مؤتمر عجمان
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Energy performance resilience of UAE buildings to climate change.

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UAE buildings context

- widespread use of modern technologies
- high thermal comfort & amenity expectations
- hot arid climate

…therefore significant challenges for low energy building

A current typical weather year

- above 24°C outdoor temperature for 75% of yearly working hours
- above 60% relative humidity for 20% of yearly working hours
- solar radiation (global) above average clear sky level of 893 W/m^2 for 15% of yearly working hours

…high conductive heat gain through fabric, high convective heat gain from incoming air, significant dehumidification needed, high solar gains

Rapid growth over past decades exhibits trends in global architectural aesthetics and building functions.

Extensive use of advanced materials and technologies (glass & cladding systems).

High rise towers, office and residential combined with commercial units and multi-storey car parks.

…however a new Emirati architectural aesthetic & broad green building credentials being established

However the main trend has been increasing proportions of glazing in facades
(Aboulnaga, 2006)

…allowing ever greater levels of solar gain and heat conduction across building envelopes

Projections of climate change indicate the extent of challenges from climatic conditions will only increase.

Study perspective

Investigation of the **fundamentals** of climate impacts on building energy performance to identify the building design attributes most influential under current and projected future climate characteristics…

Study approach

Commercial buildings account for 47% of total electricity demand

Air conditioning typically accounts for 65-80% of annual energy demand in UAE buildings (Radhi, 2010)

Typical basecase building (average moderate/high performance envelope)

- *high rise office tower*
- *mid-floor (33rd floor) square open plan office with central services core*
- *standard internal heat gains*
- *8.0 l/s per person fresh air*
- *typical element constructions, external walls U = 0.38 W/m^{2}K, adiabatic roof and floor*
- *38% glazing, U = 1.8 W/m^{2}K, solar transmission 0.28*
- *airtightness 0.25 ach*
- *no overshadowing*
- *no external shading devices or window recesses*
- *indoor setpoint of 24°C with 10 hour daily operation (08:00-18:00)*
- *dehumidification control setpoint of 60%, no humidification*

Previous studies *(climate change building energy impacts in UAE/GCC)*

Studies reported in the literature based on detailed whole building models focussed on technologies to reduce annual cooling demand.

- residential villas 10% to 35% increase in air conditioning demand by 2050 *(depending on future growth scenario)*

- effective commercial building retrofit options identified as additional insulation, increased thermal mass and sizing of chillers

- building specific approach dilutes transferability of findings

Study aims

Examine drivers of cooling energy demand

(implications of UAE climate on the fundamental heat exchange processes driving cooling demands)

- understand the relative influence of the various heat exchange paths on whole building total energy performance

- identify generic design issues to be tackled

- findings that can be readily understood for any building in UAE

- interpretations that can be applied at architectural concept design stage and when planning retrofits

Studies of building energy impacts of future climates

- Growth and development scenarios
- Climate models – GCM's and RCM's
- High uncertainties
- Probabilistic methods (Jenkins et al., 2011)

Projected future climates *(2020, 2050, 2080)*

Morphed GCM hourly data to hourly weather data files for dynamic simulation

- CCWorldWeatherGen (Jentsch et al., 2013)

- HadCM3, A2 SRES growth scenario 'business as usual' *(sustained moderate to high CO_2 emissions)*

- IWEC annual hourly weather data file *(EPW file format)*

Projected future climate *(2020, 2050, 2080)*

Year	Proportion of working hours T_{ext} > 24.0°C	Annual mean temperature °C	Proportion of working hours RH_{ext} >60 %	Proportion of working hours I_g > 893.0 W/m^2
Current	75%	27.14	20%	15.8%
2020	79%	28.56	18%	15.7%
2050	86%	29.94	17%	15.1%
2080	92%	31.86	16%	14.6%

Note: I_g = 893.0 W/m^2 is the amount of solar radiation under average clear sky conditions

- increasing frequency of high external air temperature

- increasing external air temperature

- reduction in relative humidity

- small reduction in solar radiation

Basecase results (no retrofits)

- future energy performance with no retrofits

- increase in annual energy demand of 22.2% by 2050

- increase in annual energy demand of 40.0% by 2080

Table 2 Basecase annual cooling and dehumidification demand intensity

Year	Annual cooling + dehumidification demand ($kWh/m^2.yr$)	Change compared to Current weather year (%)
Current	149.6	-
2020	165.8	+10.8
2050	182.8	+22.2
2080	209.3	+40.0

Basecase results (no retrofits)

Table 3 Basecase heat gains

Year	External conduction gain (MWh/yr)	Infiltration gain (MWh/yr)	Total air system input / Ratio sensible:latent (MWh/yr)	Solar gain (MWh/yr)	Internal gains (MWh/yr)	Cooling + dehumidification demand (MWh/yr)
Current	3.0	3.6	31.6 / 2:1	30.6	80.0	172.9
2020	4.0	6.1	40.5 / 2:1	30.7	80.0	191.7
2050	4.9	8.5	50.6 / 1.3:1	30.6	80.0	211.3
2080	6.3	11.8	67.0 / 1:1	30.5	80.0	242.0

Note: Internal gains include those due to people, lighting and equipment. Air system input includes both sensible and latent demands of conditioning incoming fresh air to 20°C.

- conduction gain across envelope doubles to 2080
- infiltration gain triples to 2080
- largest environmental heat gains are conditioning of supplied fresh air & solar gain
- solar gain doesn’t increase into the future but gain from fresh air does
- latent heat gain from supplied fresh air becomes as influential as sensible heat gain

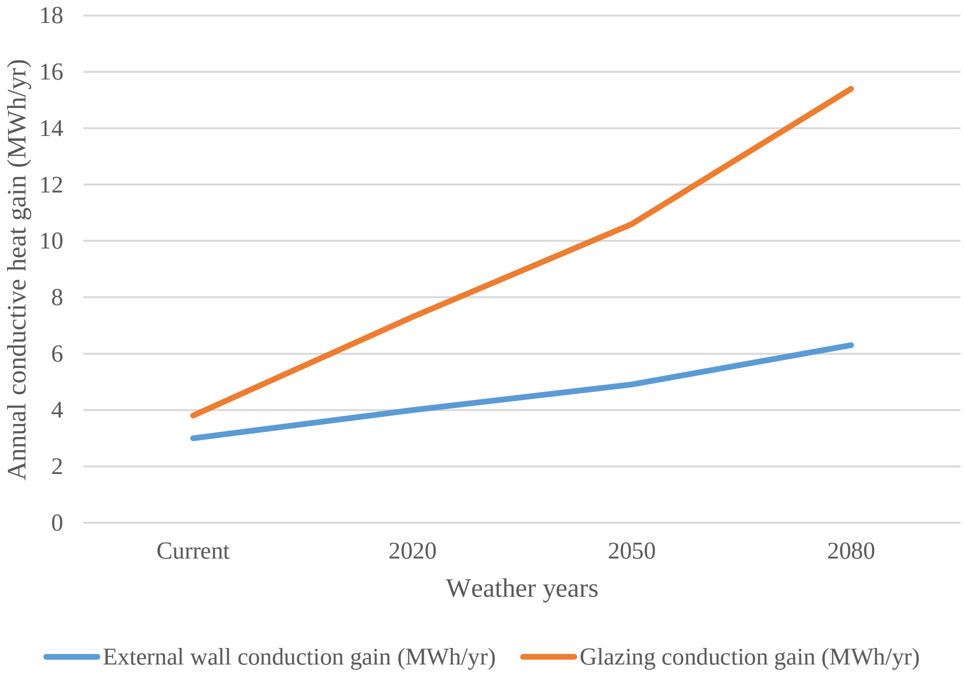
Basic fabric retrofit options

Table 4 Glazing annual conduction gains

Year	Basecase glazing annual conduction gain (MWh/yr)	Retrofit glazing annual conduction gain (MWh/yr)	Retrofit glazing reduction in annual coo demand compared to Basecase (%)
Current	3.8	2.8	1.5
2020	7.3	4.5	1.5
2050	10.6	6.2	2.5
2080	15.4	8.7	3.1

Table 5 External wall annual conduction gains

Year	Basecase external wall annual conduction gain (MWh/yr)	Retrofit external wall annual conduction gain (MWh/yr)	Retrofit external wall reduction in ann cooling demand compared to Baseca (%)
Current	3.0	1.6	0.5
2020	4.0	2.1	0.8
2050	4.9	2.6	0.9
2080	6.3	3.3	1.0



- external shading *(i.e. 1.5m fixed shading device on all glazing)* reduces cooling demand by 5.5% under current conditions to 3.9% in 2080.

Conclusions

- external **solar shading** provides largest reductions in cooling demand but does not increase resilience into the future

- improving **fabric insulation** levels has little impact on cooling demand but does increase resilience

- high levels of **airtightness** have comparatively significant impact on cooling demand and also increases resilience

- comparatively large reductions in cooling demand and increased resilience, similar in magnitude to external shading, lie in increasing the **efficiency of conditioning fresh air** supply