Aquatic Centres and Heat Pumps: some basics for a low carbon future

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Overview

- Evolving thinking:
  - 1970s – solar thermal heating
  - 1990s – cogeneration – efficient heat and electricity from cheap, 'clean' gas
  - 2020s – rethinking energy flows, rooftop PV, RE PPAs, decarbonisation, electrification
- Emerging issues
  - Need for cooling of aquatic centres in hotter weather
  - Improvement of building thermal performance
  - Understanding complex and very variable energy flows and value of heat recovery
  - Understanding of complexities of heat pumps, managing risks and capturing potential benefits
  - Differences between indoor and outdoor pools and increasing variety of activities and services

Aquatic centre energy flows – not so simple... (Source: adapted from Trianti-Stourna et al 1998)

% of energy

**Thermal energy inputs:**

- Heat for pool, building and hot water

- Cooling, dehumidification of building

- Electricity for fans, pumps, appliances, lighting, etc (heat from them)

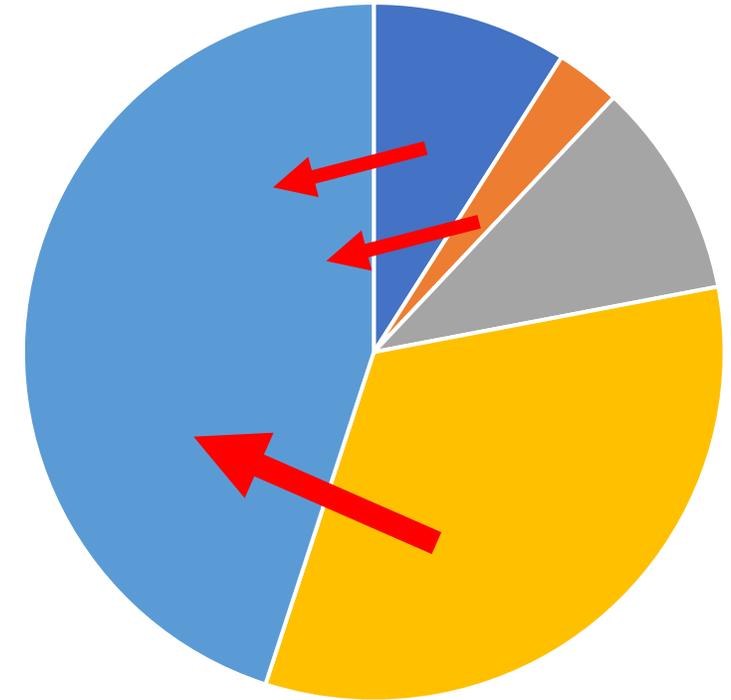- Solar gain, building fabric in hot weather

- Heat from active people

Thermal energy outputs:

- Building fabric – conduction, radiation, air leakage

- Hot, humid exhaust air

- Air leakage from entry/departure of people

- To ground

Heat recovery from exhaust air
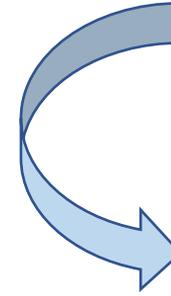
- Equipment and lighting
- Hot water
- Heat/ventilate rest of bldg
- Heat pool water
- Ventilate, heat & cool pool hall

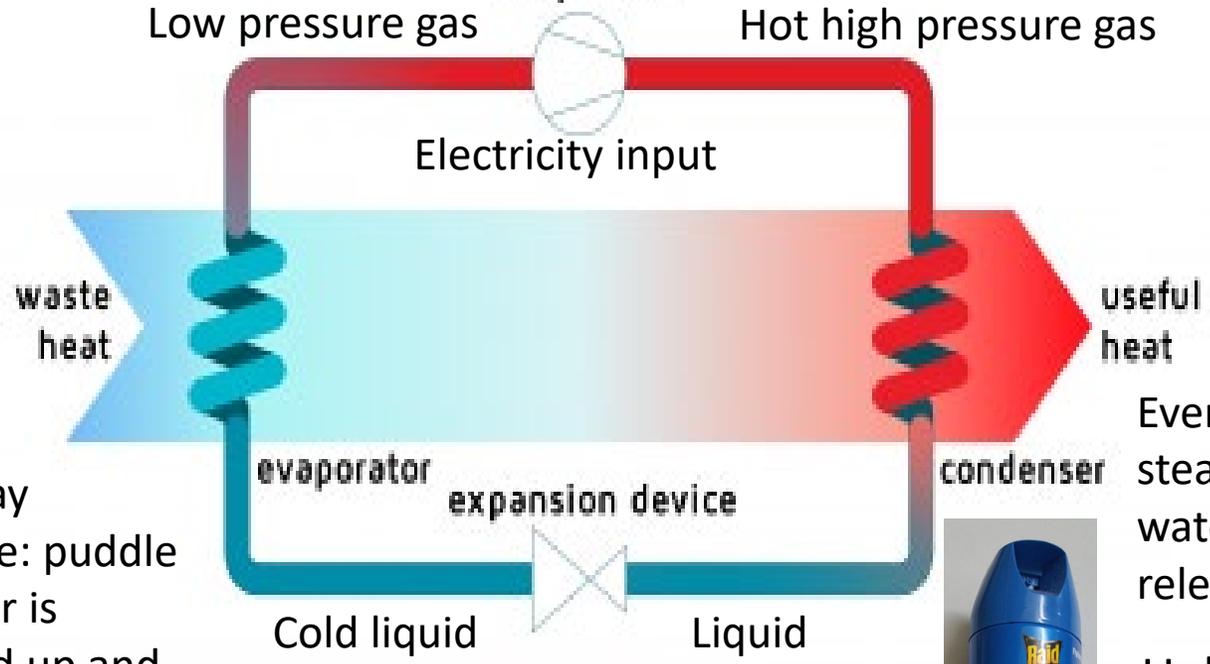# How does a Heat Pump Work ? Principles and everyday examples of processes
Source of graphic: De Kleijn 2017, www.industrialheatpumps.nl

Everyday example: bike pump heats up air as it compresses it

Thermodynamics: *heat (energy) content of a substance has zero energy baseline at zero degrees Kelvin (Absolute Zero) minus 273 degrees Celsius. So a 'cold' substance at minus 20C (253K) is really HOT and contains a lot of energy*

compressor

Low pressure gas

Hot high pressure gas

Electricity input

waste heat

useful heat

evaporator

expansion device

condenser

Cold liquid

Liquid

Everyday example: puddle of water is warmed up and evaporates as it absorbs heat from surroundings, sun and wind

Everyday example: liquid under pressure in spray can is released – becomes colder
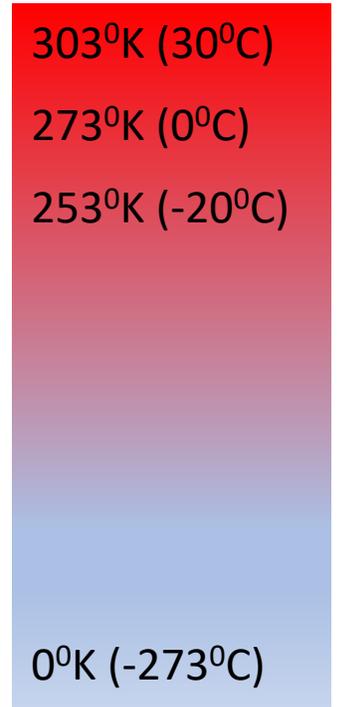
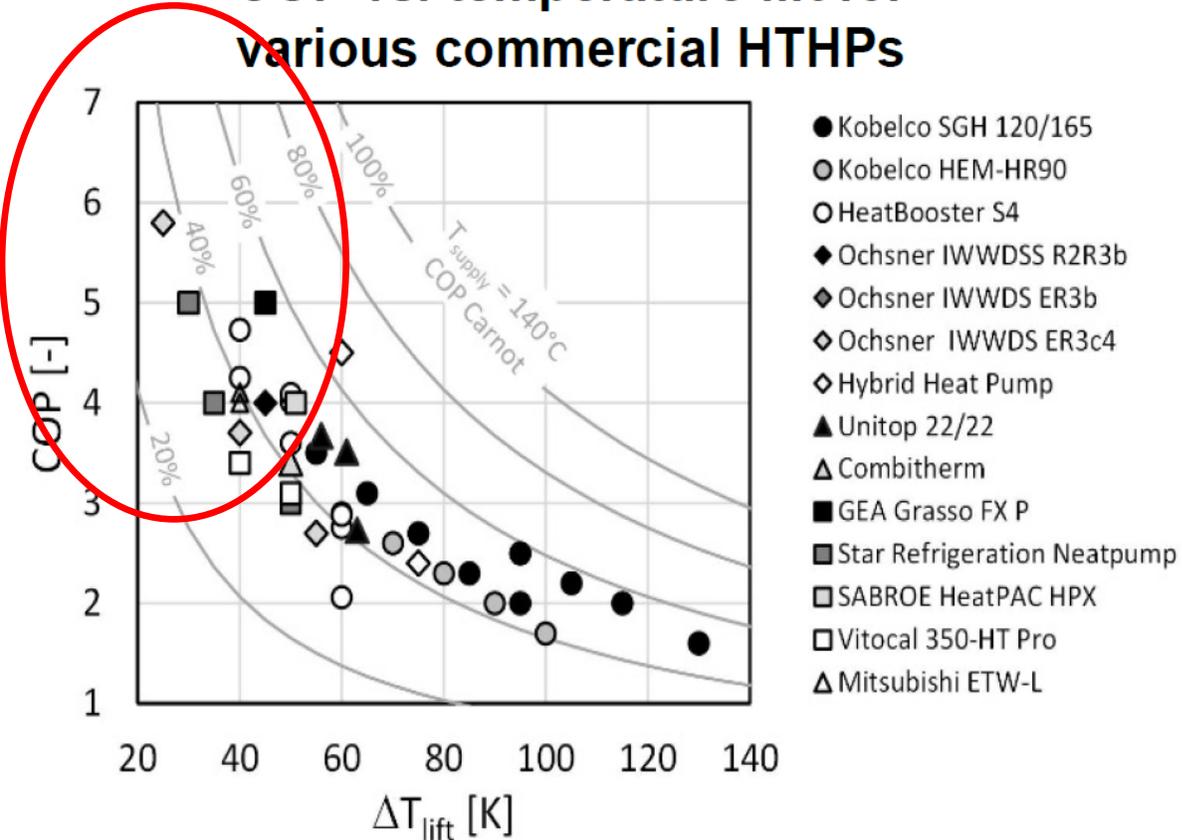Everyday example: steam condenses to water as it cools, releasing heat

Unlike resistive electric heating and fuel combustion, heat pump efficiency can be far higher than 100%!
HP can heat and cool at the same time – at even higher efficiency!

303^0K (30^0C)

273^0K (0^0C)

253^0K (-20^0C)

0^0K (-273^0C)

Aquatic Centre Heat Pump Efficiencies –
Coefficient of Performance (COP)= units of heat per unit of electricity

**COP vs. temperature lift for various commercial HTHPs**

- Kobelco SGH 120/165
- Kobelco HEM-HR90
- HeatBooster S4
- Ochsner IWWDSS R2R3b
- Ochsner IWWDS ER3b
- Ochsner IWWDS ER3c4
- Hybrid Heat Pump
- Unitop 22/22
- Combitherm
- GEA Grasso FX P
- Star Refrigeration Neatpump
- SABROE HeatPAC HPX
- Vitocal 350-HT Pro
- Mitsubishi ETW-L

Source: Arpagaus presentation to A2EP session

- Average values: COP = 3.2 ± 0.9
   ΔT_{Lift} = 66 ± 24 K
- Most data points between 40 to 60% Carnot efficiency (at 140°C supply temperature)

Smaller temperature difference **b/w evaporator and condenser** = higher efficiency (COP) for most refrigerants – not necessarily for transcritical CO2
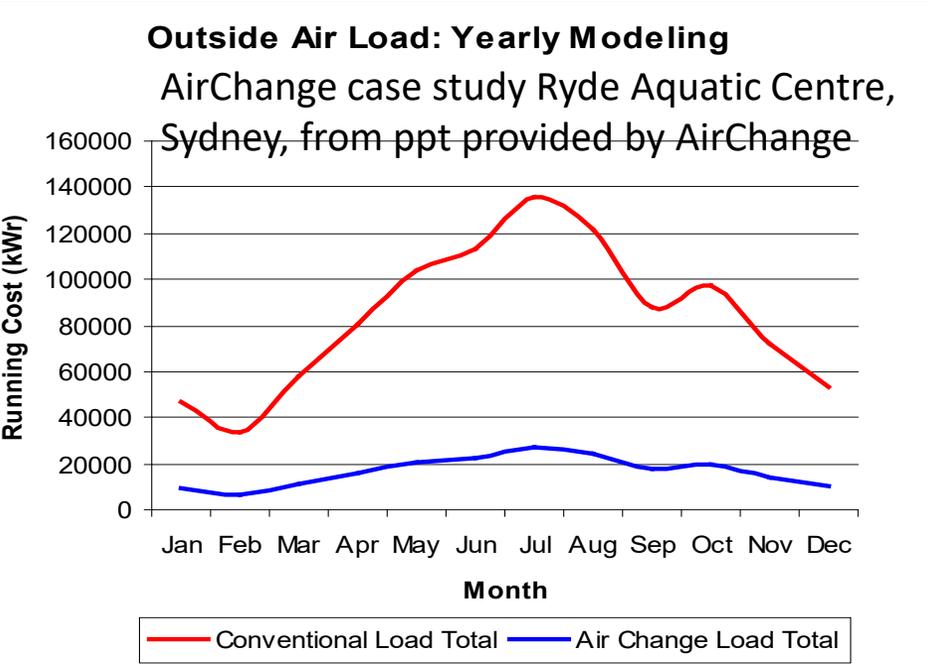
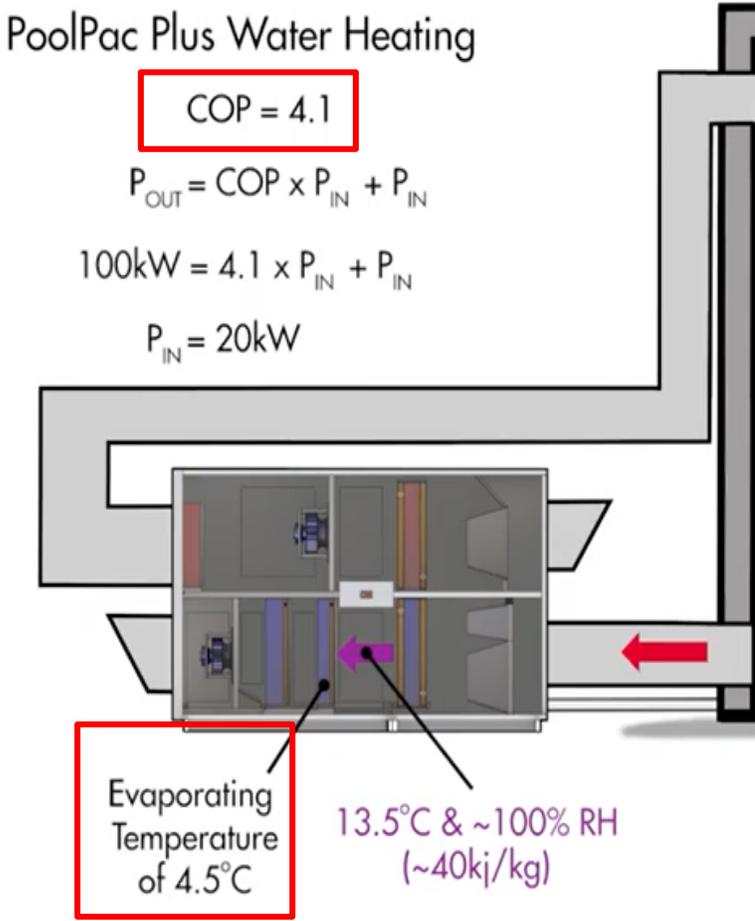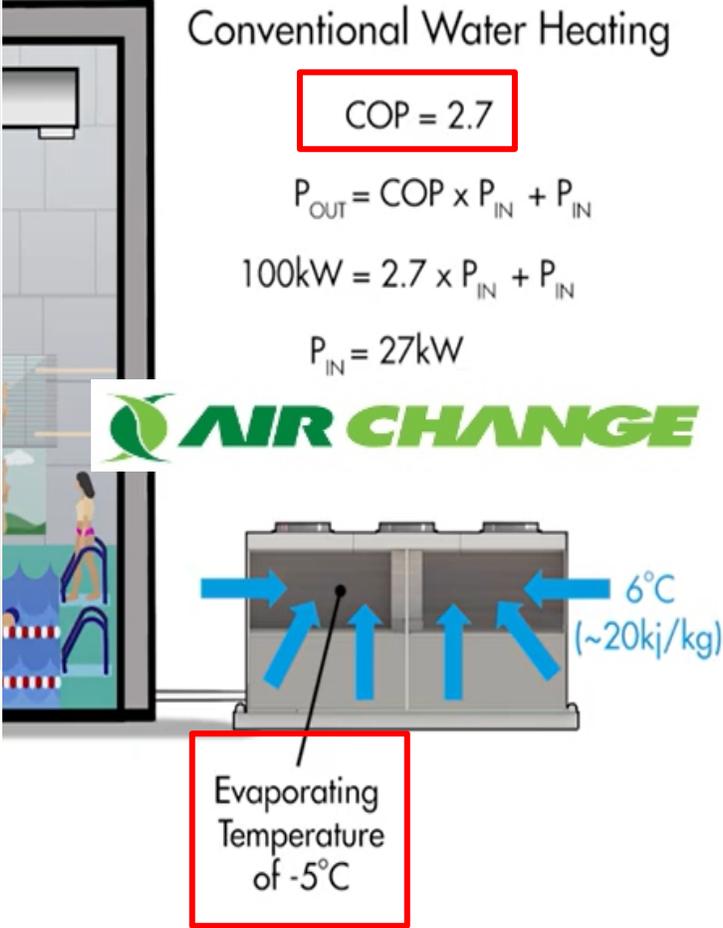Smaller temperature difference across heat pump = higher capacity

Heat Pump Capacity
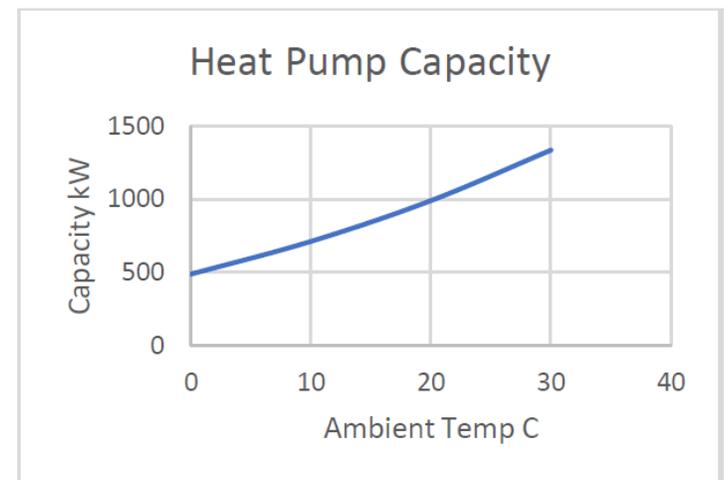
Potential performance of low charge ammonia HP to provide water at ~40C (Kimpton 2021)

Example: effective recovery of latent heat from exhaust air improves COP and reduces risk of 'icing up' at low ambient temperatures

NOTE: to evaporate a litre of water consumes about 2.4 megajoules of heat ~2.8 MJ of gas or 0.67 kWh of electricity (0.5 MJ or 0.133 kWh of electricity assuming a heat pump with COP of 5)

Outside Air Load: Yearly Modeling

AirChange case study Ryde Aquatic Centre, ~~Sydney, from ppt provided by AirChange~~

Chart — Running Cost (kWr) vs Month (Jan–Dec)
- Conventional Load Total
- Air Change Load Total

Poolpac Plus heat recovery benefit is maximum in winter – when risk of gas shortages and high prices is increasing and solar generation is lowest

Conventional Water Heating

$COP = 2.7$

$P_{OUT} = COP \times P_{IN} + P_{IN}$

$100kW = 2.7 \times P_{IN} + P_{IN}$

$P_{IN} = 27kW$

6°C (~20kj/kg)

Evaporating Temperature of -5°C

PoolPac Plus Water Heating

$COP = 4.1$

$P_{OUT} = COP \times P_{IN} + P_{IN}$

$100kW = 4.1 \times P_{IN} + P_{IN}$

$P_{IN} = 20kW$

Evaporating Temperature of 4.5°C

13.5°C & ~100% RH (~40kj/kg)

AIR CHANGE

Source: https://www.airchange.com.au/cms/?product=pool-pac-plus

Simplified exploration of thermal energy flows through a pool hall building envelope

The building:
Floor area 1200 m2
Gross wall area 960 m2
Glass areas 288m2 (144m2 in 'Eff+low glass')
Glazing U values: 11.6 W/m2-deg C for single glazed 5C and 20C (assumes condensation and high air movement), 6 for SG at 40C, 0.37 for all Low-e DG

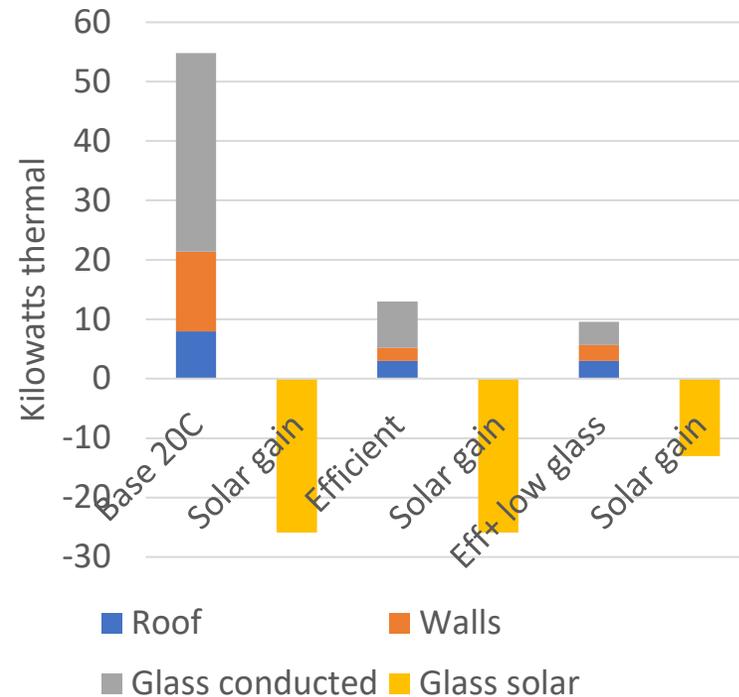Thermal resistance of fabric: Roof R1.5/R4, walls R0.5/R3
Solar radiation 300 watts/m2 on 30% of glazing: 100 W/m2 for Eff summer

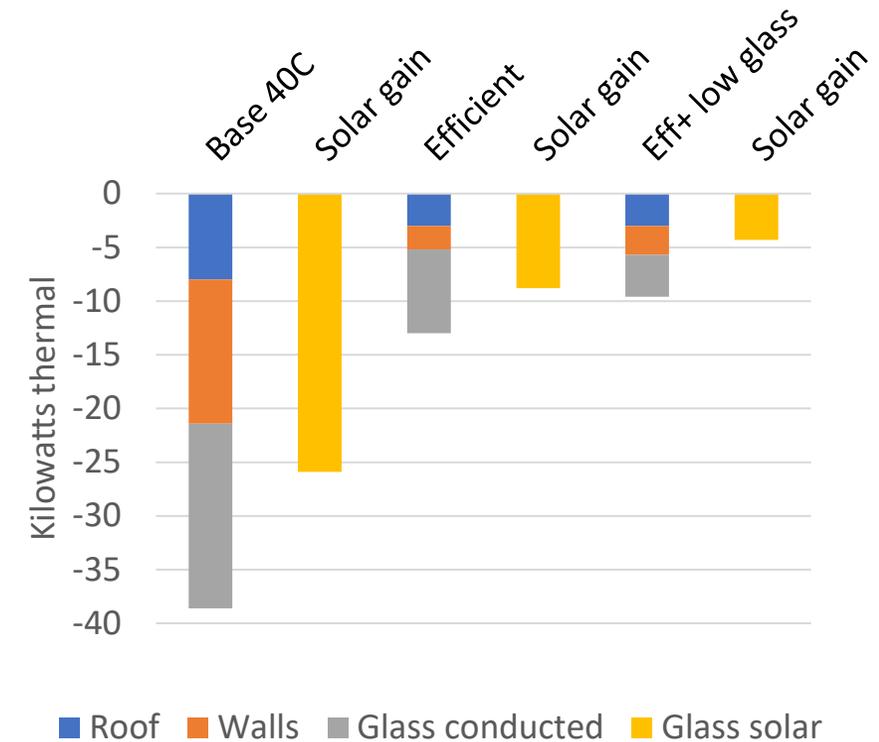Simple steady state calculations ignoring air and water vapour flows, heat coming from pool and losses to ground

Heating required at 5C ambient temperature
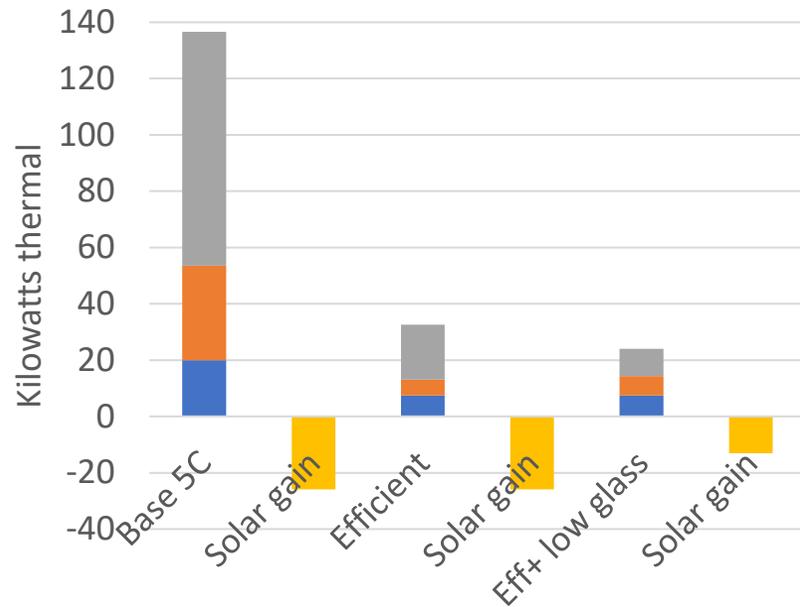
Heating required at 20C ambient temperature

Cooling required at 40C ambient temperature

Outdoor pools

From a base of 3m/sec wind speed and 25C pool temperature in Melbourne (using 1970s CSIRO model), indicative factors are:

1 metre/second change in wind speed changes heating energy required by ~23%

1C change in pool temperature changes heating energy required by ~10%

So protection from wind, use of a pool cover (or equivalent) and temperature setting, are very important.
Strategically placed pool shading may also reduce wind impact.
Management of solar radiation can help to optimise pool temperature and reduce heating

Glazing

High thermal performance glazing (and fabric insulation) mean temps of surfaces are higher so building can run at higher humidity without condensation problems, reducing evaporation from pool
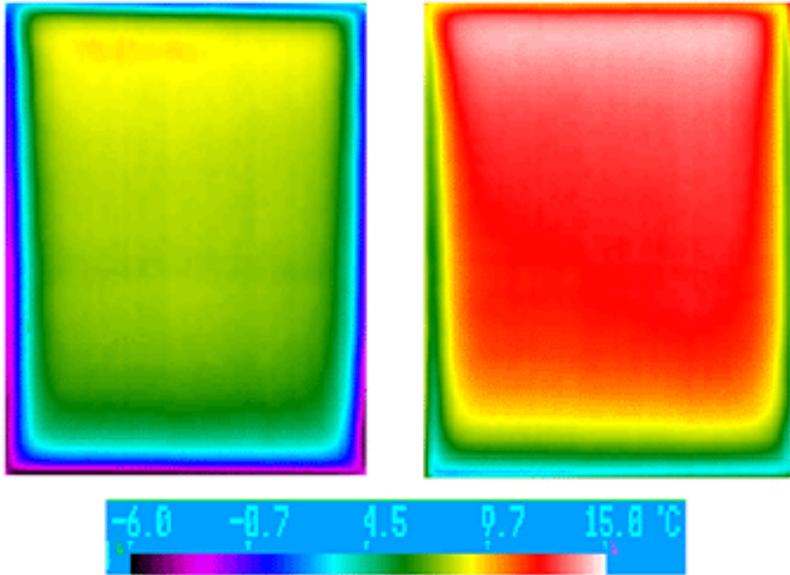
Indoor temperature of low-e and standard double glazing at -18C – std DG covered in condensation
https://www.efficientwindows.org/condensation.php

THE END

THANKYOU