The Potential of Passive and Hybrid **Downdraught Cooling**

Rosa Schiano-Phan, Sao Paulo 23rd Jan 2017

Downdraught Cooling

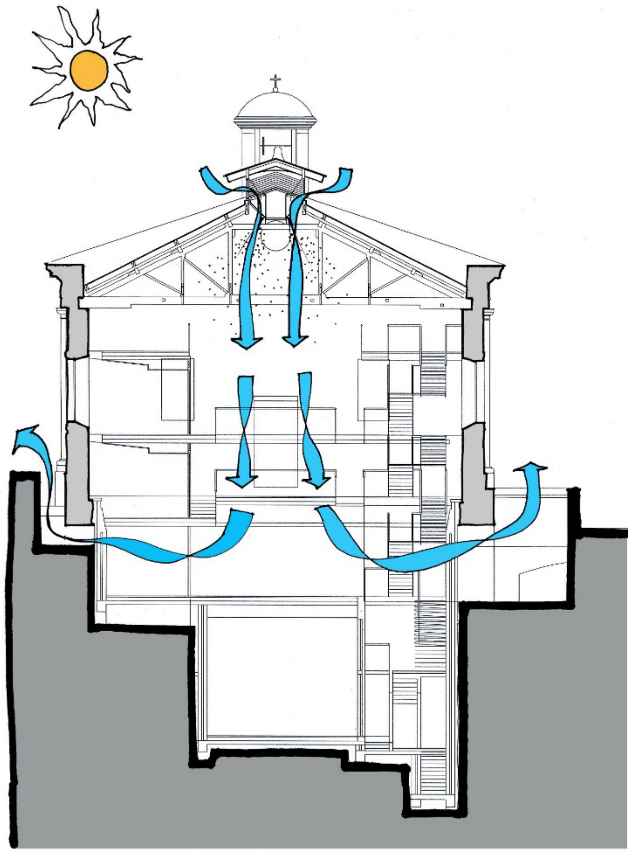
- Why Passive Cooling?
- What is Downdraught Cooling/PDEC?
- Background on PDEC Research & Application
- Building Case Studies

Why Passive Cooling?

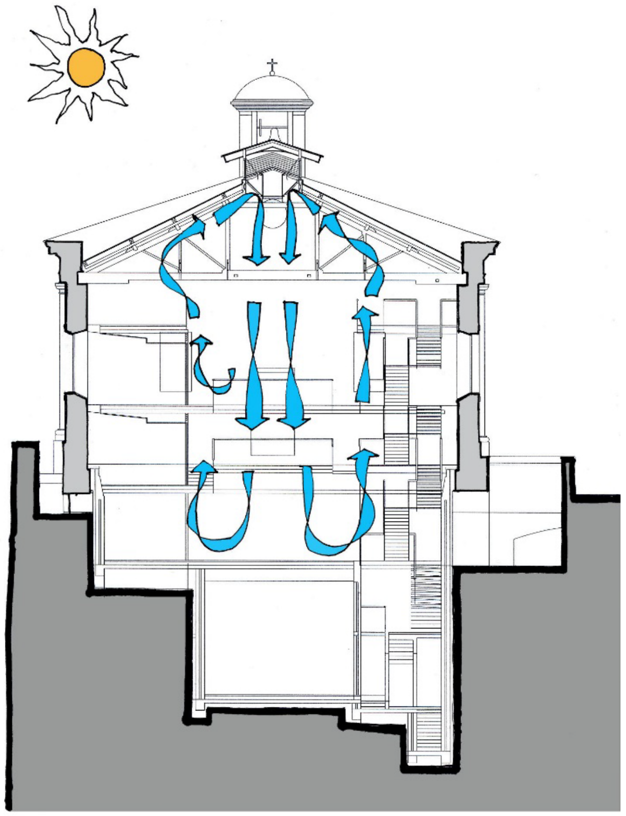
- Energy crisis (crude oil price: from 19 to 90$/barrel in 40yrs)
- Heat waves of 2003 and 2006 (excess deaths in EU)
- Increased use of A/C (70% sales increase in S EU + China, India)
- Peak electricity loads and risks of blackouts in summer
- Global warming potential of refrigerants (GWP HFCs)

What is Downdraught Cooling?

Passive & Hybrid Downdraught Cooling (PHDC)



Evaporative Cooling (in dry conditions)
PASSIVE



Cooling Coils (in humid conditions)
HYBRID

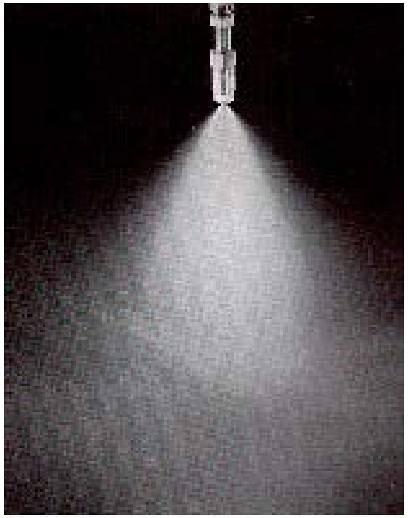
Passive Downdraught Evaporative Cooling (PDEC)

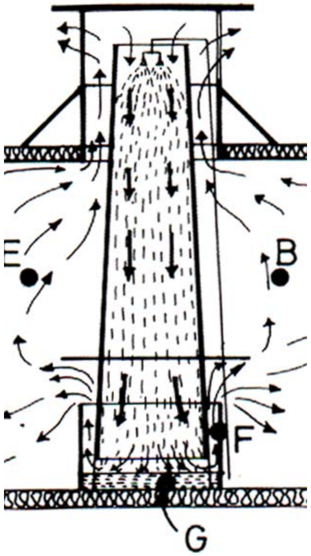
It involves the creation of a cold downdraught of air by evaporating water within an air-stream.

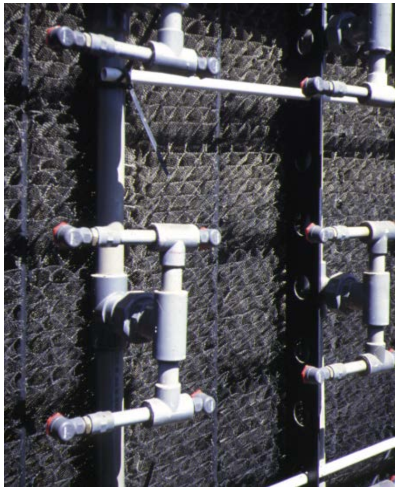
- mist of water
- irrigation of a cellulose matrix
- droplets of water
- wetted porous surfaces

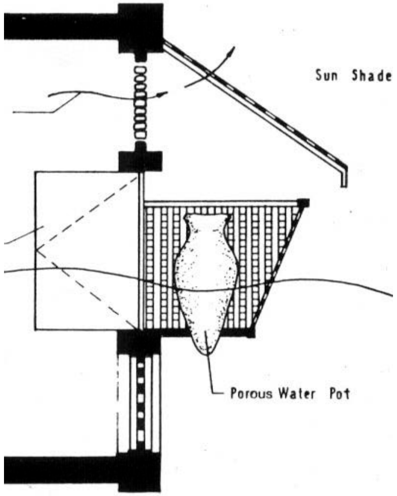
PDEC is only appropriate in hot dry conditions.

The Hybrid system has wider applicability.

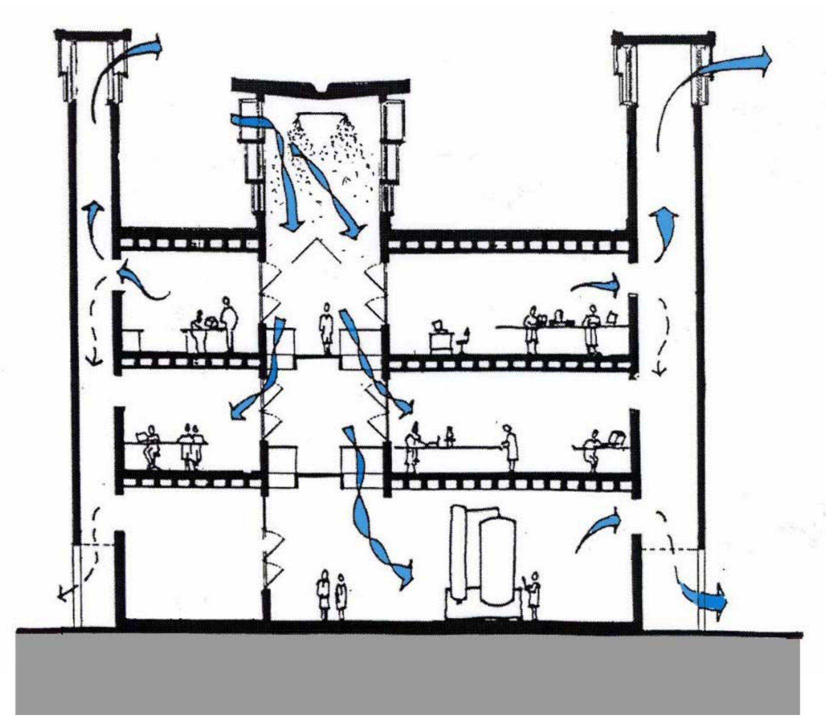


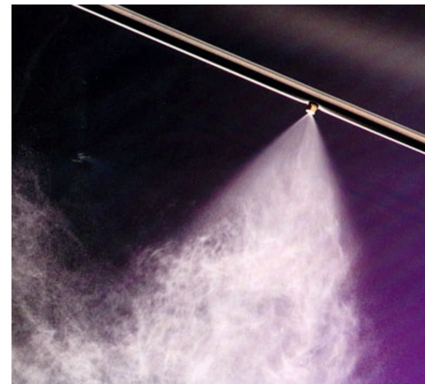




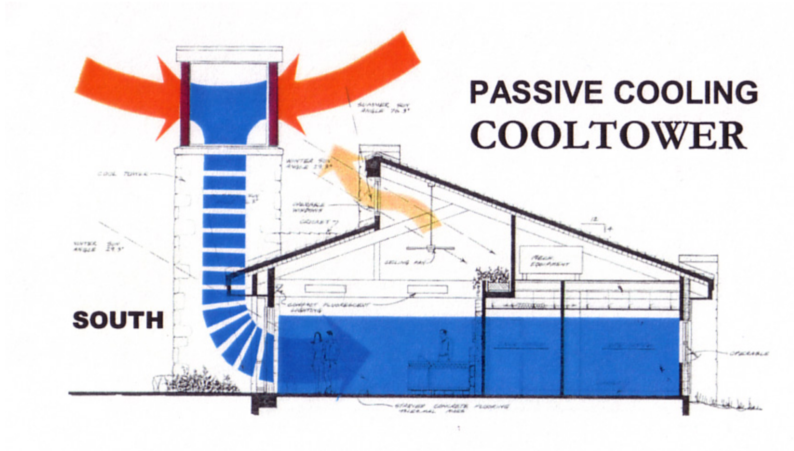


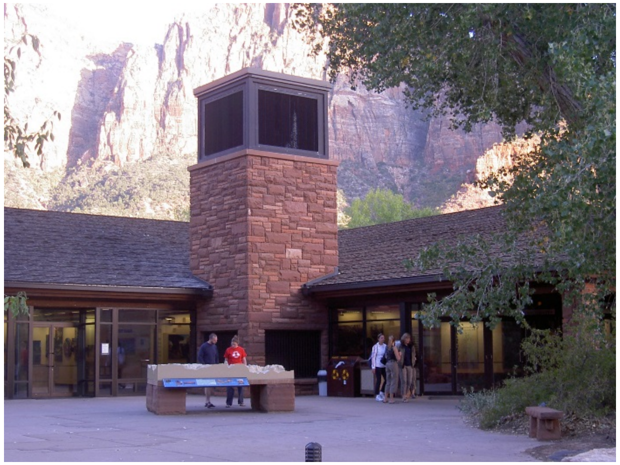
PHDC Typologies: Passive Downdraught Evaporative Cooling (PDEC)



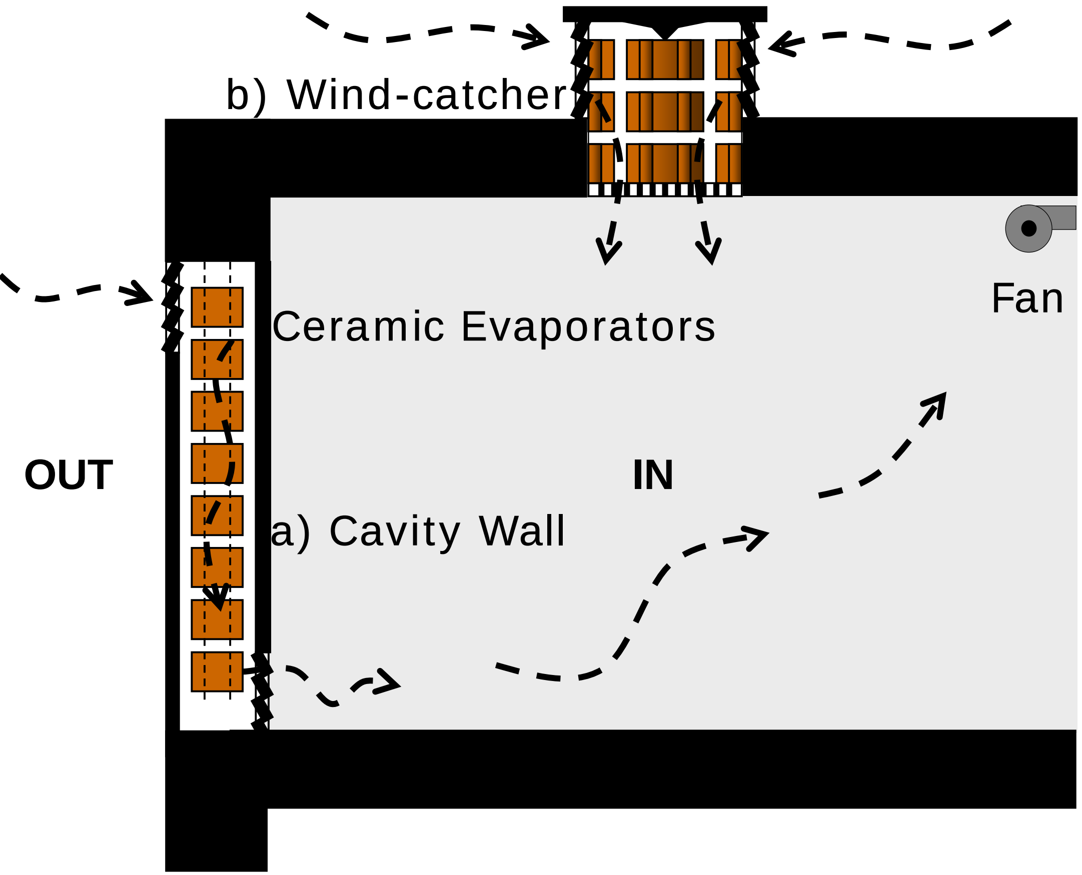


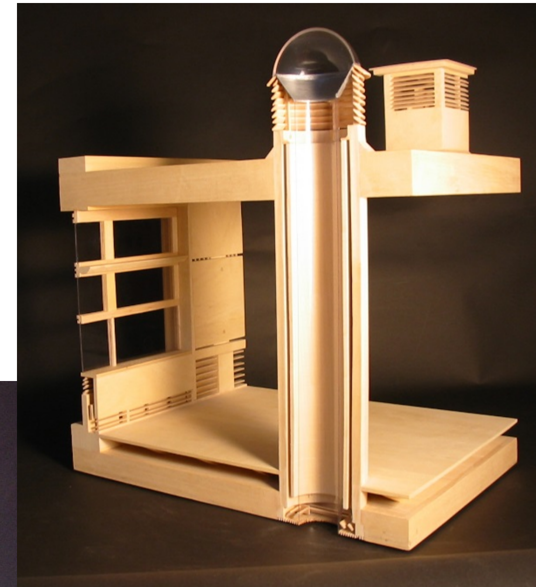
PHDC Typologies: 'Cool Towers'



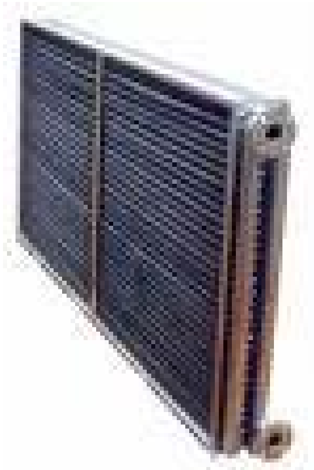


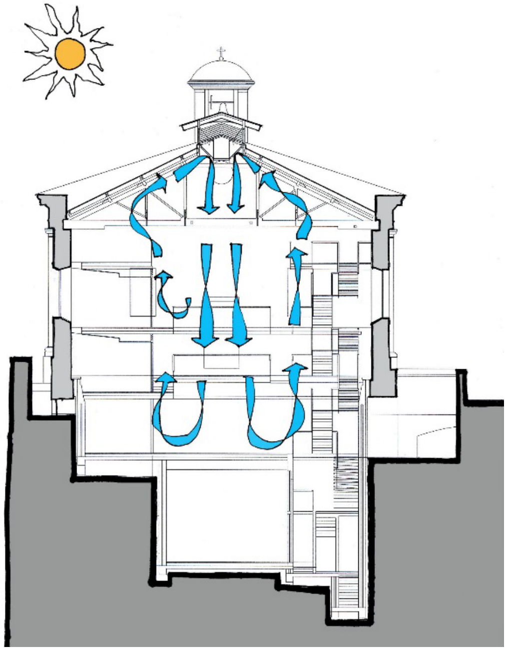
PHDC Typologies: Direct Evaporative Cooling using porous ceramic evaporators (EvapCool)



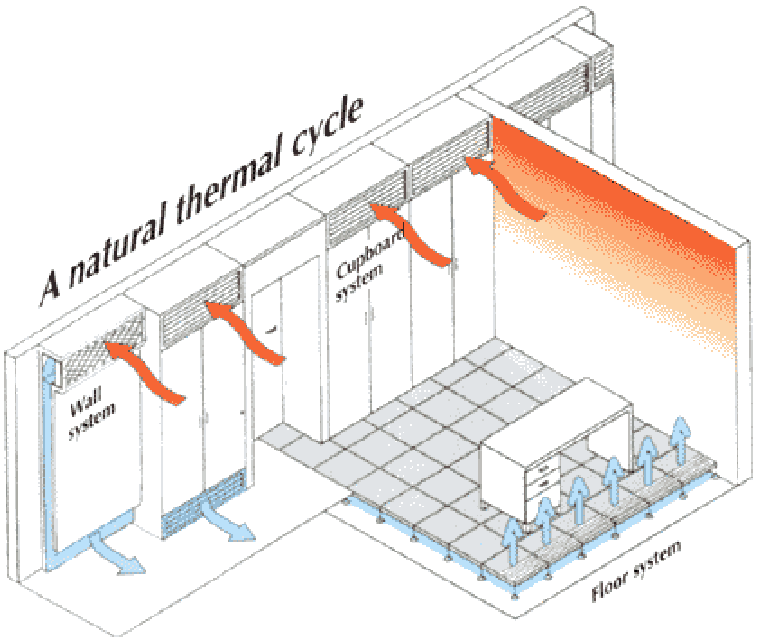


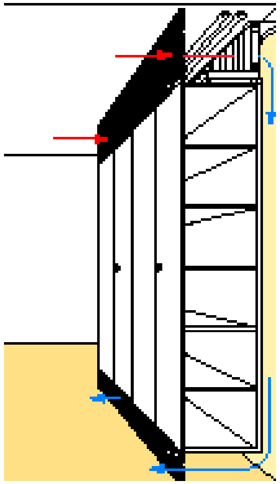
PHDC Typologies: Chilled Water Cooling Coils

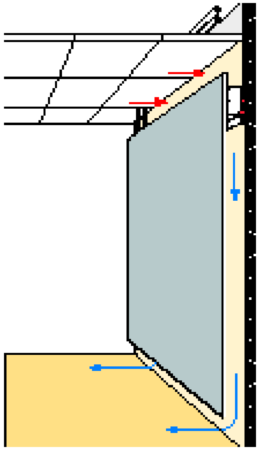




PHDC Typologies: gTherm System, ADO

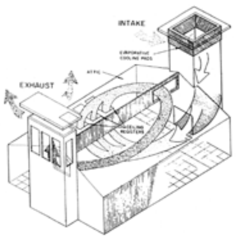






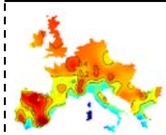
PDEC Timeline: Research & Application

Cunningham & Thompson Experimental Building



PDEC Project

EvapCool & Altener



EvapCool PhD

Sourcebook

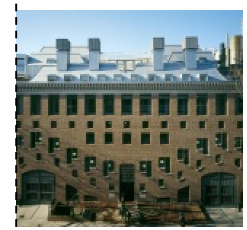
PHDC

1989 **1992** **1996- 99** **1998** **2001- 03** **2005** **2006** **2007- 10**

Seville Exposition

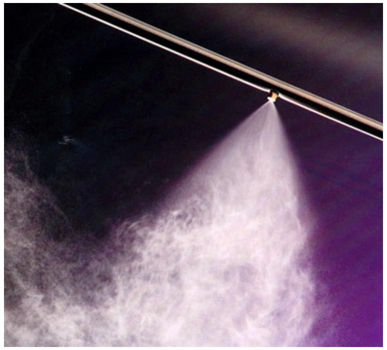
Torrent RC, India

MSE, Malta



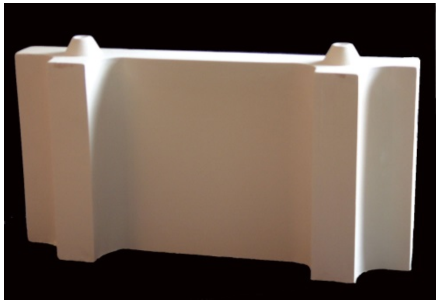
SSEES, London

Research on PDEC:



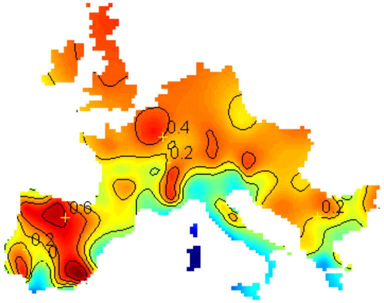
PDEC (1996-1999):

- meets 85 % of cooling load of typical office building
- deals with urban noise and pollution
- 6% capital cost saving over mechanical option



Evapcool (2001-2003):

- meets cooling loads of residential building
- avoids problems of potential microbiological contamination
- LCC smaller than conventional A/C



Altener (2001-2003):

- PDEC is applicable to 80% of S European building stock
- Energy and CO2 savings
- Can save 15% of energy demand of existing commercial buildings

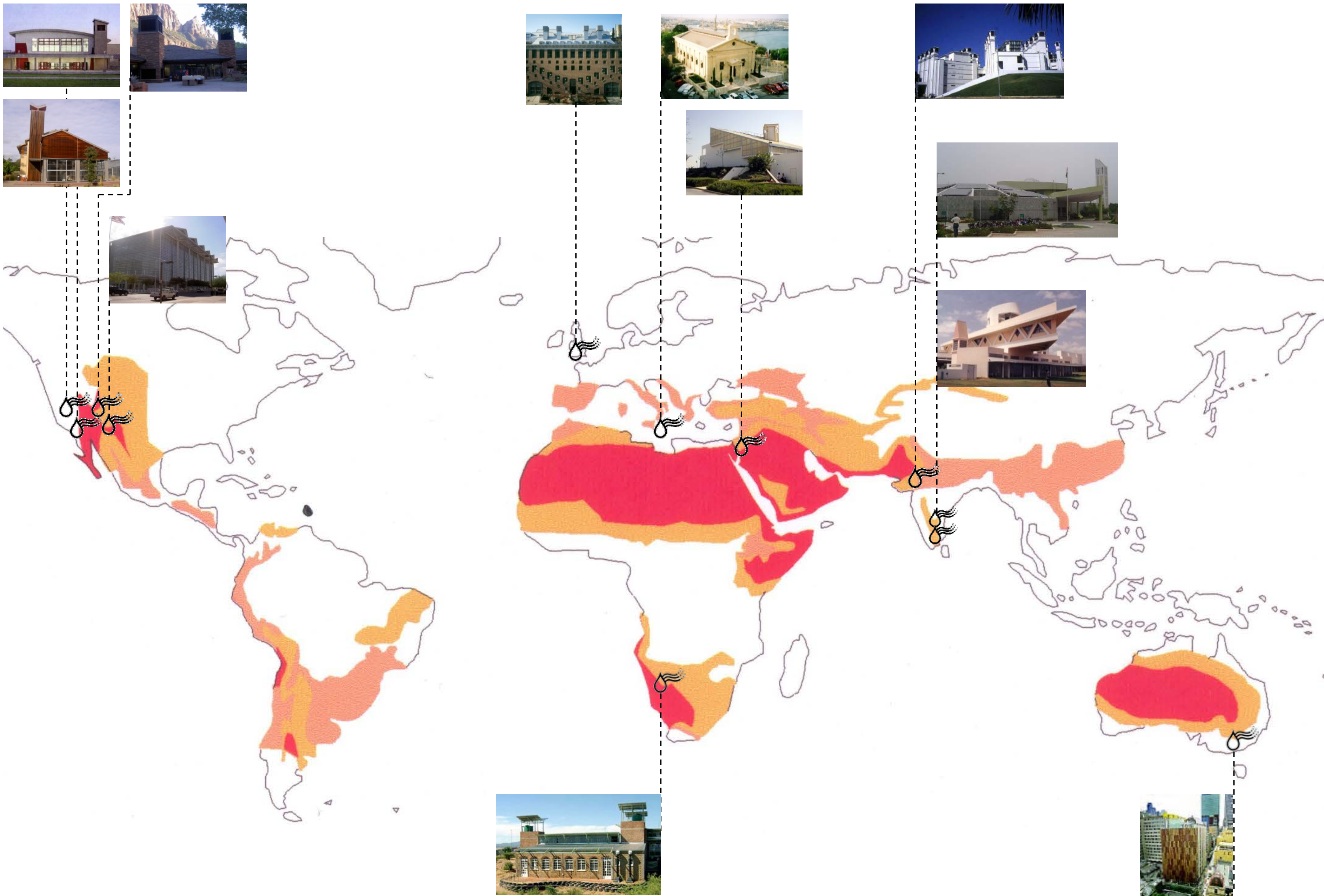
PHDC Project (2007-2010)

Dissemination of Previous Research

- Promote PHDC amongst building/design professionals and users

- Disseminate the results of previous EC research projects on PHDC and the knowledge arising from pioneering buildings

PHDC Case Study Buildings



Where can PHDC be used?

Climate Types :

- Hot Dry Regions
  Direct Evap. Cooling

- Warm Humid Regions
  Ind. Evap. + Hybrid

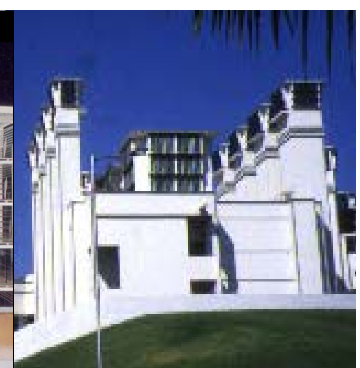
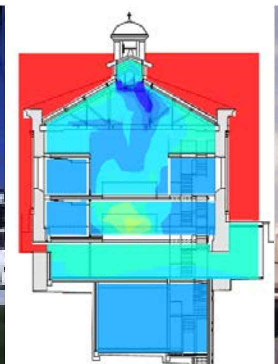
Locations:

- India
- USA
- Europe
- Middle East
- China
- S. America

Building Types :

- Residential buildings
- Offices
- Laboratories
- Educational Buildings
- Large Volume Buildings
- Commercial & Industrial




Criteria of Applicability

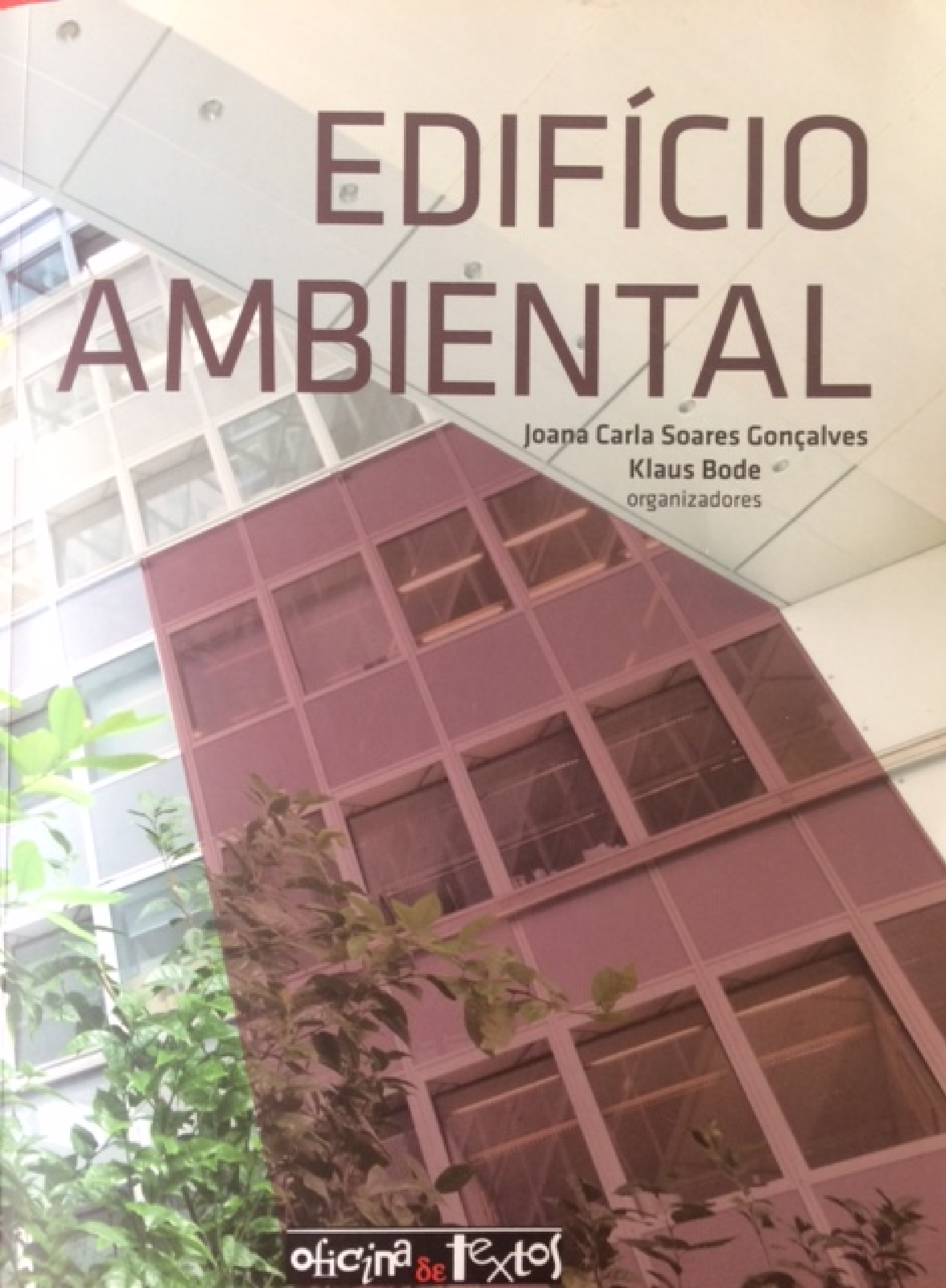
- **Max WBT not to exceed 22-24degC** (Santamouris)
- **WBT threshold: 24degC** (Givoni)
- **WBT > 24degC for 100hrs max + RH < 40%** (Liveris)
- **Rule of thumb: Passive Downdraught Evaporative Cooling can provide temperature drop = 70-80% of WBT depression**

$$T_{pdec} = DBT_a - 0.8*(DBT_a - WBT_a)$$

Post Occupancy Evaluation of non-domestic buildings using downdraught cooling:

Case Studies in the US



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A tecnologia pioneira de sfriamento evaporativo: lições difícios norte-americanos, um do de avaliação pós-ocupação

Rosa Schiano-Phan

impacto ambiental da dependência exagerada dos sistemas ati- riamento de edifícios, o conhecido condicionamento de ar, tem as últimas décadas o desenvolvimento de pesquisas na busca de ssivas alternativas. É sabido que, arquitetonicamente, a dependên- amento ativo desconecta os ocupantes do seu contexto climático, aços selados, nos quais o edifício não responde mais ao clima ex- várias linhas de pesquisa sobre resfriamento passivo nos últimos esfriamento evaporativo passivo por efeito de vento (inverso ao iné), em inglês conhecido como Passive Downdraught Evapora- g (PDEC) tem provado ser uma alternativa viável aos meios ativos ais de resfriamento de edifícios em climas quentes e secos.

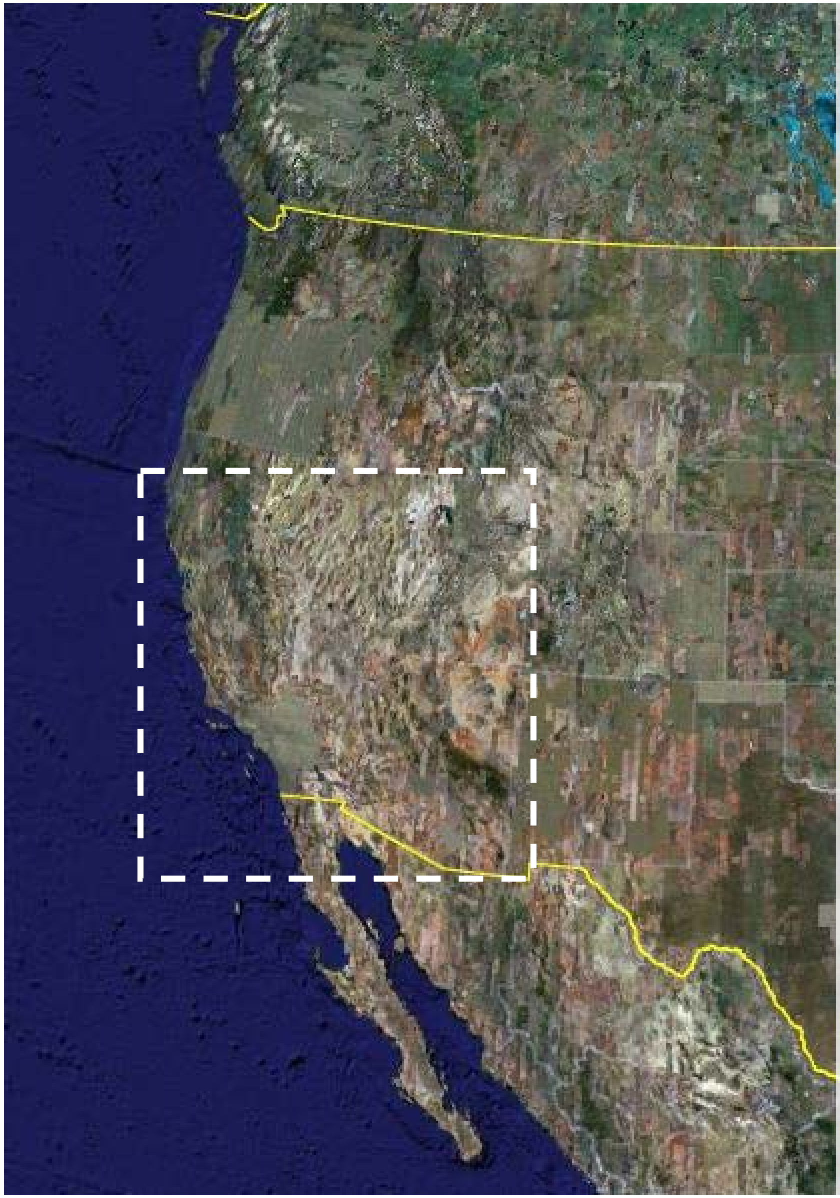
ência ao trabalho teórico e experimental de Givoni (1994) em ingham e Thompson (1986) no Arizona, há mais de duas décadas, ícios pioneiros que adotaram essa técnica inovadora tem crescido do. Essa primeira geração de edifícios demonstra a aplicação do e de uma estratégia maior, em prol do melhor desempenho ambi- o. Entretanto, dada a sua originalidade, são vários os questiona- corporação dos sistemas de PDEC, incluindo dúvidas sobre a in- ônica, a eventual interação com os sistemas prediais e a percepção uários.

dos de casos com a técnica de PDEC foram identificados nos Esta- Utah e Califórnia, nos Estados Unidos, para os quais um estudo de realizado em 2010, como parte de um projeto de disseminação com o apoio da Comissão Europeia. Esses edifícios utilizaram e sistema PDEC, acompanhados de diferentes estratégias de inte- jeto arquitetônico e de sistemas prediais. Como no caso de outras as, o estudo mostrou que a percepção de satisfação dos usuários é influenciada pela possibilidade de controle sobre as condições

pelo resfriamento de edifícios é crescente em diferentes partes do que a maior parte da população global vive em regiões de clima pelo globo. Somado a isso, a internacionalização da cultura do ado vem alimentando nos últimos anos o mercado mundial do , que ainda cresce rapidamente (IEA, 2011).

Unidos, o condicionamento de ar para o resfriamento de ambien- onsável por aproximadamente um quarto da energia consumida

PHDC Case Studies - the US context



- A/C is responsible for 16% of the US energy consumption and for 43% of the peak loads

- US air-conditioning market value in 2007 amounts to US$12 billion and expected to grow

- In August 2003 over 50 million people in eastern and central US and Canada experienced a two day loss of electrical power, with an economic cost estimated to run into billions of dollars

- In summer 2007 Phoenix experienced 32 days in same year with DBT>43˚C; draught and fires in the SW of the US

- Pioneering buildings in SW illustrating examples of passive downdraught cooling systems as alternative to A/C

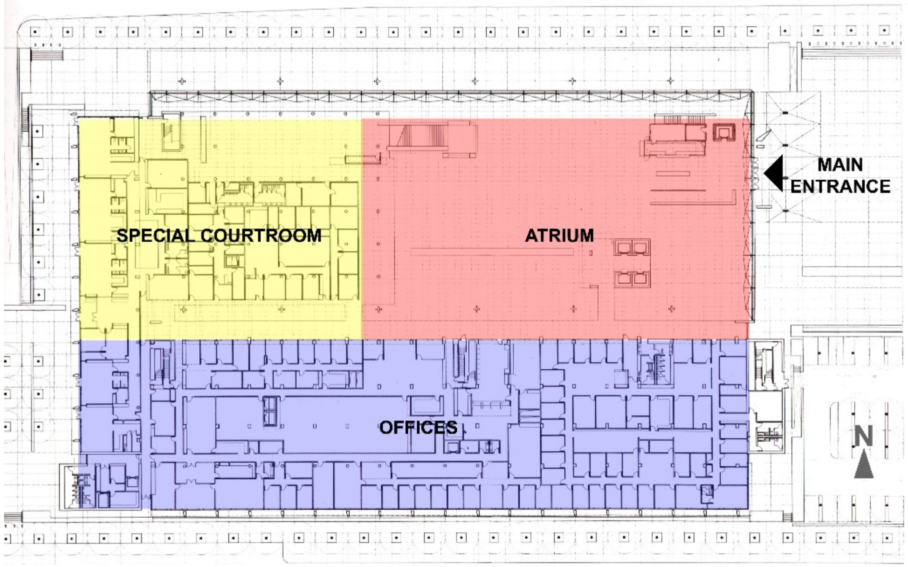
Case Study Buildings

PHDC Typologies

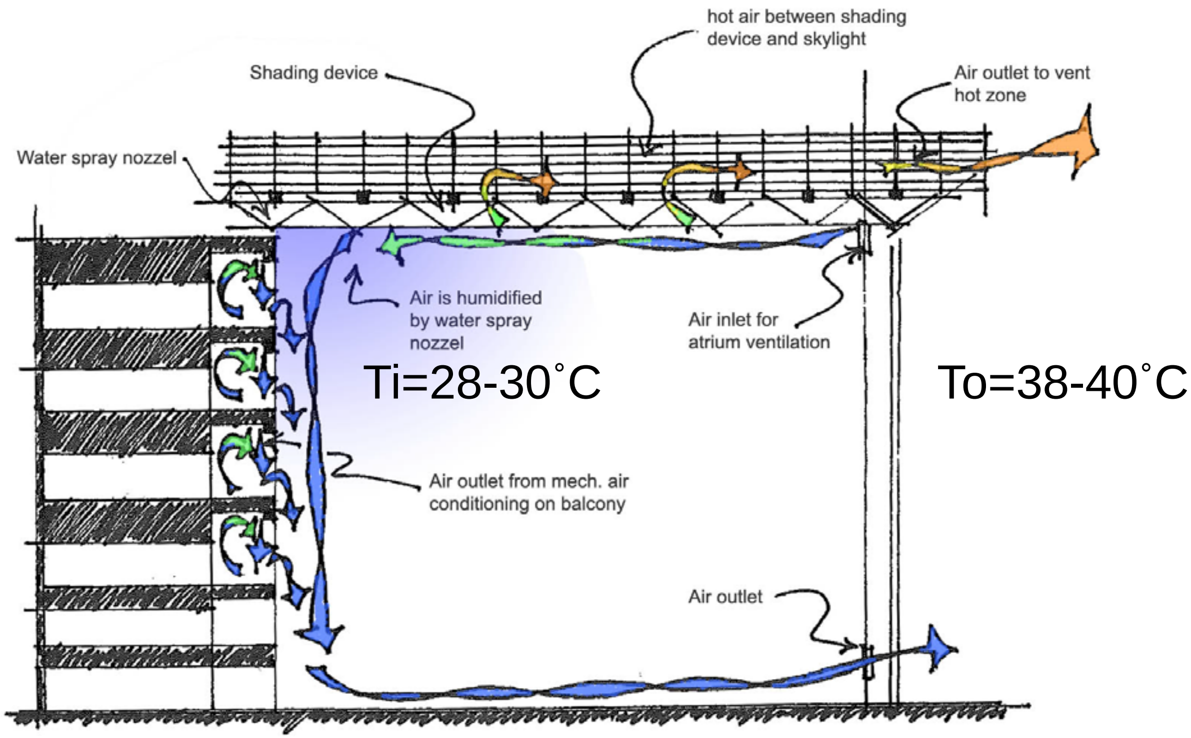
Phoenix Courthouse, Arizona (33º 26' N, 112º 04' W)

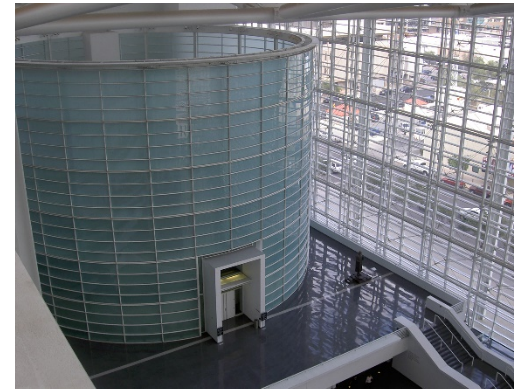
- Richard Meier Architects, 2000
- 46,500sqm six storey building
- Glazed atrium as transitional area

Photo by Scott Frances / ESTO



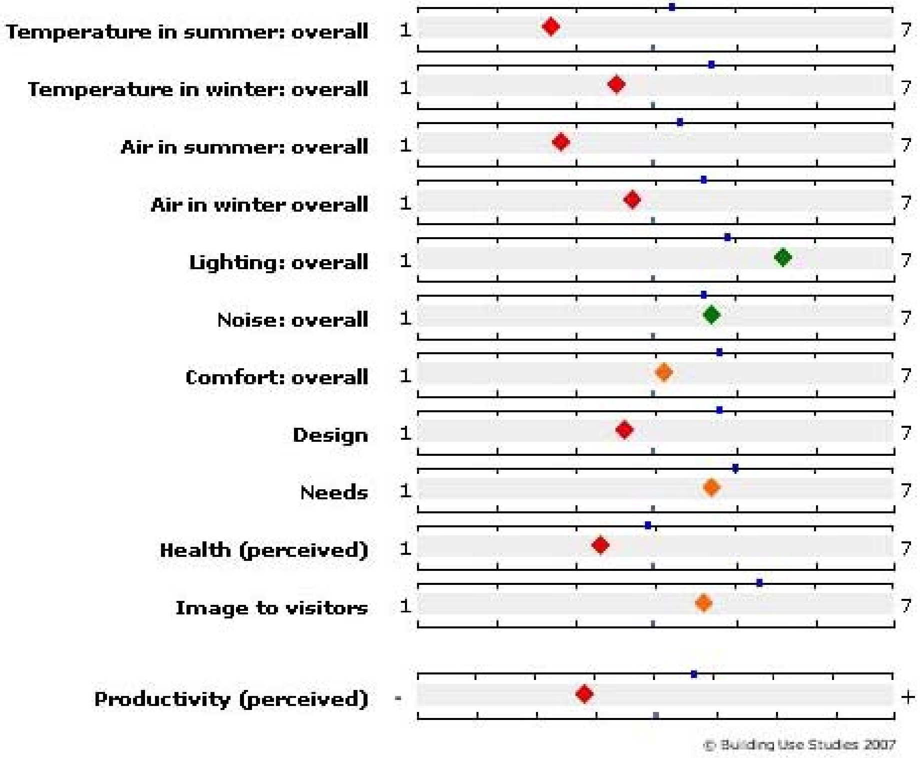
Phoenix Courthouse: Cooling Strategy





- Atrium: Passive Downdraught Evaporative Cooling (PDEC)
- Balconies & Offices: Mechanical cooling

Phoenix Courthouse: POE Results



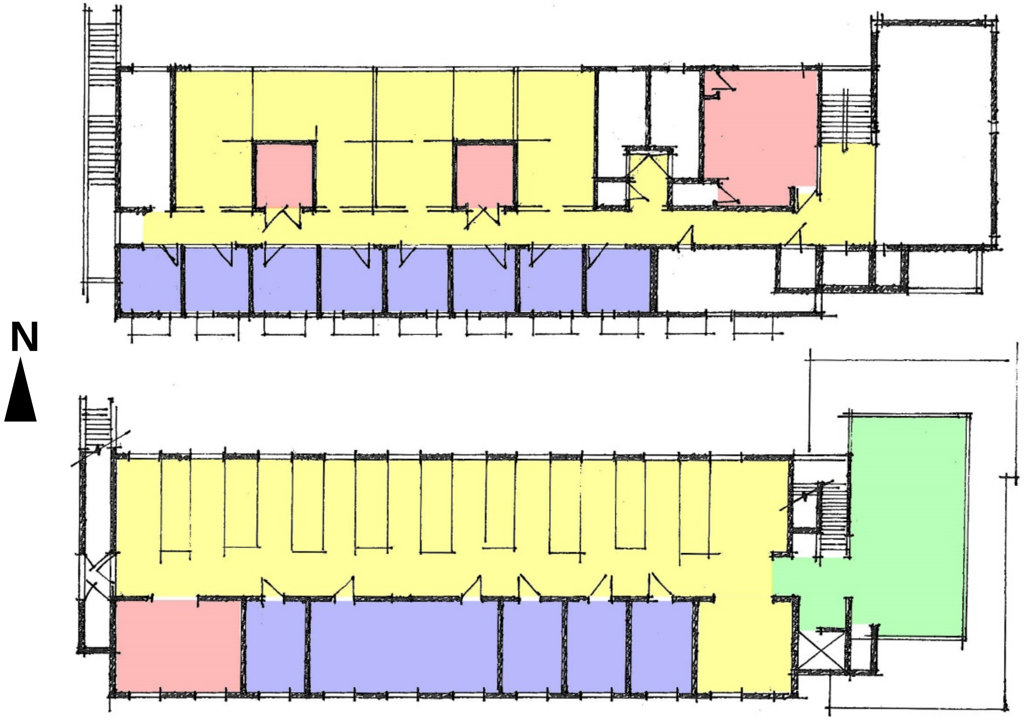
- 88% found temperature in summer too hot
- a third found that it varied during the day
- 75% had no control over heating cooling and ventilation
- Perceived decrease in health and productivity

Phoenix Courthouse: Main outcomes

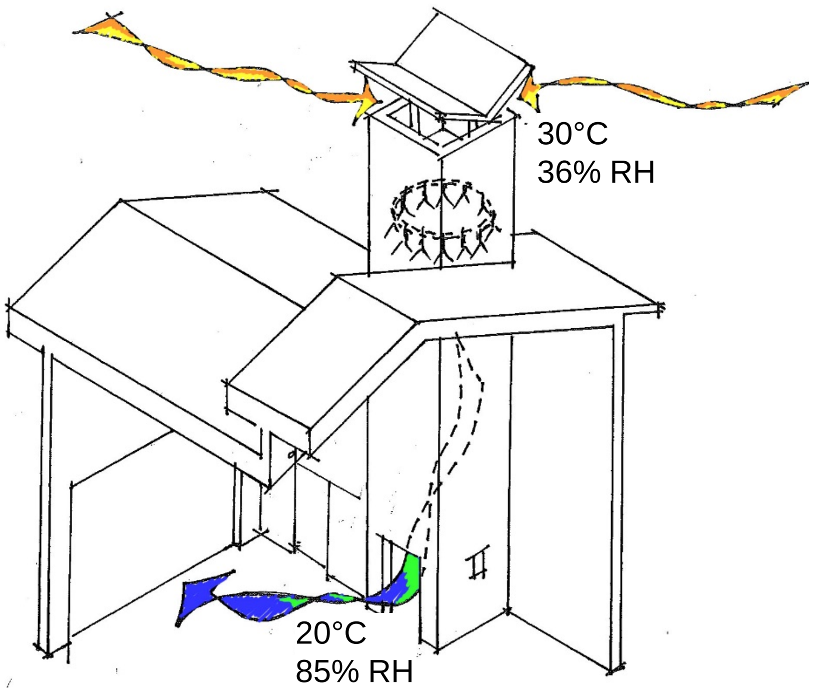
- Occupants expectations influenced perception
- Misunderstanding of the cooling strategy
- Initial technical problems with dripping of nozzles, pressure losses, control logic
- Water supply and filtration is costly and inefficient

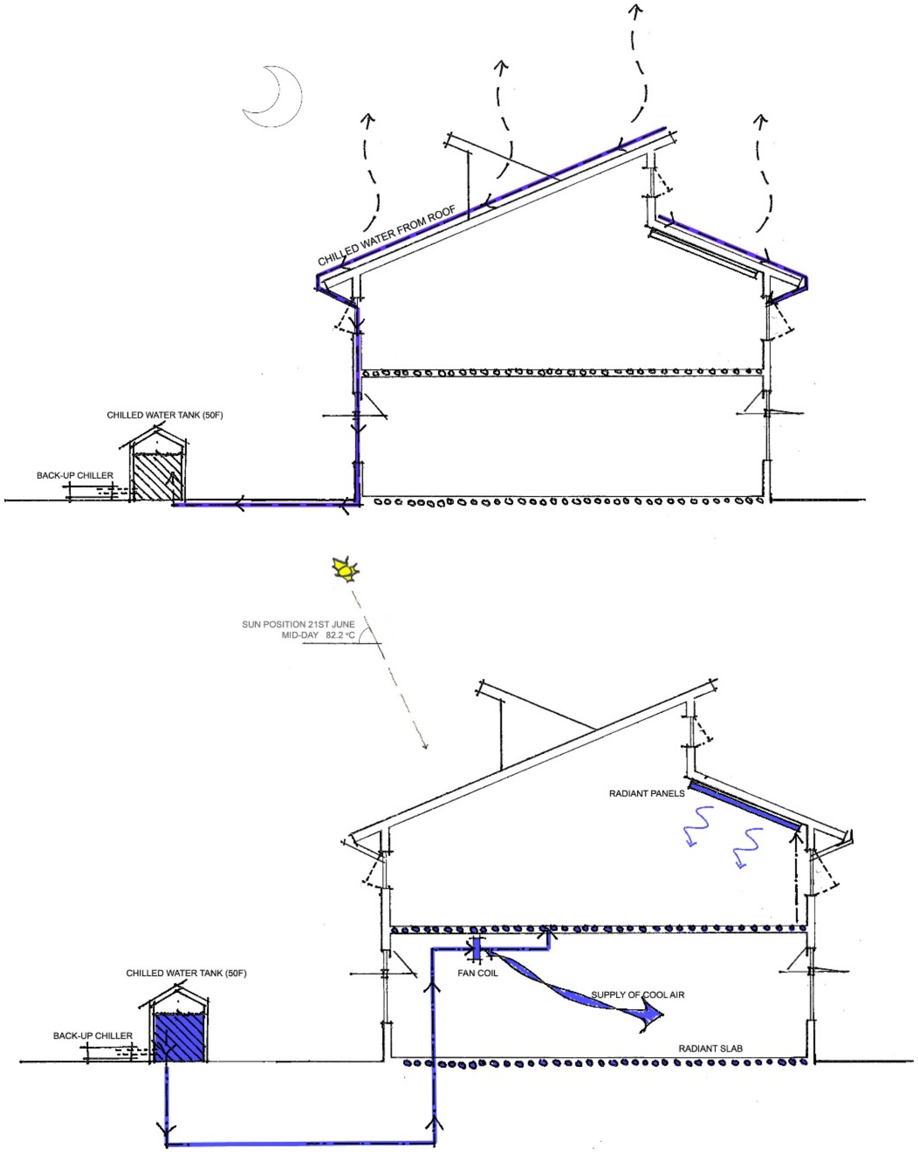
GERC Stanford, CA (37º 44' N, 122º 16' W)

- EHDD Architects, 2004
- 1,000sqm two storey building
- PDEC Tower



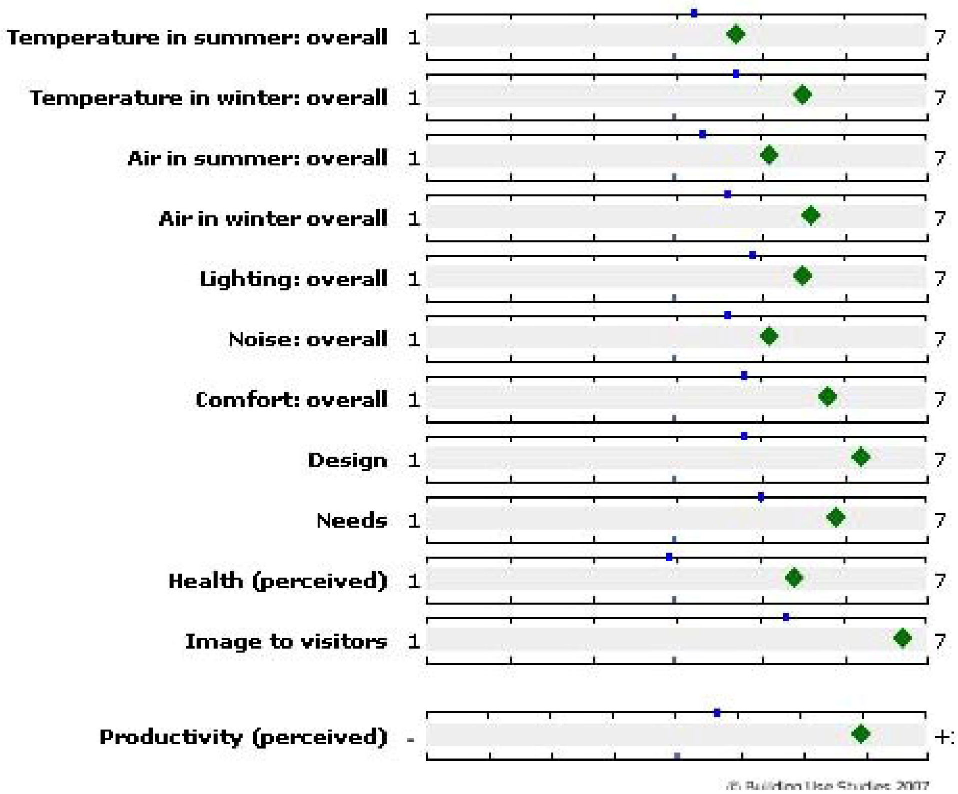
GERC Stanford: Cooling Strategy





- Lobby: PDEC Tower
- Labs: Mechanical ventilation
- Offices: Radiant Cooling

GERC Stanford: POE Results



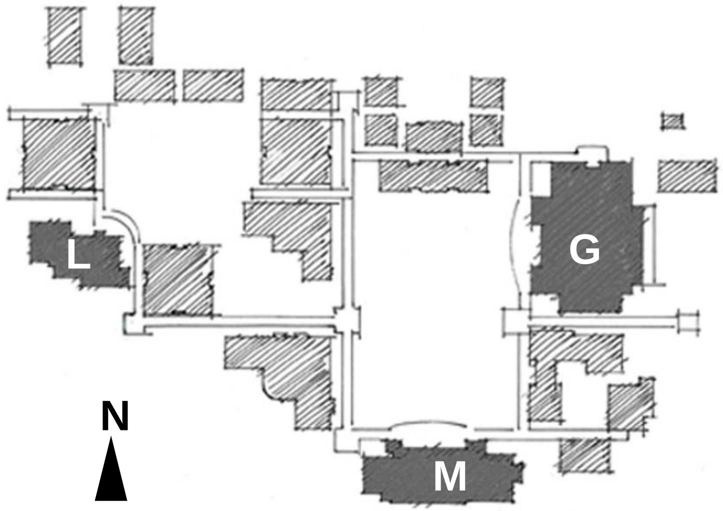
- 71% thought temperatures to be comfortable overall
- 59% found temperature in summer to be slightly warm to hot
- 47% found conditions dry
- 44% has control over ventilation
- Improved productivity

GERC Stanford: Main outcomes

- Occupants perception was influenced by their level of control over building
- Strategy and way the building works is clear amongst occupants
- PDEC is marginal but day-lighting and radiative cooling work well
- Problems with pressure of PDEC system

Kenilworth Junior High School, California (38°14’N, 122°37’W)

LIBRARY BUILDING



GYMNASIUM

- Kwok-Quattrocchi Architects, 2003-05

- Library, Gym, Multifunction Room

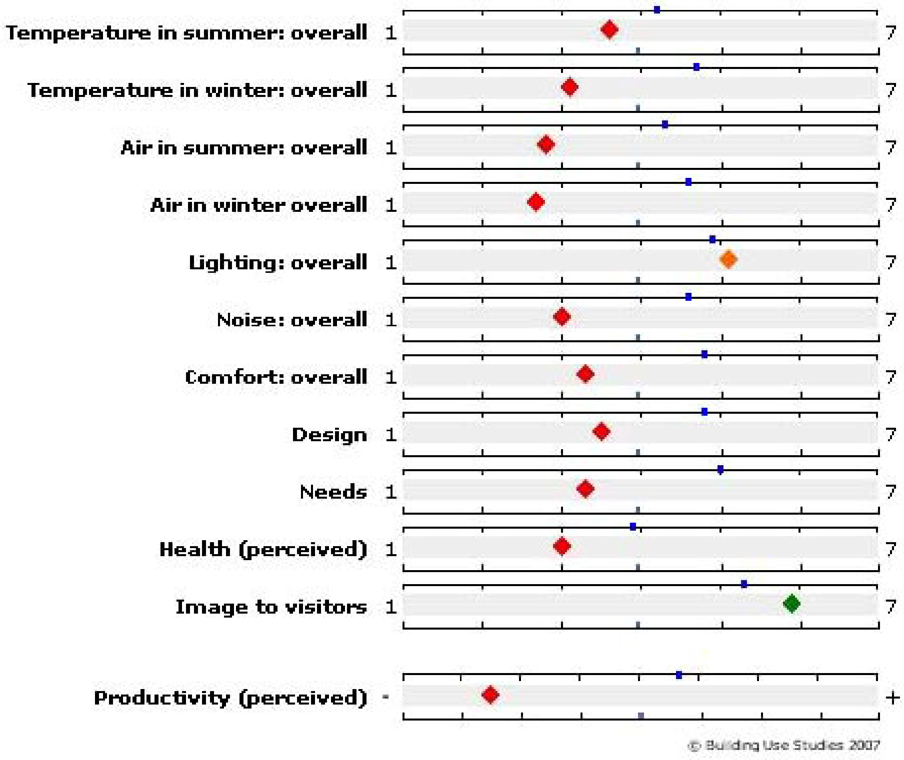
- 2,500sqm gross area

MULTI-USE ROOM

Kenilworth JH School: Passive Cooling Strategy

- Cool Towers
- Wet Cellulose mats (CELdek)
- No clear strategy of air-movement
- Gym Towers never operational
- Clash with space requirements

Kenilworth JH School: POE Results



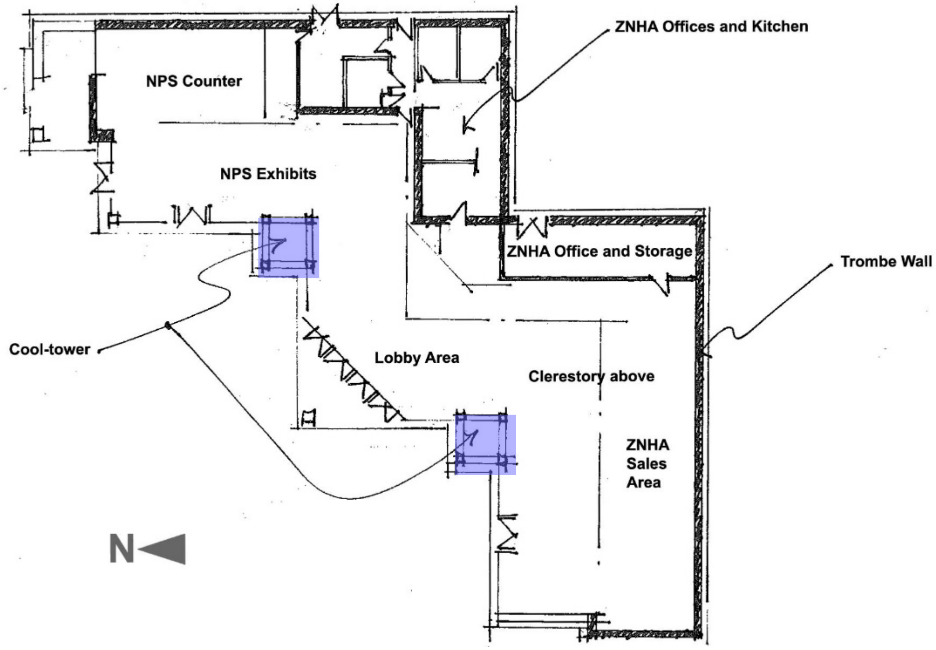
- 67% found temperature in summer too hot
- 62% were dissatisfied with air quality in summer (stuffy, smelly)
- 100% had no control over heating, cooling and noise
- Decrease in health and productivity

Kenilworth JH School: Main outcomes

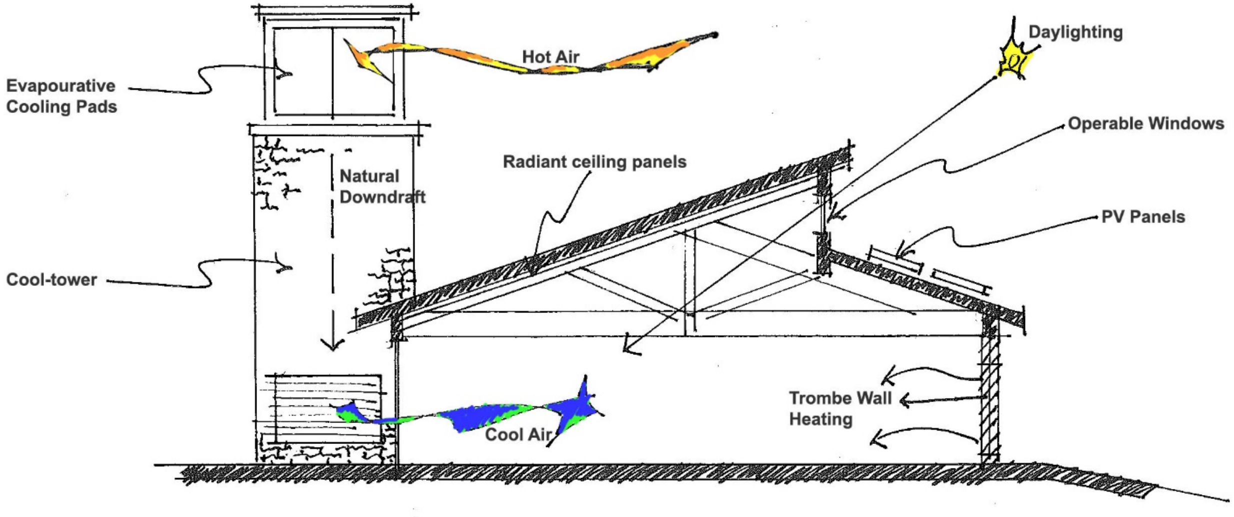
- Disregard of occupants’ needs at brief stage
- Occupants feel totally alienated by buildings
- Problems of noise in multifunction and gymnasium
- High RH in the library
- Poor performance due to exposure of wet pads to solar gains and bird nesting

Zion National Park Visitor Centre, Utah (37°18'N, 112°99'W)

- 800sqm one storey building
- Designed by NPS, 2000
- Two Cool Towers

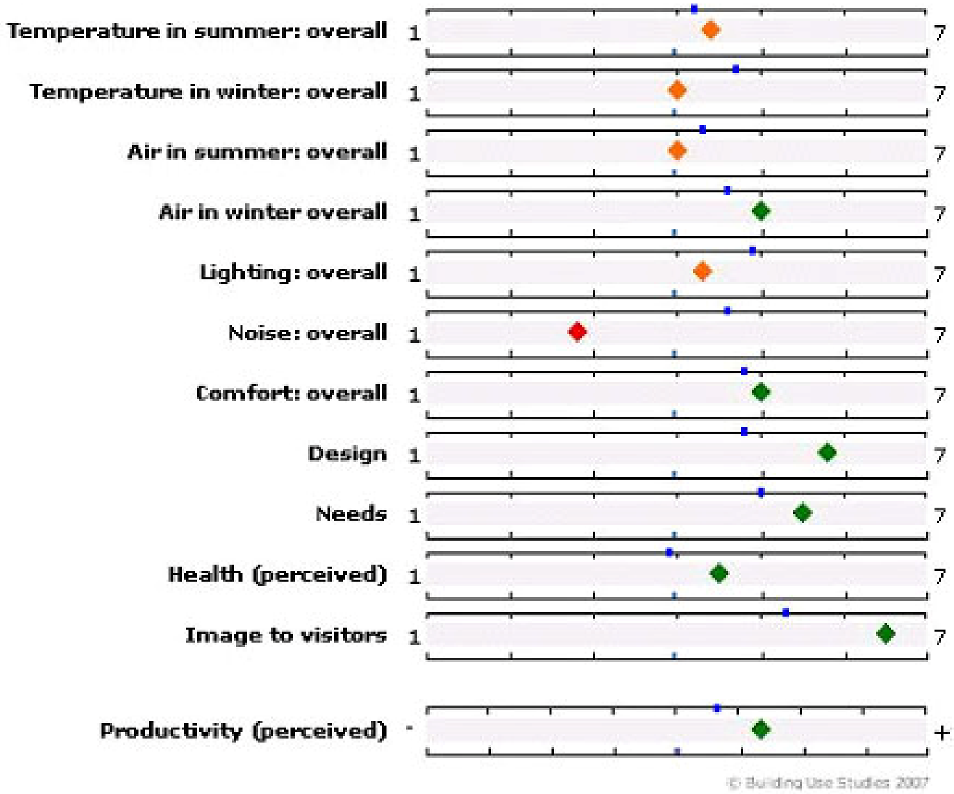


Zion Visitor Centre: Passive Cooling Strategy



- PDEC in main reception area and bookshop
- Wet Cellulose mats (CELdek)
- Monitoring revealed Ti=27˚C when To=47˚C

Zion Visitor Centre: POE Results



- 60% found that temperatures in summer were hot and varied during the day
- 83% had no control over heating cooling and ventilation
- Perceived increase in health and productivity

Zion Visitor Centre: Main Outcomes

- Troubleshooting handled very efficiently by building manager
- Strategy and way the building works is clear amongst occupants
- Cool Towers are well maintained
- Discomfort during periods of high occupancy

Conclusion

PDEC systems are a practical option to avoid mechanical cooling but their success, both in terms of performance and occupants' perception, will depend on:

- Appropriateness of the overall building design strategy
- Suitable system design
- Components' specification
- On site maintenance
- Robustness of control system
- Occupants' awareness of building strategy
- Occupants' degree of control over their working environment.

Obrigada!

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