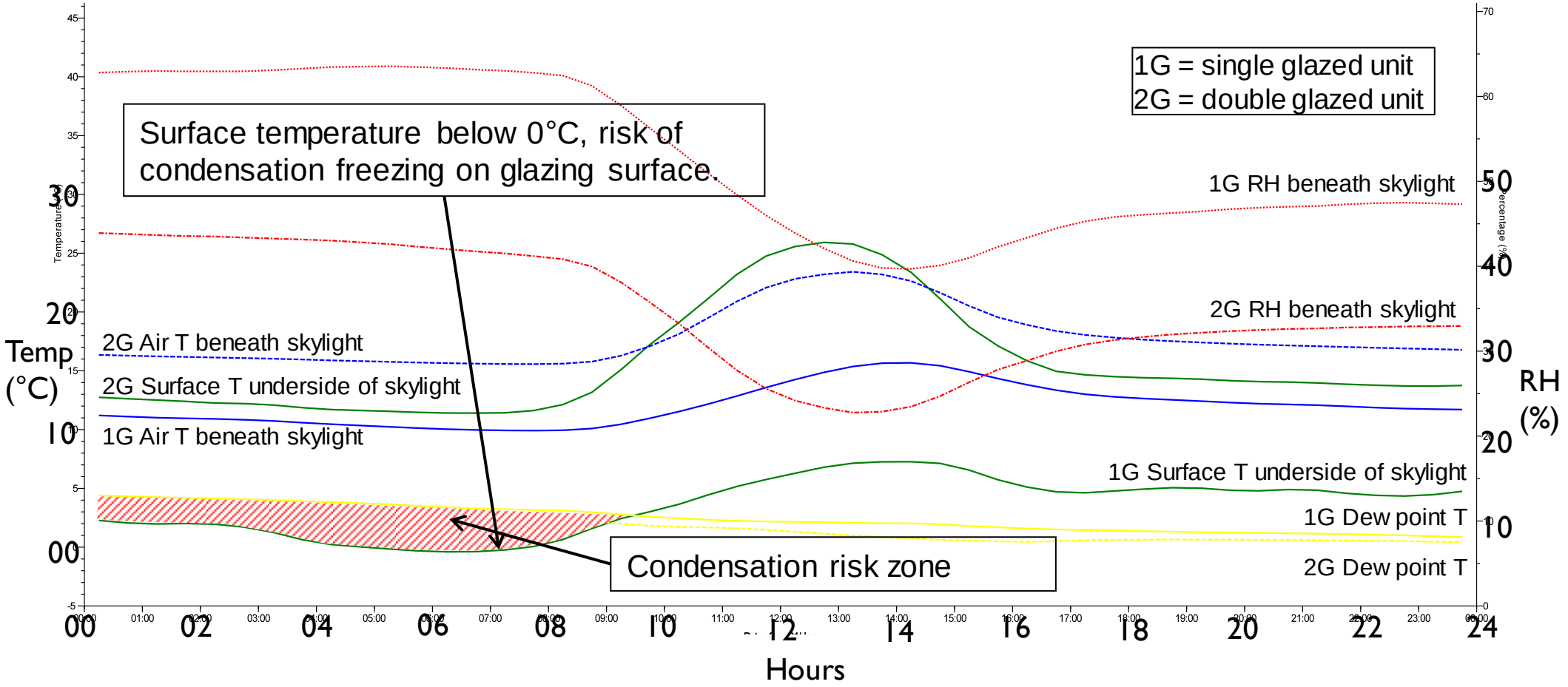




6 min time step recording at 6 min intervals

- Detailed scrutiny exposed excessive switching
- Default / notional air temperature band width used (1K)
- Modified approach for controls strategy

Communicating results



- Good communication includes simulation outputs that can be easily read and understood

Are you competent for the intended application?

Level 1: Understands how to drive the software and get the results out
Level 2: Successfully implements the standard test models
Level 3: Understands the principles behind the software
Level 4: Good knowledge of the technical manual and/or online help so that non-standard applications can be implemented
Level 5: Clearly explains results at the appropriate level
Level 6: Recognised supervisor on the application of the software
Level 7: Implements user code
Level 8: Recognised expert

CIBSE Guide AM11 'Building Performance Modelling'
(2015 – to be published soon)

Some ideas for graduates

- Sensitivity test 1D solar and thermal transmission calculations to better understand heat transfer mechanisms / g-value / U-value formulation at 'surface property' level
- Build 'box models' to test application, sensitivities and tolerances of software application for 'single physics', e.g. long wave radiation
- Examine how your software deals with convective and radiative components of internal heat gains and how the heat is distributed
- Think about statistical positioning of climate data and potential impact of using different targets

Turning WYSINWYG into WYSIWYG

Education Education Education!
(understanding and training)

Application Application Application!
(what's appropriate and practical in budget and time?)

Defaults Defaults Defaults!
(watch out for and understand the…)

Limitations Limitations Limitations!
(know and explain your…+ assumptions + simplifications)

Interpretation Interpretation Interpretation!
(a 'measured' sale of your message is a valued one)

Black Box = Blind Box = Pandora's Box!

YAFIYGI

Any Questions?


Arts, Culture and Heritage


Courts and Emergency


Data Centre and Mission Critical

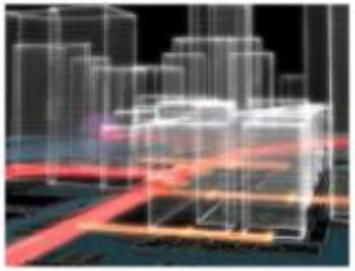

Defence


Distribution


Education


Healthcare


Hotels and Resorts


Infrastructure and Energy


Leisure


Manufacturing and Process


Prisons


Residential


Retail


Science and Research


Sport


Transport


Workplace