WORLD SB14 BARCELONA October 28/30th 2014
Sustainable Building: RESULTS

What conditions must models and methods fulfill on an urban scale to promote sustainability in buildings?
Session 121 10-11:30 AM Thursday

Mitigation of the energy-water collision through integrated rooftop solar and water harvesting and use for cooling: A critical review

Peterson, Eric

Centre for Biodiversity and Conservation Science and School of Civil Engineering, University of Queensland, St Lucia, Australia

Institute for Sustainability and Innovation, Victoria University, Melbourne, Australia

The University of Queensland Australia

Victoria University of Technology

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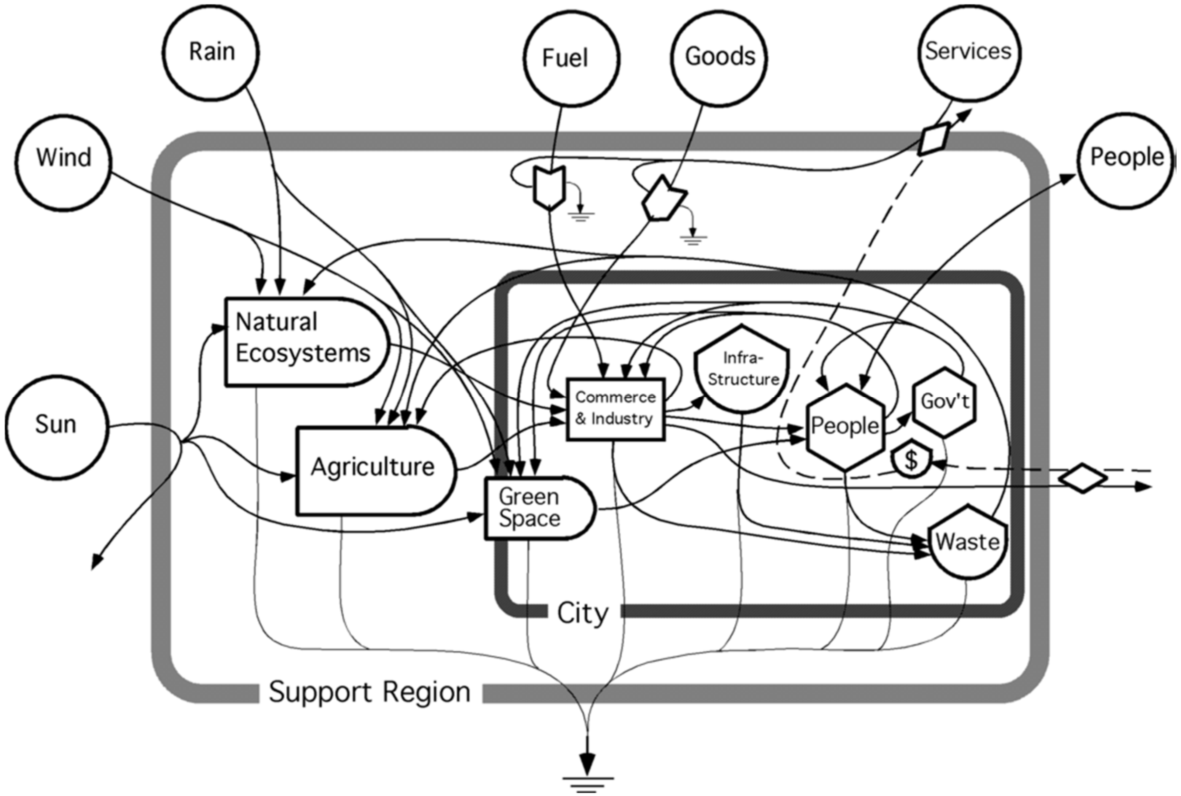
What conditions must models and methods fulfill on an urban scale to promote sustainability in buildings?

*Energy is measured by intraconvertable units, but these do not ensure that a particular source of energy will serve a useful purpose. - Odum 1973 "*Energy, ecology and economics".

Consider the useful antonym of energy, "***coolth***" to provide pleasantly low temperatures indoors and outdoors, nested within an urban setting.



Coolth is maintained indoors by pumping waste heat outwards, contributing to urban heat island warming.

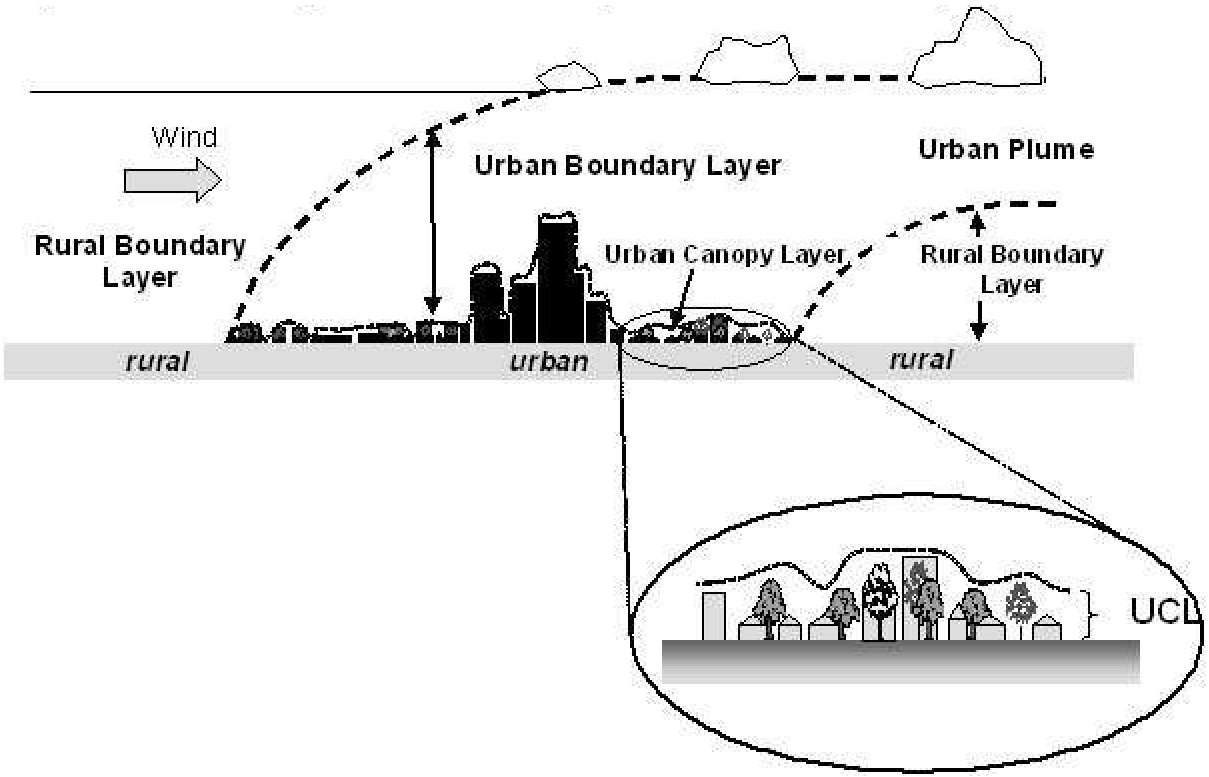
Urban Metabolism literature neglects the generation and degradation of coolth, which is related to energy and water.

Systems diagram of a city
commons.wikimedia.org (Brown 2010)

Urban Heat Island

waste heat accumulation

Mean air temperature of 1 million population metropolitan areas are typically 1–3°C warmer than surroundings.



Main components of the urban atmosphere from Voogt (2004) Urban heat islands: hotter cities

Wind through urban areas heats the boundary layer, and within the local urban canopy layer.

Mitigation of Urban Heat Islands
(promoting sustainability on an urban scale)

Promote street trees and cool roofs. Community-wide greening and passive cooling design of buildings circumvents much of the demand for air-conditioning. Residual demand for ***coolth*** can be delivered in dry weather with condensed refrigerant R718, to avoid the power demand of vapour-compression air-conditioning.

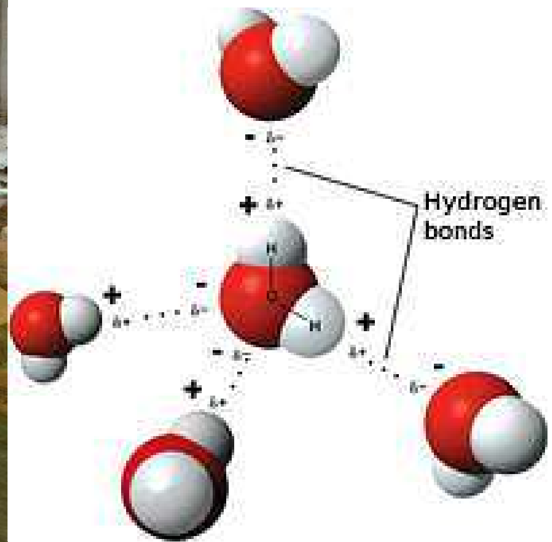
House in Townsville, Australia used for roof and interior temperature measurements (after application of the reflective white paint) from Suehrcke, et al. (2008) Energy and Buildings 40:2224–2235

Passively comfortable building, supplemented with shade and evapo-transpiration effect of vegetation - irrigated with rainwater harvested from the roof.

What is Refrigerant R718?

- **Water**


“Rome - A summer week in the eternal city” by seb.nl

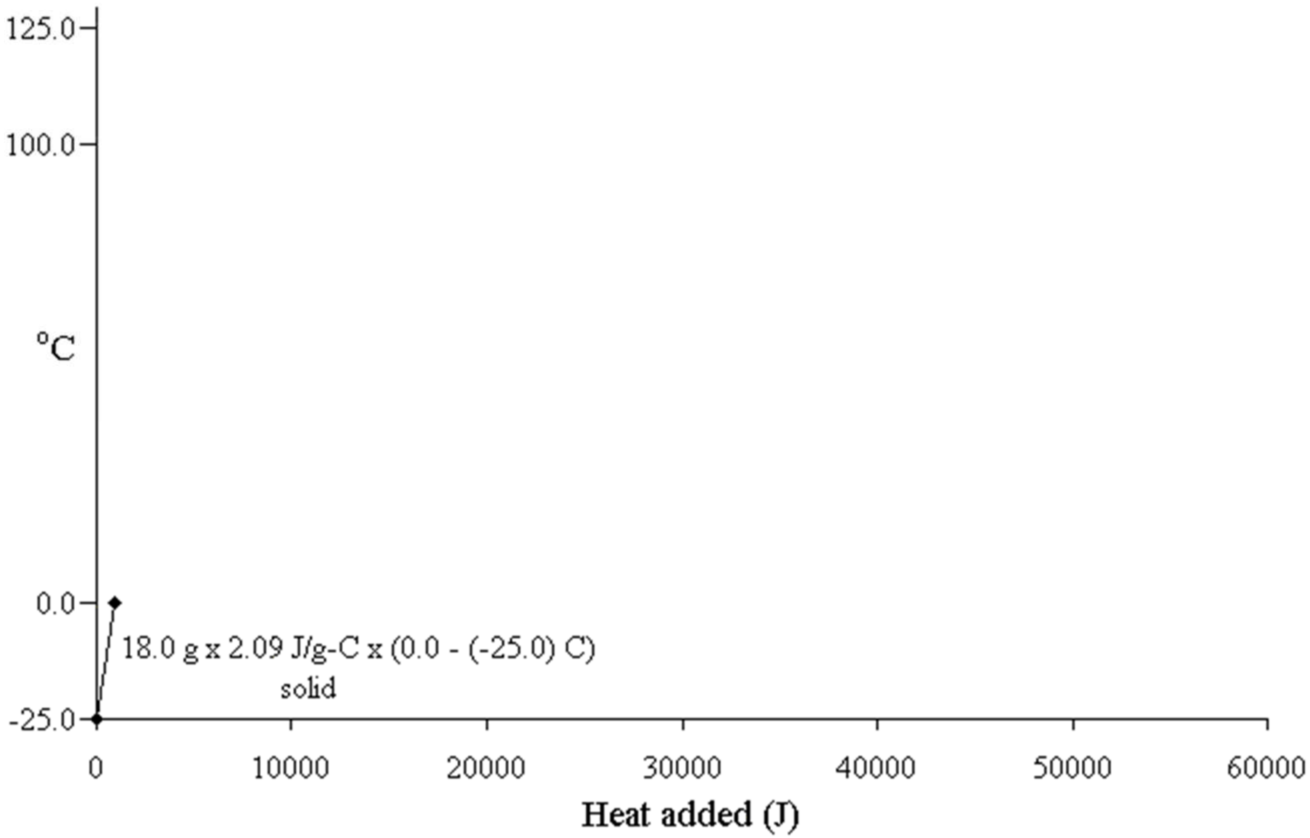


ΔH_{vap} Latent heat of evaporation *-2.3* ***M****J$_c$/litre = 2.4kWh of ‘coolth’ per US gal*

Sensible heat of liquid water *4.18 kJ$_c$/litre-Δ°C*

Seawater desalination uses 10 kJ$_e$/litre (reverse osmosis with energy recovery)
“Current state-of-the-art SWRO” reviewed by Elimelech, et al. 2011
… incidentally the same magnitude as the energy to pump water 1000 m elevation

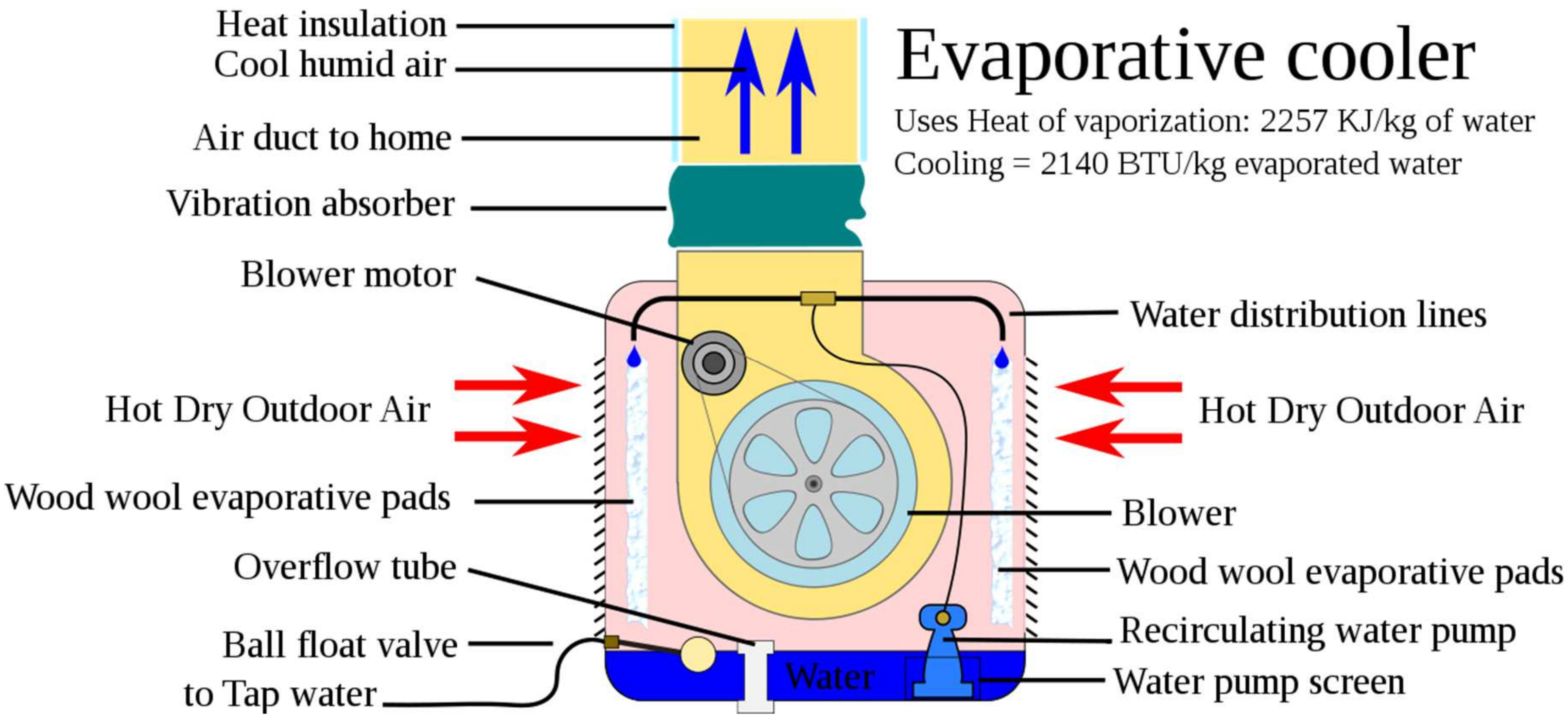
Phase change of water (R718)



Stepwise Heating Curve for 18 g H_2O from -25^oC to 125^oC

Penn State Chemistry Professor Alan Jircitano's URL http://chemistry.bd.psu.edu/jircitano/

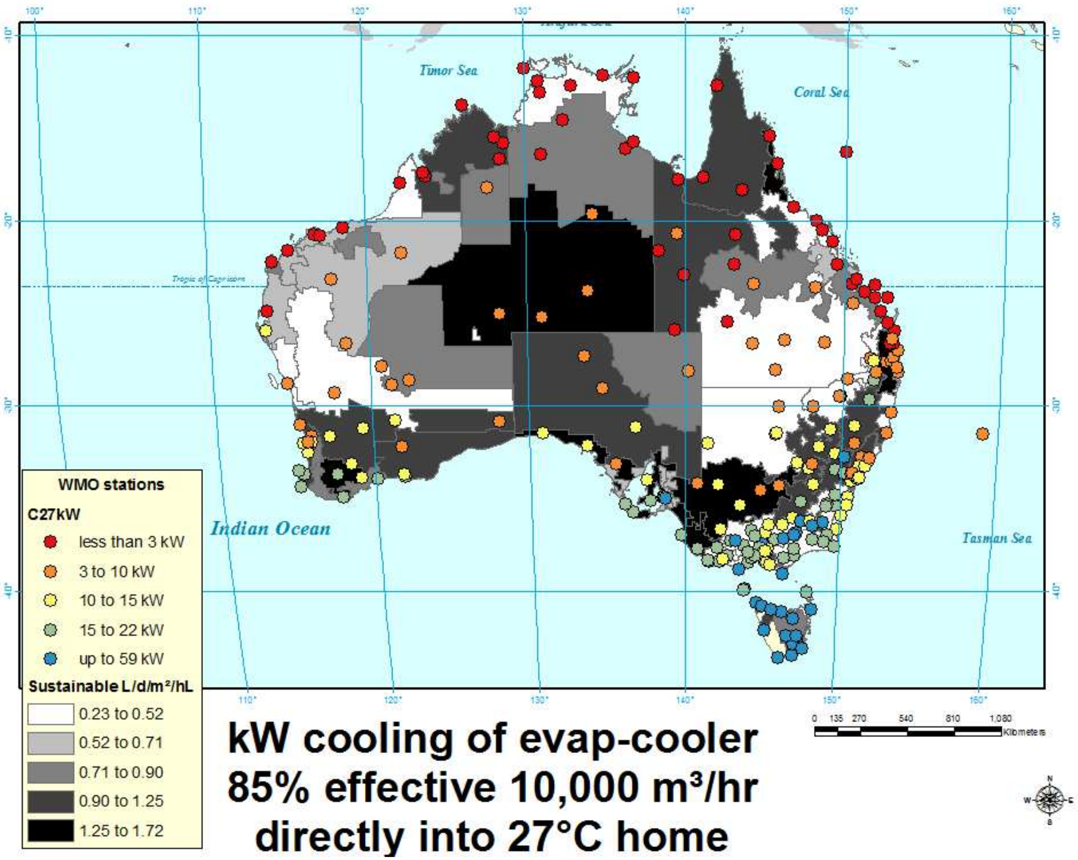
Evaporative Cooling with Refrigerant R718 (H_20) promotes sustainability by avoiding electricity use



Evaporative cooler illustration commons.wikimedia.org (Nevit Dilmen 2010)

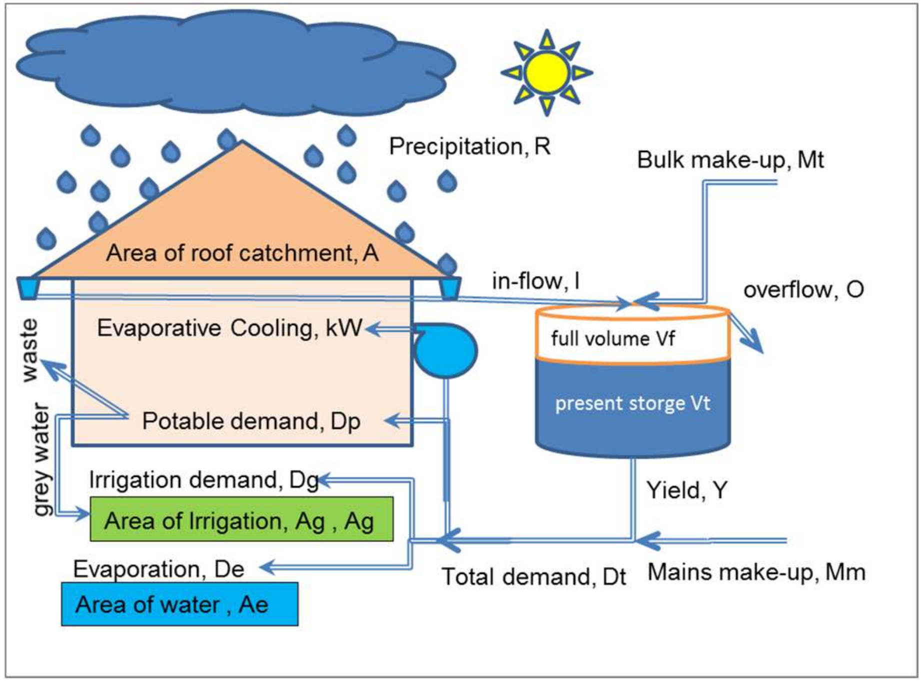
Liquid water (taken from a well, cistern or water mains) is a tremendous refrigerant resource if used in evaporative coolers instead of dry air-cooled air-conditioning.

Evaporative cooler capacity is limited in hot-humid climates and further restricted by extended dry seasons or drought.



Circles color-code evaporative cooling ASHRAE 99% design conditions.
Polygons shade rainwater harvesting system reliability in drought.
Rooftop Solar PV powered air-conditioning is an alternative.

Rainwater harvesting and demand of evapotranspiration & evaporative-cooling modelled at http://GetTanked.org/



Given the nominated rationally-sized cooling capacity ***kW*** find loadper Kelvin ΔT,

UA = kW/(DDB - 24°C) (1)

Fan ***airflow*** = kW/($\Delta T \times \rho_{air} \times C_p$) (2)

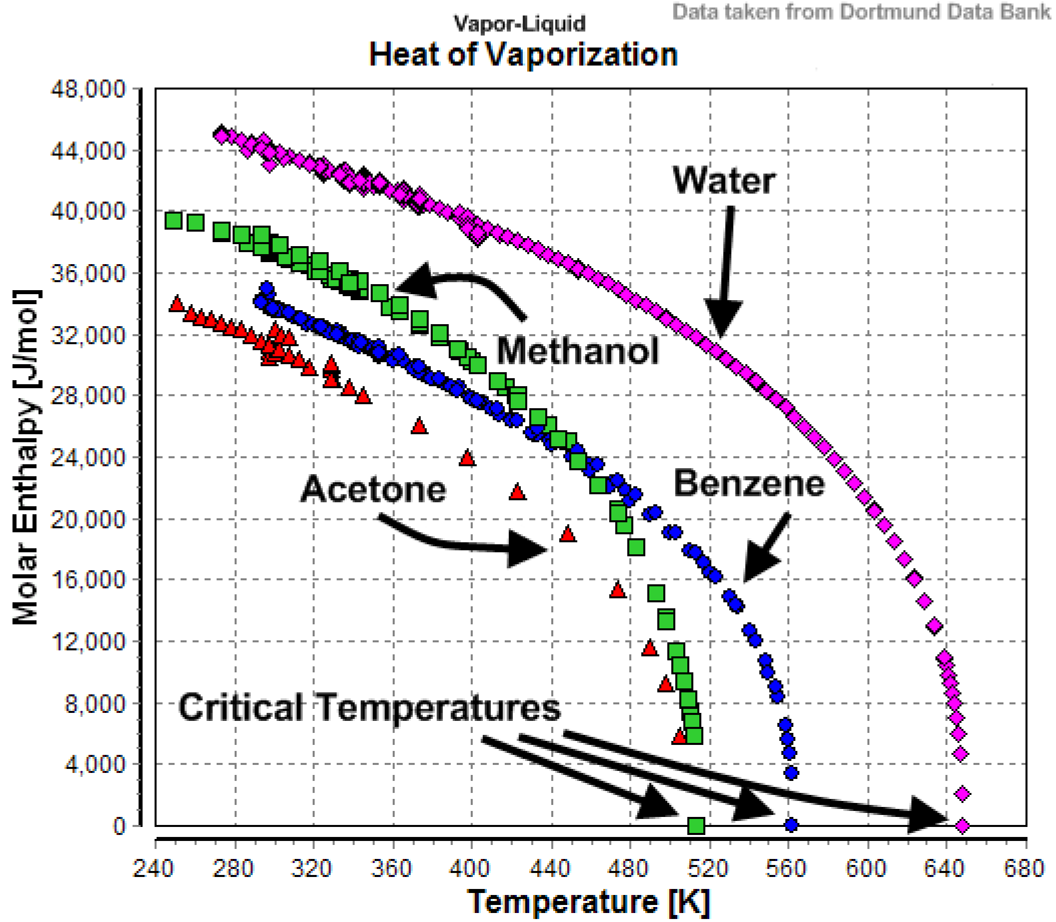
Cooling demand, $\boldsymbol{kW_t}$ = UA × CDD_t (3)

Cooling capacity, ***kW*** = airflow × $WBCDD_t \times \rho_{air} \times C_p$ (4)

Delivered evaporative cooling, $\boldsymbol{kW_{evap}}$ = minimum{kW_t, kW} (5)

Evaporative water use = $kW_{evap} \times 3600 \times 24/(\Delta H_{vap} \times \rho_{water})$ (6)

Enthalpy of vaporization of water varies with temperature T



Boiling water 100°C (373 K) consumes 2232 Joules per gram evaporated from the liquid state at 958 grams per litre, therefor coolth effect is 2.139 MJ per litre

Ambient 27°C (300 K) consumes 2437 Joules per gram evaporated from liquid water with density of 996 grams per litre, therefor coolth is 2.428 MJ per litre

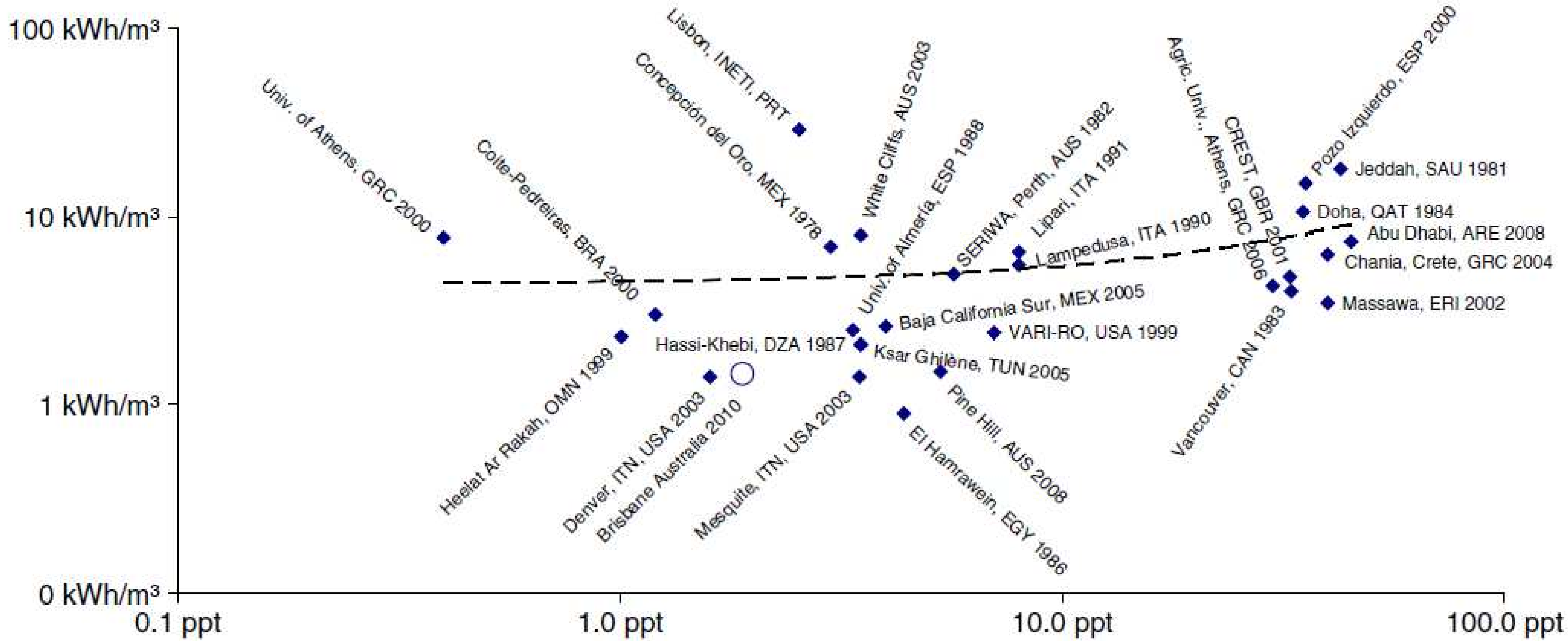
In case of drought
consider reverse osmosis RO of seawater

Based on the 27°C evaporative coolth value of liquid water 2.428 MJ/litre and

Seawater RO desalination production 250 L per kWh electricity (Einav, et al. 2002)

Evaporative coolth yields are practically 168 times the investment in seawater RO delivered by solar PV panels. Peterson and Grey (2012) used brackish water:

E.L. Peterson, S.R. Gray / Desalination 293 (2012) 94–103



What conditions must models and methods fulfill on an urban scale to promote sustainability in buildings?

- Mitigation of urban heat islands through energy-efficient buildings and green cityscapes. Both the indoor and outdoor sides of the problem can often be largely mitigated with the evaporation of water, a.k.a. condensed R718.

- If the province surrounding a city is arid or susceptible to drought then water-conservation policies may support rooftop solar PV electric generation to provide desalted water or power for air-cooled vapour-compression cooling.

- Ultimately the competing demands for energy and water conservation should both be meet with rooftop solar power and storm water harvesting for cooling.

Widespread rooftop solar & water harvesting could avoid ***energy-water collisions*** – where thermal power stations could be forced to shutdown during drought.

Contact Eric Peterson e.peterson@uq.edu.au
University of Queensland School of Civil Engineering
and Victoria University Institute for Sustainability and Innovation