



An investigation into the energy efficiency of tall office buildings in Western Australia

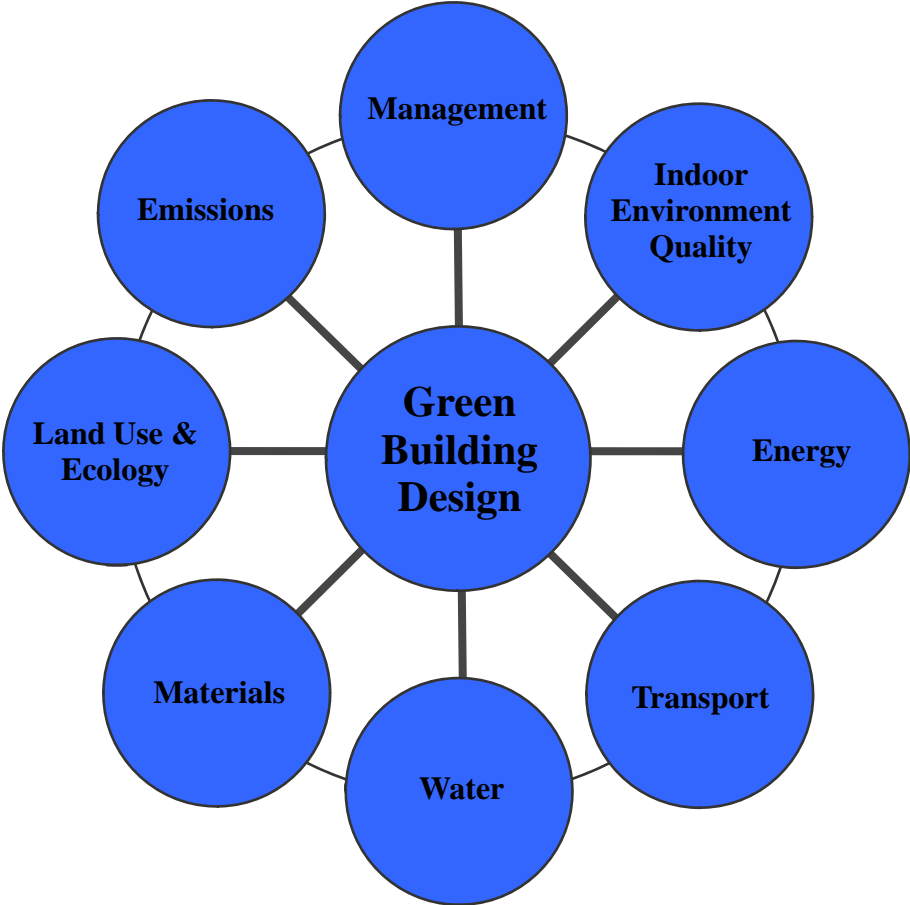
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Outline

- Introduction
 - The importance of sustainable building design
 - What makes a “Green Building”?
 - Examples in Western Australia
- The role of computer modelling in Green Building design
 - Energy modelling
 - Lighting/Daylighting simulation
 - Computational Fluid Dynamics
 - Electrical load calculations
- Development of an holistic approach
- Preliminary analysis
- Conclusions/Further work
 - Optimisation

What makes a “Green Building”?



... and there are just green buildings!



Examples in Western Australia

- Durack 2
(2 Victoria Avenue)
- 6-star “Green Star Design”
Rating
 - World leadership



Examples in Western Australia

- 140 William St
- 5-star “Green Star Design” Rating
 - Australian leadership



Examples in Western Australia

- 167 Westralia Plaza
 - 54 Mounts Bay Road
 - Pier St.
 - 130 Stirling St
 - Others...
-
- 4-star “Green Star Design”
Rating
 - Best practice



Why is building design important?

Environmental impact of green buildings*

- 42 % Energy
- 12 % Water
- 40 % Air Emissions
- 40 % Waste to Landfill

Other effects:

- Sick building syndrome
- Lower productivity

We all spend the most part of our time occupying a building of some type!

* Note: figures presented are illustrative based on OECD figures across all building types and sectors. Other reports have revised estimates lower based analysis of building sectors. Refer: Centre for International Economics (2007): Capitalising on the building sector's potential to lessen the costs of a broad based GHG emissions cut.

The role of computer modelling

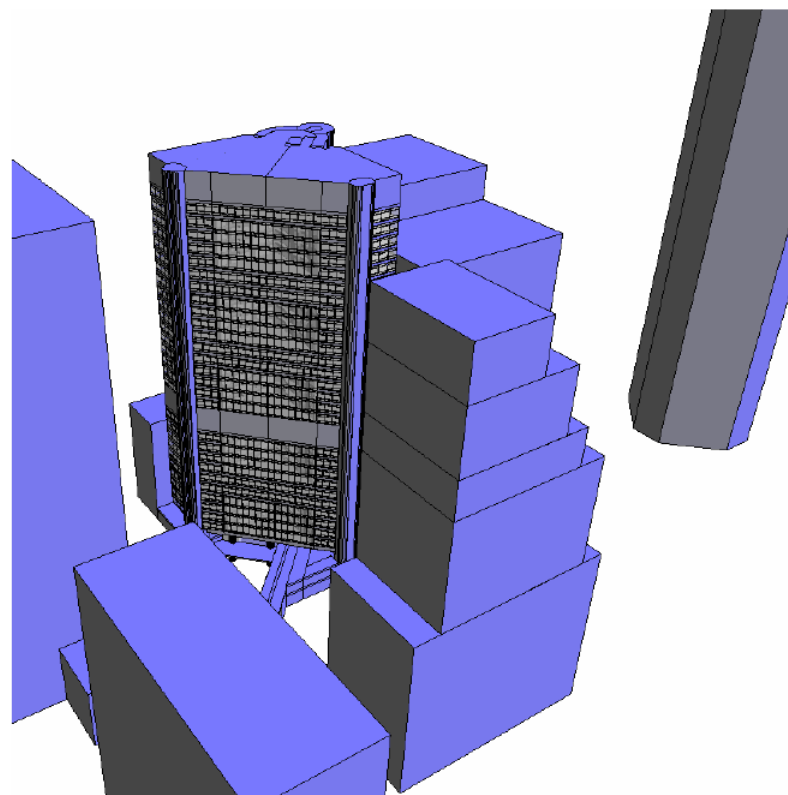
Computer modelling is becoming an increasingly important tool within the building industry for virtual prototyping of building design.

- Identify energy potential for energy savings
- Optimise design features
- Calculate building performance to set energy targets and ensure they are met as-built
- Influence design in early stages when the largest impact can be made
- Identify potential for upgrading existing building performance

Energy modelling

Calculation of building HVAC related loads and energy consumption

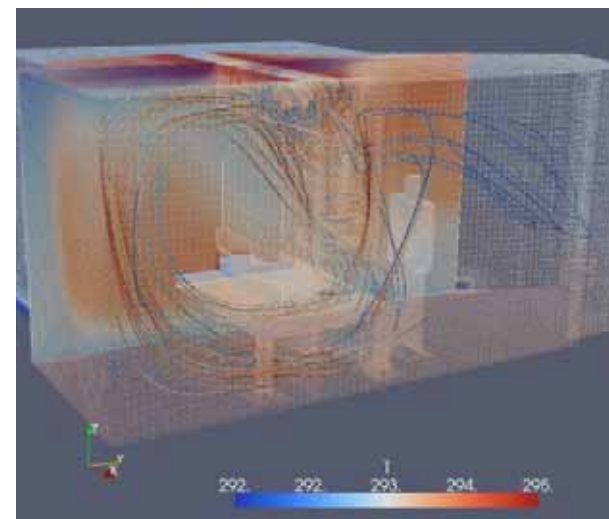
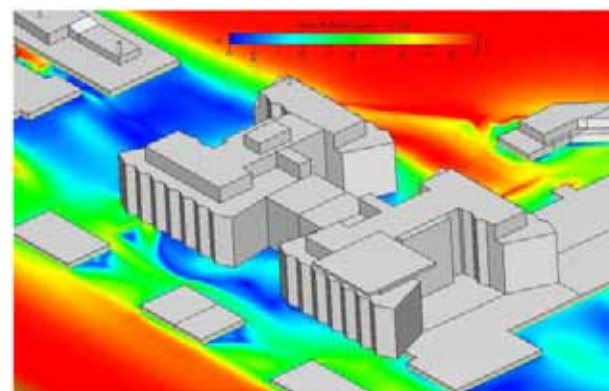
- Energy efficiency (ENE-1)
- Effect of shading on HVAC loads
- Solar loads



Computational fluid dynamics

Used for modelling of detailed heat and air movement

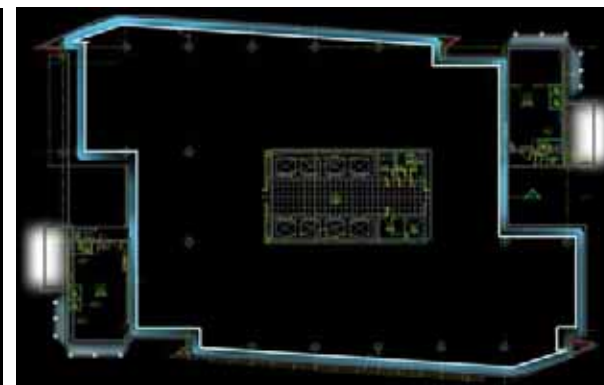
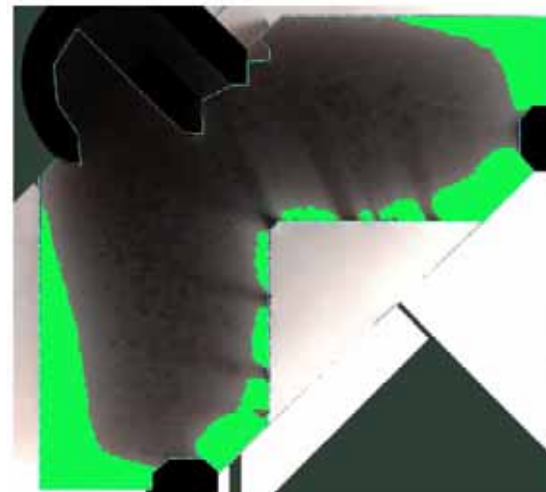
- Air Change Effectiveness (ACE)
 - Green Star credit IEQ-2
- External flow
 - Wind turbine positioning
 - Natural ventilation
- Pollutant control
- Infection control



Lighting/daylighting simulation

Used in design to take advantage of natural light and reduce energy consumption through artificial lighting

- Natural light (IEQ)
- External views
- Glazing selection
- Light selection

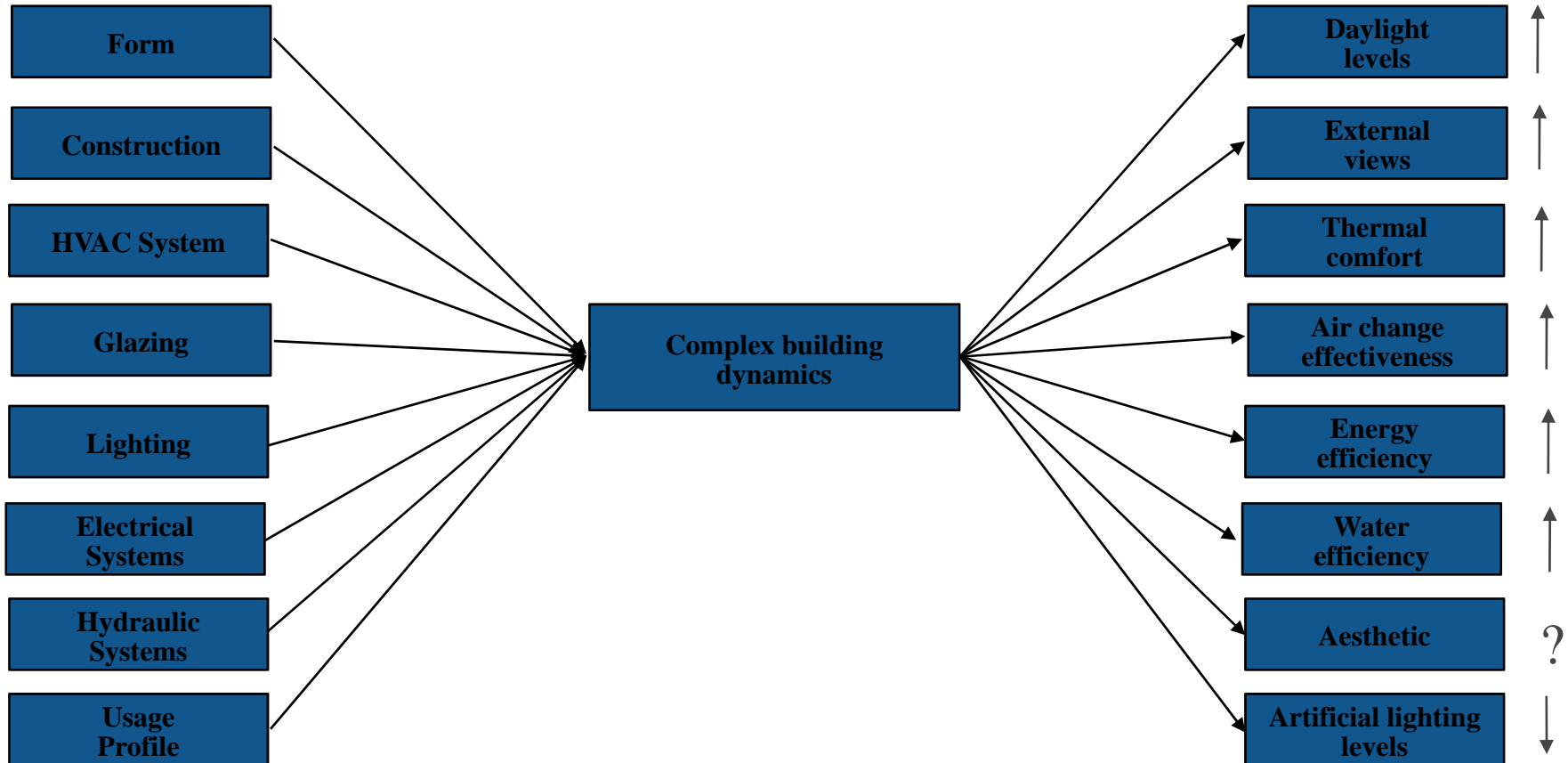


Other modelling

- Electrical load calculations
- Acoustic modelling
- Detailed mechanical design
- Etc.

Combining the analysis

- Modelled building aspects give varying levels of performance creating an extremely complex optimisation problem.



Combining the analysis

- Currently performed manually
 - Few iterations possible prior to final design
 - Have we reached an optimal point across all design criteria?
 - Probably not
 - May miss some small changes which will have a significant impact on building optimisation

A fundamental approach...

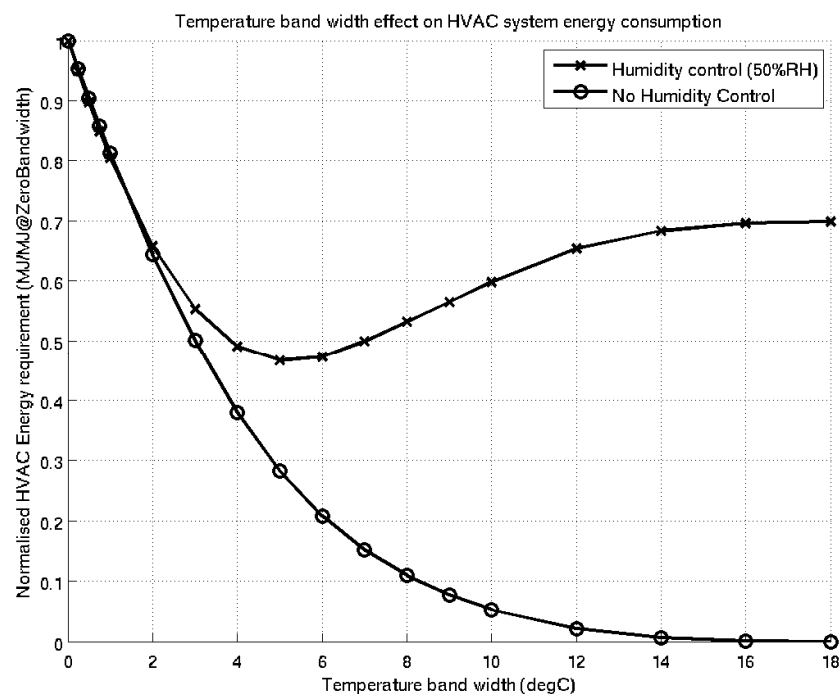
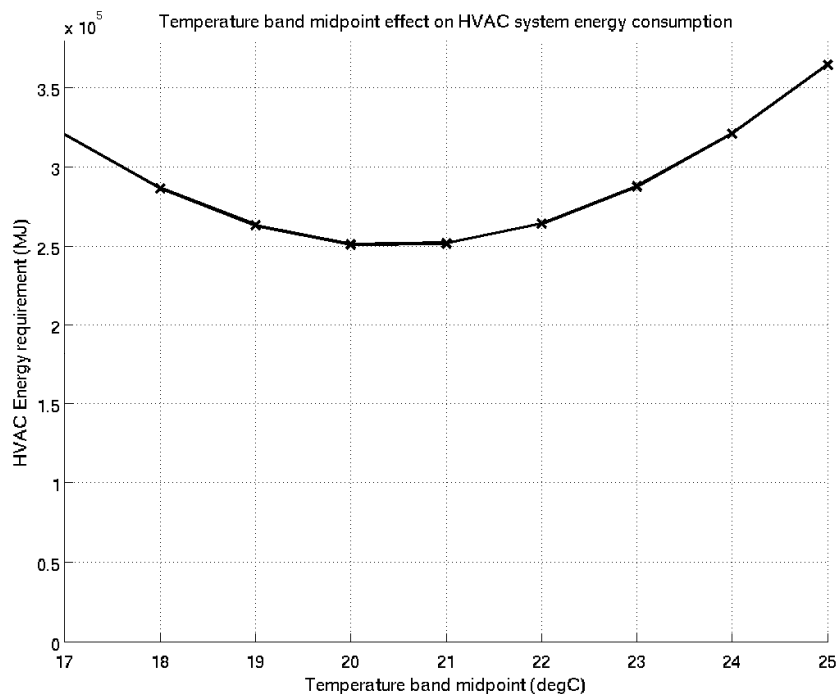
Considering a single level as a closed system permits a more rigorous assessment of the carbon-neutral potential of a building in within the context of both passive and active design features.

The basic model:

- A typical level of a cylindrical tall building
- CFD to calculate wind energy availability
- Solar energy on façade calculated with energy modelling
- HVAC system and equipment loads estimated through a simple model

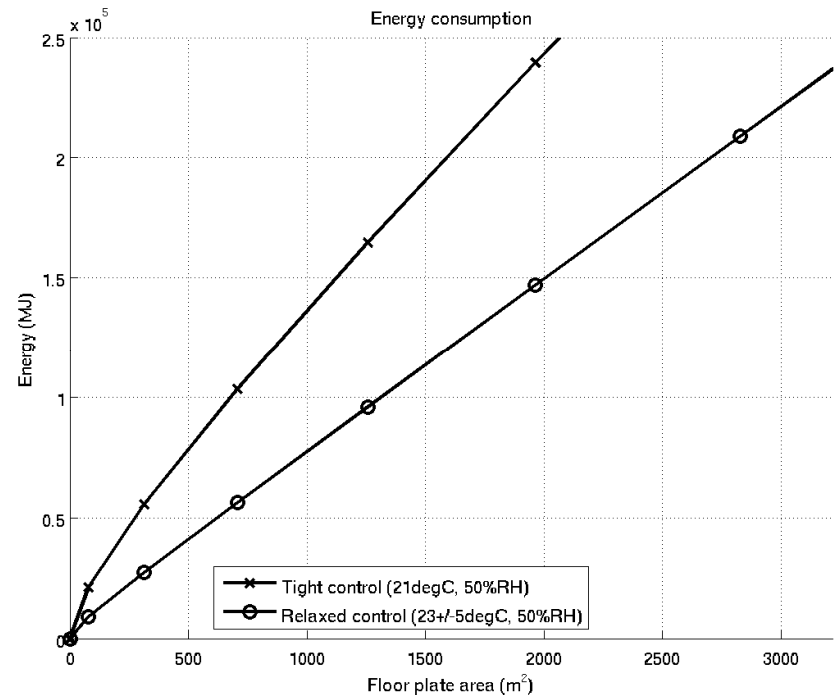
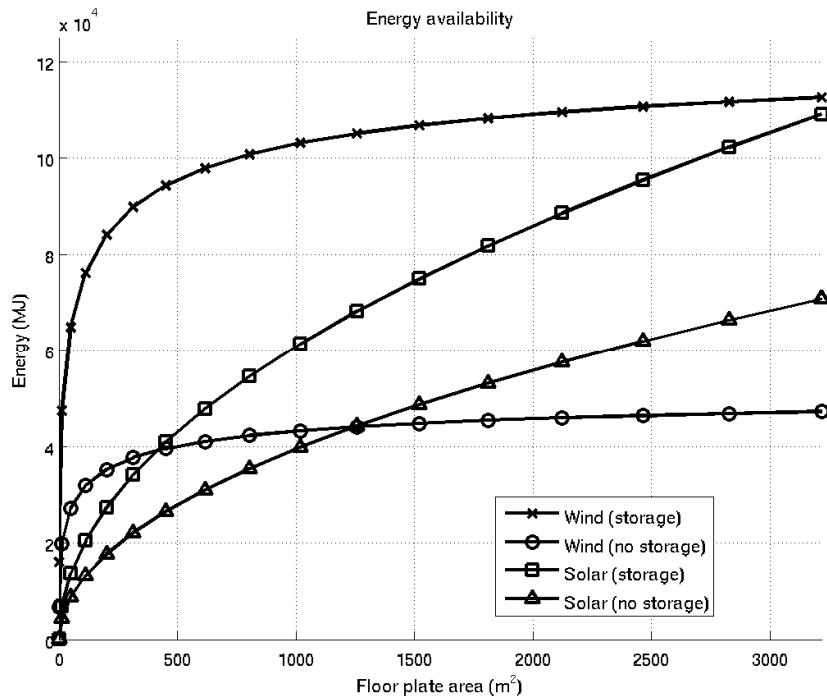
Temperature control bands

- HVAC system energy consumption depends on:
 - Temperature band midpoint
 - Temperature (and humidity) band width



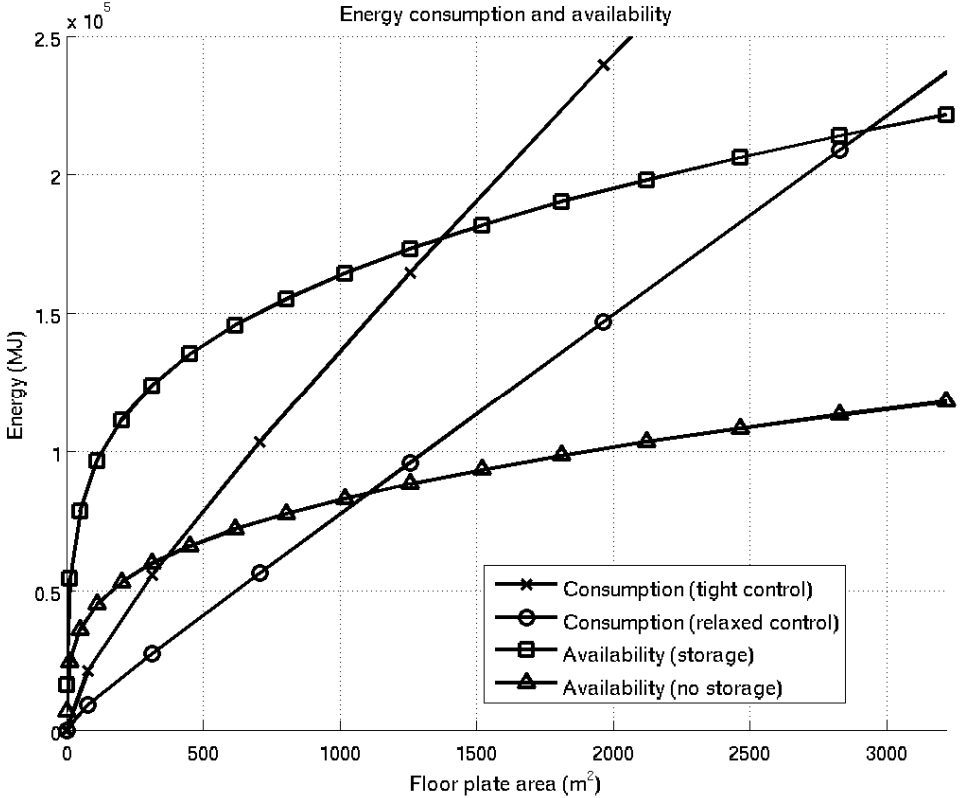
Energy availability and consumption

- The harvestable wind energy (within 3m of the façade) varies with NLA toward a limit.
- Solar energy availability increases with the square root of the NLA
- Energy required increase roughly linearly with the floor plate area



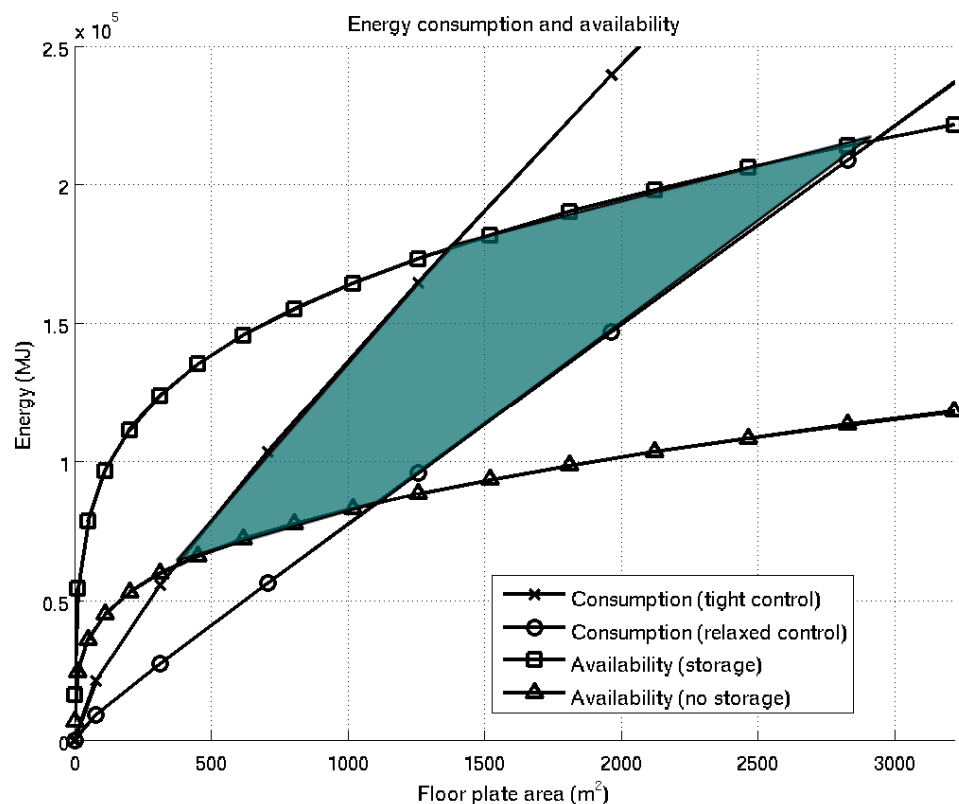
Carbon-neutral potential

- Adopting relaxed temperature control limits with on-site harvesting or passive use of available energy (with storage potential) can have a significant effect on the potential NLA that may be energy-neutral.



Carbon-neutral potential

- Adopting relaxed temperature control limits with on-site harvesting of renewables (with storage potential) can have a significant effect on the potential NLA that may be energy-neutral.



Conclusions

- Due to the availability of renewables for the typical level of a tall office building there exists a theoretical limit where self-contained carbon neutrality is feasible.
 - Results give novel insight into the approach that should be taken towards “greening” existing buildings
 - Provide a reference-point against which to compare sustainable potential
 - Design challenges:
 - Maximise the NLA for which carbon-neutrality is possible
 - Paradigm shift in design from “improvements on a predetermined design” to “design feasibility established within constraints”
- The adoption of advanced design tools such as energy, CFD and lighting modelling is necessary to accomplish ambitious sustainability objectives
 - The end of “rule of thumb” design

Further work

Further work:

- Investigate the variation of building form, shading and systems to maximise the carbon-neutral limit.
 - Optimisation to yeild the optimal building form and system for a particular location and site layout.
 - Genetic optimisation within constraints.
- Develop the modelling to include consideration of other design criteria
 - Daylighting, glare, temperature/humidity/PMV

Thank you

Final thoughts:

- Increase regulation
- Adopt advanced design tools
- Develop advanced design tools freely and openly
- Further research in IEQ

Conclusions

- Analysis times and optimisation between various analyses must keep pace with the development of metrics for determining occupant comfort
- Temperature and humidity bands have a significant effect on the ability of a building to achieve carbon-neutrality
 - Social challenges:
 - Adapt to the environment rather than adapt our environment to ourselves

Methods of assessment

Design

As-built

Regulatory

