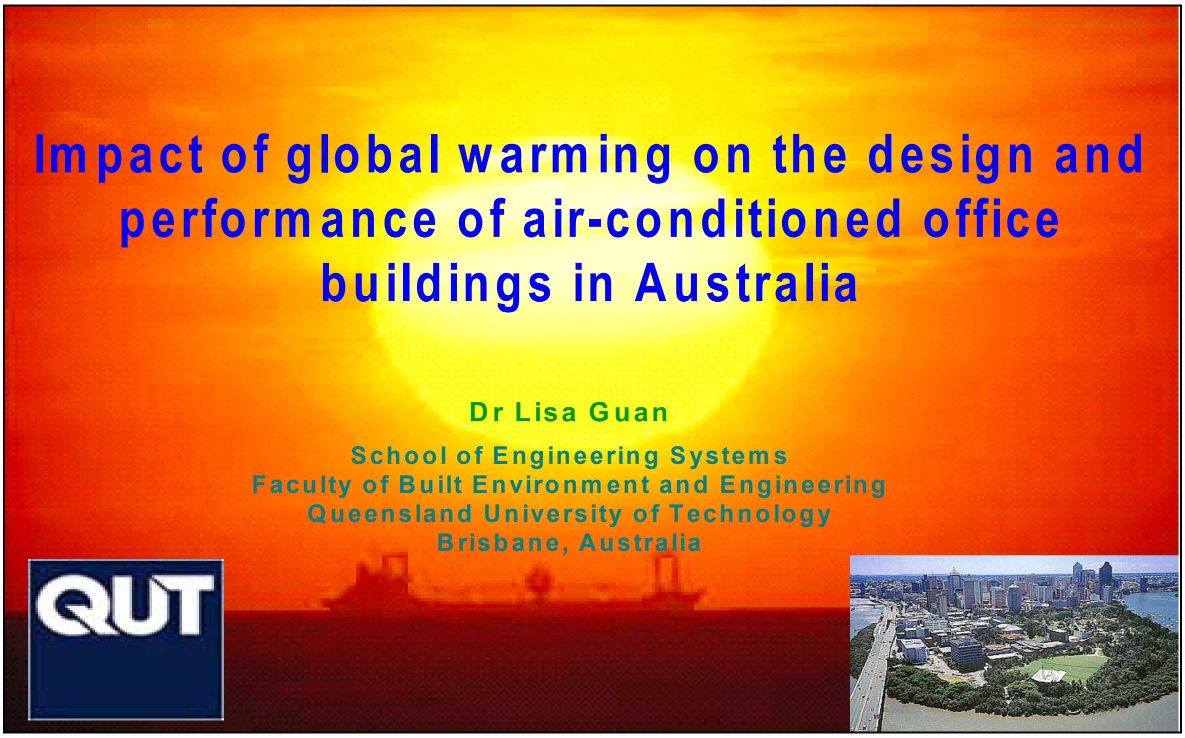
Impact of global warming on the design and performance of air-conditioned office buildings in Australia
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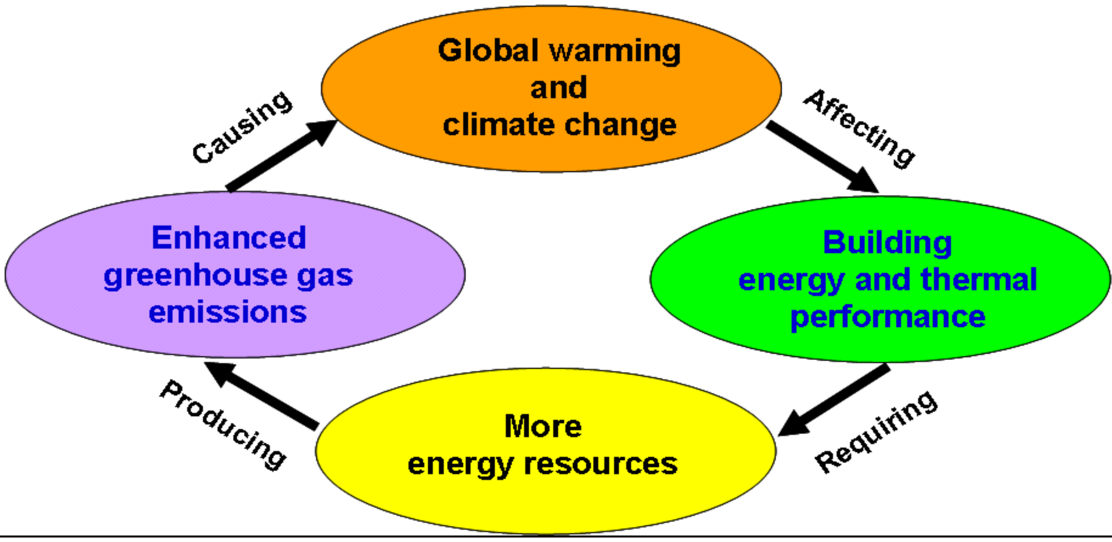
Overview of Presentation
Research background
Research methodology
Results and discussions
Conclusion

Research Background

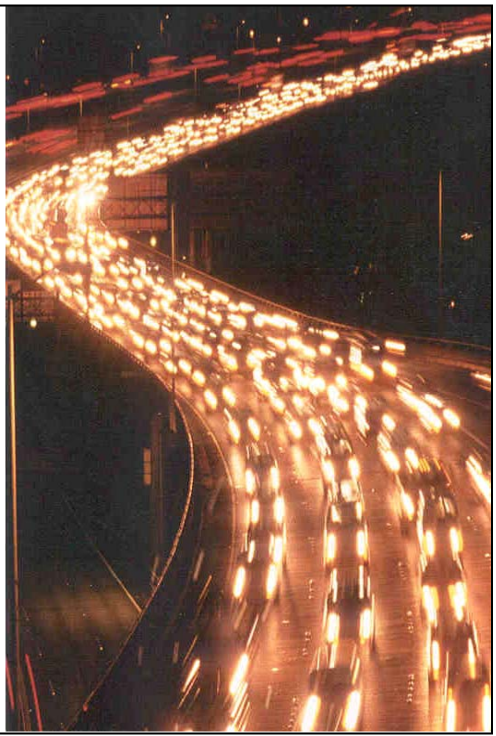
Why this research



Research Background

AUSTRALIAN
Greenhouse
Office

According to Australian Greenhouse Office, buildings contribute **more** greenhouse gases than all the cars on Australian roads !!



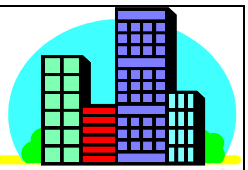
Research Background

Impact of climate change on built environment

- Building energy uses;
- Internal thermal environment;
- External fabric;
- Structural integrity;
- Construction process;
- Service infrastructure.

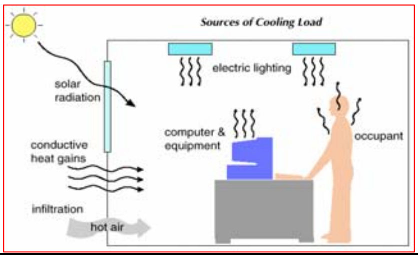
Research Background

Why Building simulation



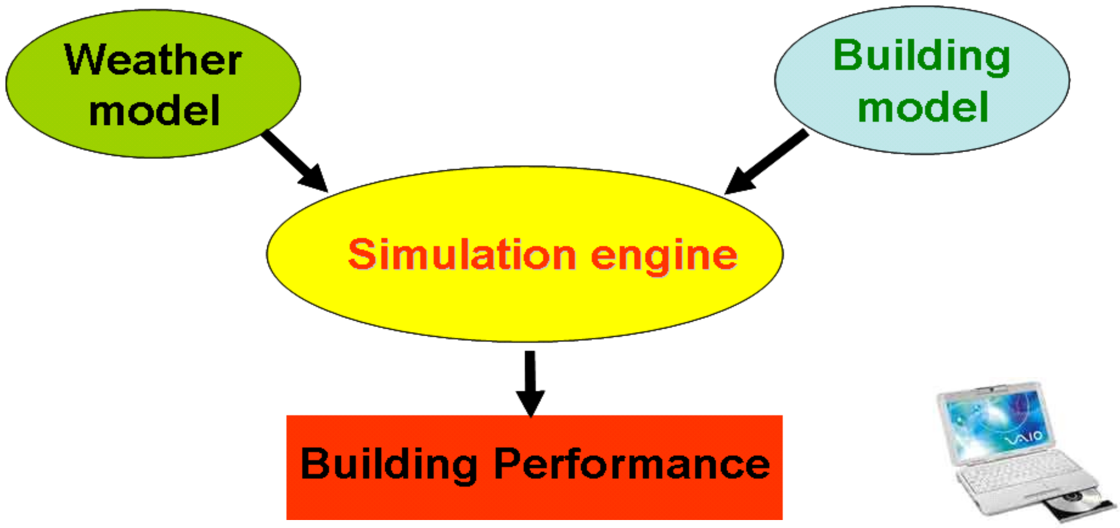
•The interaction between the building systems and global warming is extremely complex, being of **dynamic** nature and involving a large number of variables.

• In many cases the use of building simulation techniques can be the **only** realistic approach.



Methodology

Building simulation method



Methodology: Simulation engine

Building simulation engine DOE-2.1E

- Developed by world-leading organizations
- Have passed through extensive verification process
- Fully dynamic
- Source codes open for inspection

DOE-2

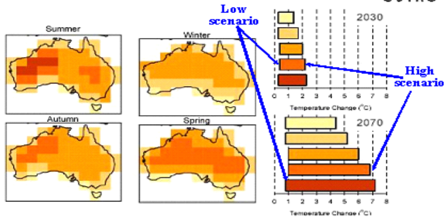
Methodology: weather

Weather scenarios

There will be five weather scenarios used for this research:

- Current weather scenario;
- Future weather scenarios
  1. 2030 Low scenario
  2. 2030 High scenario
  3. 2070 Low scenario
  4. 2070 High scenario

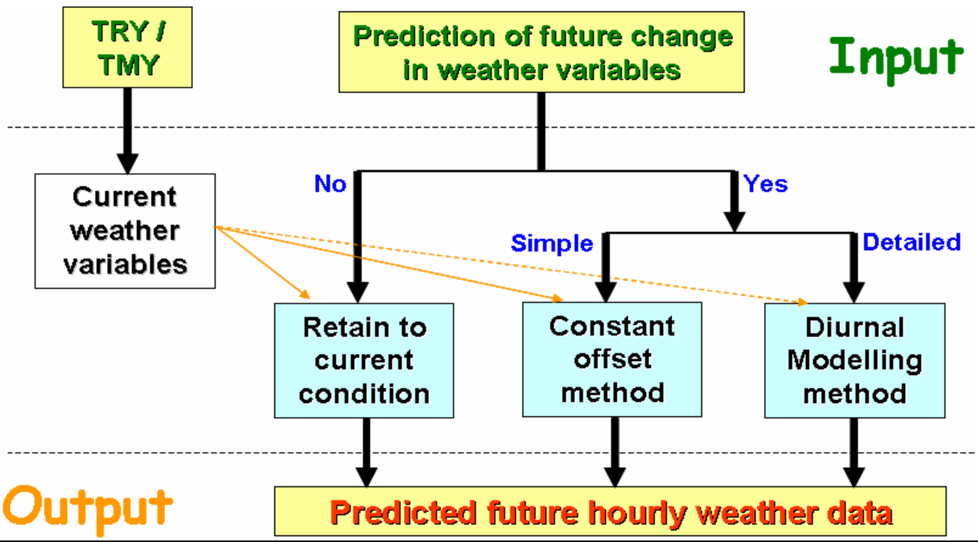
Projected temperature change by CSIRO

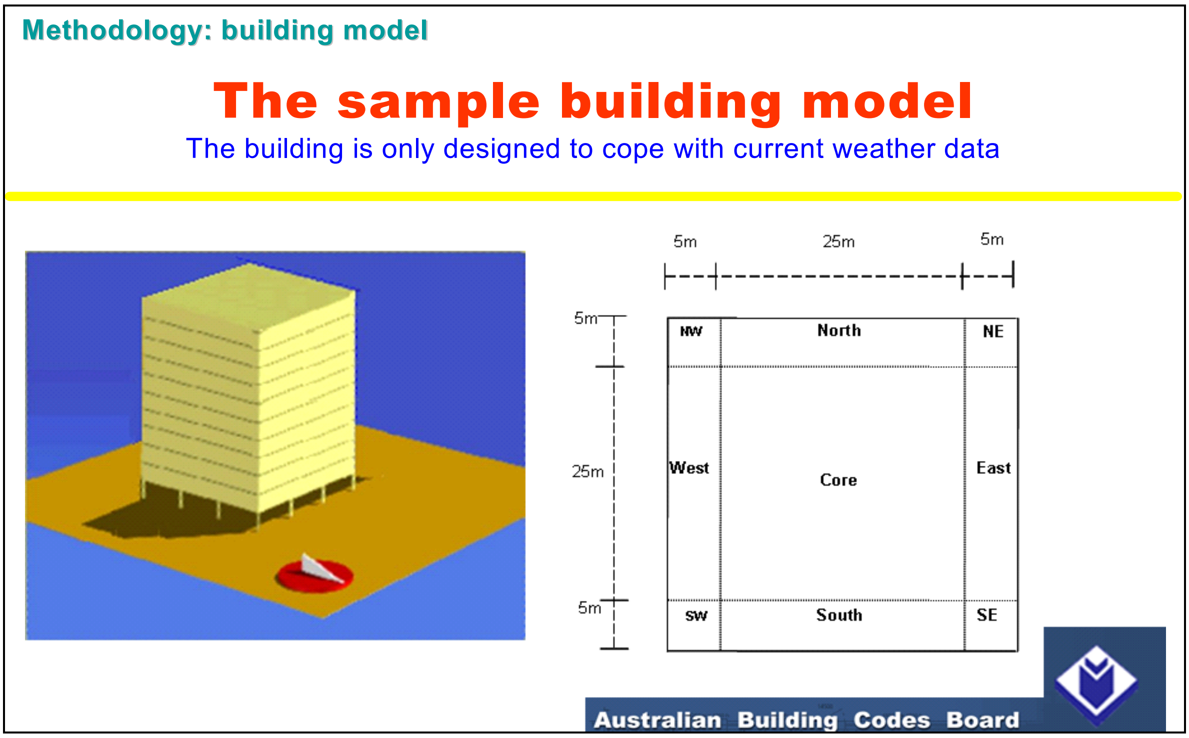


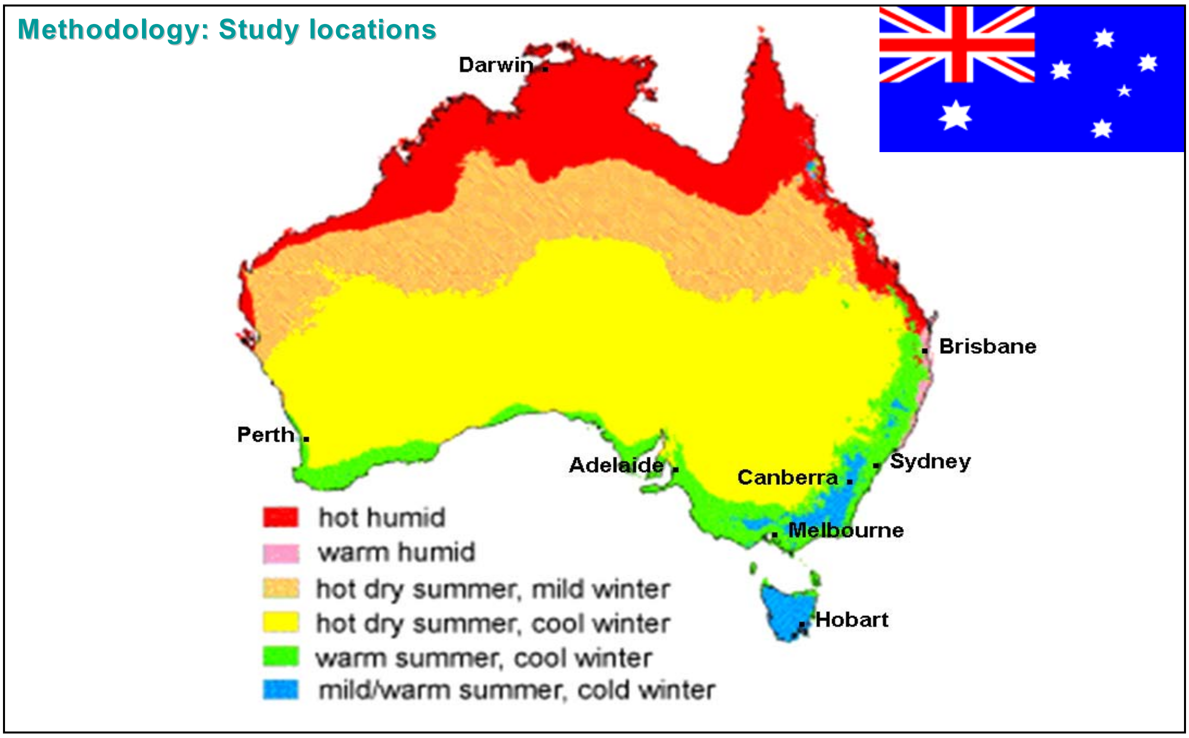
Methodology: weather data

Method for future weather data generation

Global climate model is used to project seasonal temperature increase, which is then forced on current weather variables




Methodology: building model
The sample building model
The building is only designed to cope with current weather data
5m
25m
5m
5m
25m
5m
NW
North
NE
West
Core
East
SW
South
SE
Australian Building Codes Board


Methodology: Study locations
Darwin
Brisbane
Perth
Adelaide
Canberra
Sydney
Melbourne
Hobart
hot humid
warm humid
hot dry summer, mild winter
hot dry summer, cool winter
warm summer, cool winter
mild/warm summer, cold winter

Methodology

Building performance indicators

There are **two** indicators used to measure indoor thermal environment and building energy performance respectively:

- One is the percentage of occupied hours (8am to 5pm) in temperature exceeding 25°C. This will be used to measure the **overheating** problem;
- Another is the change of building cooling load and total energy use. This will be used to illustrate the impact of global warming on the building **energy** performance.

Methodology: CO_2 estimation

Estimation of the change in CO_2 emission

The annual greenhouse gas emission (GHG)

=

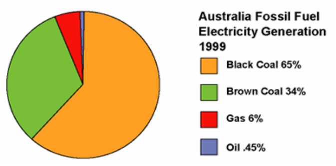
Emission Factor × Energy Intensity × Floor Area

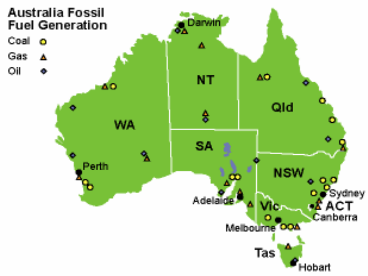
- ***GHG*** - kg CO_2 equivalent/yr;
- **Emission Factor** - kg CO_2 equivalent/kWh;
- **Energy Intensity** - kWh/m²yr;
- ***Floor Area*** - m².

Methodology: CO_2 estimation

Emission factors for electricity generation in Australia

State	Full Fuel Cycle Emission Factor (kg CO_2 equivalent/kWh)	Full Fuel Cycle Emission Factor (kg CO_2 equivalent/GJ)
New South Wales	1.054	293
Australian Capital Territory	1.054	293
Victoria	1.392	387
Queensland	1.058	294
South Australia	0.96	267
West Australia	1.053	293
Tasmania	0.006	2
Northern Territory	0.742	206

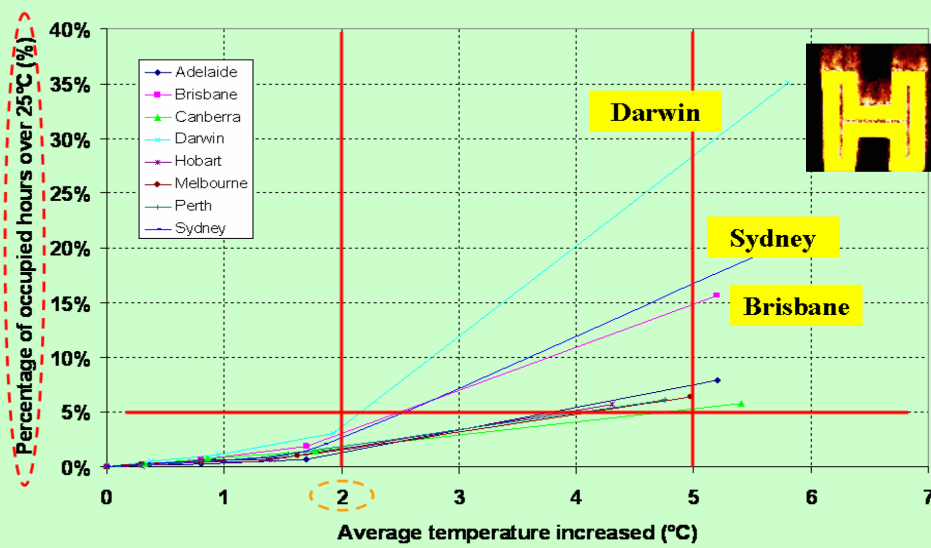


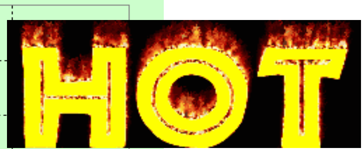


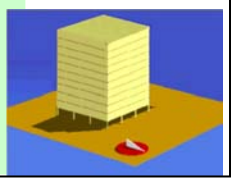
Results and Discussion

Indoor thermal environment

(% of indoor temperature > 25°C)





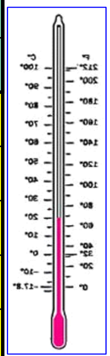


Results and Discussion

Indoor thermal environment

(% of indoor temperature > 25°C)

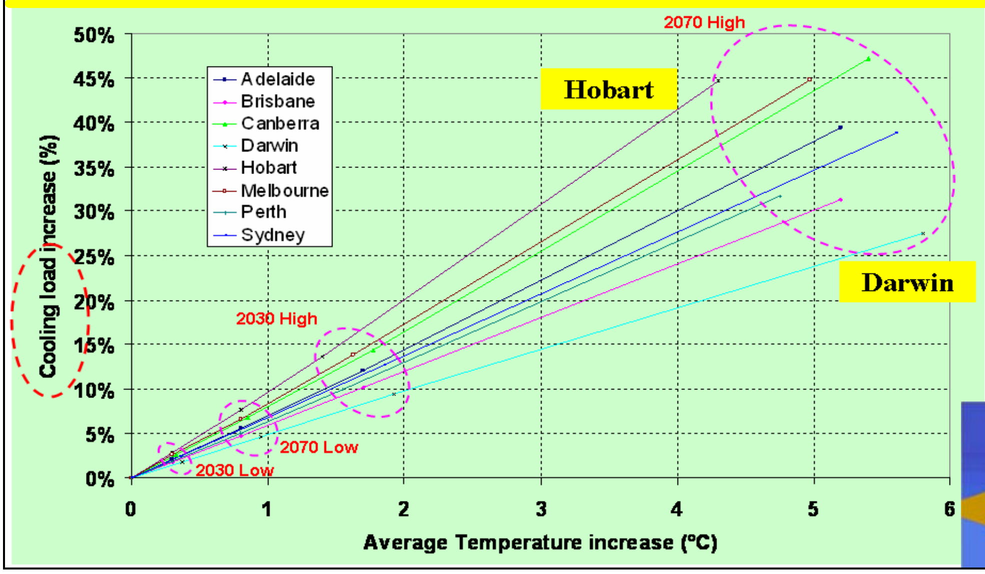
Location	Current	2030		2070	
		Low	High	Low	High
Adelaide	0.0%	0.1%	0.7%	0.2%	8.0%
Brisbane	0.0%	0.1%	1.9%	0.7%	15.7%
Canberra	0.0%	0.2%	1.4%	0.8%	5.8%
Darwin	0.0%	0.5%	3.1%	1.1%	35.0%
Hobart	0.0%	0.1%	0.7%	0.4%	5.7%
Melbourne	0.0%	0.2%	1.0%	0.5%	6.4%
Perth	0.0%	0.2%	1.2%	0.5%	6.1%
Sydney	0.0%	0.2%	2.0%	0.7%	19.6%

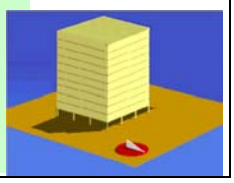


Results and Discussion

Building energy performance

(cooling load)

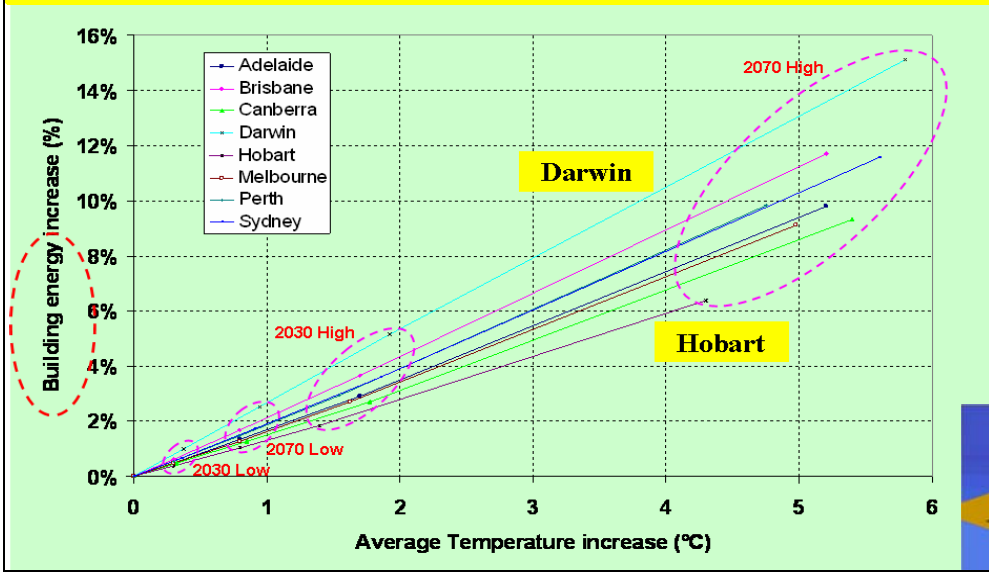


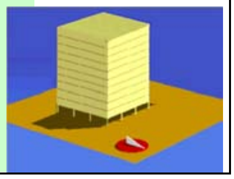


Results and Discussion

Building energy performance

(total energy use)





Results and Discussion

Projected annual increase of CO_2 emission

(kg CO_2 equivalent/m²)

Location	Year of 2030		Year of 2070	
	Low	High	Low	High
Adelaide	1.1	6.5	3.0	21.8
Brisbane	1.7	9.9	4.6	31.7
Canberra	1.1	6.3	2.9	21.8
Darwin	2.3	11.8	5.8	34.6
Hobart	0.0	0.0	0.0	0.1
Melbourne	1.5	8.3	3.9	28.3
Perth	1.4	7.5	3.8	25.2
Sydney	1.6	9.0	4.3	29.1

Results and Discussion

Projected annual increase of CO2 emission

(kg CO_2 equivalent for modelled office building)

Location	Year of 2030		Year of 2070	
	Low	High	Low	High
Adelaide	13385	79333	36248	267099
Brisbane	20935	121429	55921	388913
Canberra	13627	77272	35857	267166
Darwin	27841	144138	70819	423551
Hobart	57	280	154	971
Melbourne	18422	101993	47540	346935
Perth	17028	92324	45959	309180
Sydney	20134	110507	52694	357009

Results and Discussion

New building designed under future projected climate

(Cooling capacity)

City	Current condition		2070 High scenario condition		Required capacity increase	
	(kW)	(W/m²)	(kW)	(W/m²)	(W/m²)	%
Adelaide	1581	129	2150	176	46	36%
Brisbane	1719	140	2319	189	49	35%
Canberra	1527	125	2132	174	49	40%
Darwin	2143	175	3109	254	79	45%
Hobart	1151	94	1486	121	27	29%
Melbourne	1577	129	2020	165	36	28%
Perth	1752	143	2303	188	45	31%
Sydney	1601	131	2554	208	78	59%

Results and Discussion

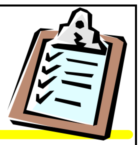
New building designed under future projected climate

(Cooling load at weather condition of 2070 high scenario)

Location	Design at Current Climate			Design at Future Climate		Difference
	Current	2070 High		2070 High		
	Cooling load (MWH)	Cooling load (MWH)	Increase	Cooling load (MWH)	Increases	
Adelaide	2026	2824	39.3%	2956	45.9%	6.5%
Brisbane	2943	3863	31.3%	4019	36.6%	5.3%
Canberra	1678	2469	47.2%	2565	52.9%	5.7%
Darwin	4395	5605	27.5%	6061	37.9%	10.4%
Hobart	1280	1851	44.7%	1928	50.6%	6.0%
Melbourne	1722	2492	44.7%	2574	49.5%	4.7%
Perth	2487	3275	31.7%	3390	36.3%	4.6%
Sydney	2408	3342	38.8%	3513	45.9%	7.1%

Conclusion

Conclusion (1)



- Global warming will entail new conditions for the built environment.
- The thermal behavior of existing air conditioned office buildings, which are typically designed based on current weather data, may also be changed.
- This paper has evaluated the impact of global warming on the design and performance of air-conditioned office buildings in Australia, which includes:
  - The likely increase of cooling loads imposed by potential global warming
  - The probable indoor temperature increases due to possible undersized air-conditioning system
  - The possible change in energy use and CO_2 emission of Australian office buildings.

Conclusion

Conclusion (2)

Through the building simulation technique, it has been found

- The existing office buildings would generally be able to adapt to the increasing warmth of 2030 year Low and High scenarios projections and 2070 year Low scenario projection.
- For the 2070 year High scenario, the study indicates that the existing office buildings, in all capital cities except for Hobart, will suffer from overheating problems.
- When the annual average temperature increase exceeds 2°C "threshold", the risk of current office buildings subjected to overheating will be significantly increased.
- With an increase of external air temperature more than 5°C, all the office buildings regardless where they are located would suffer from the overheating problem.

Conclusion

Conclusion (3)

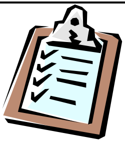
For existing buildings which are designed under current climate condition, it has been shown that

- There is a nearly linear correlation between the increase of average external air temperature and the increase of building cooling load and total energy use.
- The increases of cooling load for existing buildings vary significantly (from 2% to 47%), depending on the assumed future climate scenarios, as well as different locations.

For the new buildings, in which the possible global warming has been taken into account in the design,

- A further increase of 4-10% of building cooling load would be required for the 2070 High scenario to improve the building thermal comfort to an acceptable standard.
- The (corresponding) required increases of the cooling capacities for the new buildings in comparison with the existing buildings vary from 27 W/m² (Hobart) to 79 W/m² (Darwin).

Conclusion

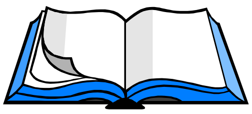


Conclusion (4)

If the energy source is assumed to be the electricity, it is found that

- Due to different fuel types and/or methods used to generate electricity, emission factors used to estimate CO_2 emission vary significantly between different states.
- in comparison with current weather scenario, the increased energy uses would translate into the increase of CO_2 emissions by 0 to 34.6 kg CO_2 equivalent/m², varying with different future weather scenarios and with different locations.

References

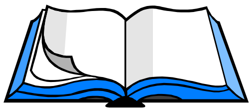


References (1)

- ABCB, 2002: Energy Use Profiles for Class 1, 2, 3, 5, 6, 7, 8, 9a & 9b Buildings [Activity Profiles]. Australian Building Code Board
- ABCB (2004), "Energy Efficiency BCA Volume 1 – Regulation Document, proposal for class 5-9 buildings RD 2004-01", Australian Building Codes Board.
- ACADS–BSG, (2003). "Australian climatic data bank – Weather_Readme.txt", ACADS-BSG Pty Ltd, 18 HIGH ST. GLEN IRIS VIC 3146
- AGO (1999), *Australian Commercial Building Sector Greenhouse Gas Emissions 1990–2010,* Australian Greenhouse Office, 1999.
- AGO (2000), *"Building for Energy Efficiency–Reducing greenhouse gas emissions from Australian buildings",* Australian Greenhouse Office, 2000.
- AGO (2003*), "AGO Emission spreadsheet tool",* Australian Greenhouse Office, 2003.
- AGO (2004),*"AGO factors and methods workbook – for use in Australian Greenhouse Office programmes",* Australian Greenhouse Office, 2004.
- Aguiar, R., Oliveira, M. and Gonçalves, H., 2002: Climate change impacts on the thermal performance of Portuguese buildings. Results of the SIAM study. Building Services Engineering Research and Technology, 23, 223-231.
- AS 1668.2-1991, 1991: The use of mechanical ventilation and air-conditioning in buildings. Australian Standard
- CSIRO (2001), "Climate change: projections for Australia", Climate Impact Group, CSIRO Atmospheric Research, Melbourne
- Dobney, P. and Sinclair, T. (1995). "Interrupting commercial air conditioning – demand management and indoor air quality implications", AIRAH Journal, Vol. 49, No. 4, pp13-18.
- Gratia, E. and De Herde, A. (2002). "A simple design tool for the thermal study of an office building", Energy and Buildings, Vol. 34, No. 3, pp 279-289
- Guan, L., Yang, J. and Bell, J.M. (2005a). *"A method of preparing future hourly weather data for the study of global warming impact on the built environment",* Proceeding of the international conference of "QUT research week", 4–8 July, 2005, Brisbane, Australia
- Guan, L., Yang, J. and Bell, J.M. (2005b). *"Implication of global warming on air–conditioned office buildings in Australia",* Proceeding of the international conference of "QUT research week", 4–8 July, 2005, Brisbane, Australia
- Guan, L. (2006). "The implication of Global warming on the energy performance and indoor thermal environment of air-conditioned office buildings in Australia", PhD thesis, Queensland University of Technology, Australia.

References

References (2)



- Guan, L. (2006). “Impact of climate change on energy uses and CO2 emissions from office buildings in Australia”. Proceedings of the International Symposium on "Advancement of Construction Management and Real Estate" held in Beijing, China, between 3 – 5 November, 2006
- LBNL (2003). "Impacts of DOE-2". Simulation Research Group, Lawrence Berkeley National Laboratory (LBNL), California, USA, http://gundog.lbl.gov/.
- Levermore, G. J., Jones, A. M. and Wright, A. J. (2000). Simulation of a naturally ventilated building at different locations, ASHRAE Transactions, Vol. 106 (PA, No. pp 402-407
- Houghton J.T, Ding Y., Griggs D.J., Noguer M., van der Linden P.J., Dai X., Maskell K. and Johnson C.A. (editors), (2001), “Climate Change 2001: The Scientific Basis”, IPCC third assessment report, Working group I, Cambridge University Press.
- Pretlove, S. E. C. and T. Oreszczyn, 1998: Climate change: impact on the environmental design of buildings. Building Services Engineering Research & Technology, 19, 55-58.
- Rosenthal, D.H., Gruenspecht, H.K. and Moran, E.A. (1995), “Effects of global warming on energy use for space heating and cooling in the United States”, Energy Journal, 1995, Vol. 16, No.2, p77-96
- Sailor, D. J. and Pavlova, A. A. (2003). "Air conditioning market saturation and long-term response of residential cooling energy demand to climate change", Energy, Vol. 28, No. 9, pp 941-951
- Scott, M.J., Wrench, L.E. and Hadley, D.L. (1994), “Effects of climate change on commercial building energy demand”, Energy sources, Vol 16, pp317-332
- SEDA (2000), *Tenant energy management handbook – your guide to saving energy and money in the workplace,* Sustainable Energy Development Authority (SEDA), ABN 80 526 465 581.
- Thomas, P.C. and Prasad, D.K., (1995); Energy efficient building envelopes - an Australian perspective, Proc. Of Thermal Performance of exterior Envelope of Buildings Conference V1, ISBN 1-883413-29-X, December, Clearwater Beach Florida, pp. 697-703.
- van der Linden, K., Boerstra, A. C., Raue, A. K. and Kurvers, S. R. (2002). Thermal indoor climate building performance characterized by human comfort response, Energy and Buildings, Vol. 34, No. 7, pp 737-744
- Winkelmann, F.C, Birdsall, B.E., Buhl, W.F., Ellington, K.L., Erdem, A.E., Hirsch, J.J. and Gates, S. “DOE-2 BDL Summary Version 2.1E” Lawrence Berkeley Laboratory, University of California, Berkeley, California, USA, November 1993
- Wright, 2002: Evidence for climate change relevant to building design in the UK, 1976-2000. Building Services Engineering Research and Technology, 23, 279-285