

CEPNZ WEBINAR

Picking the right heat pump refrigerant: R290 v CO2

Using simulation analysis to assess what refrigerant performs best for your project

PRESENTED BY

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DATE

28 September 2026

AUDIENCE

CEPNZ members and guests

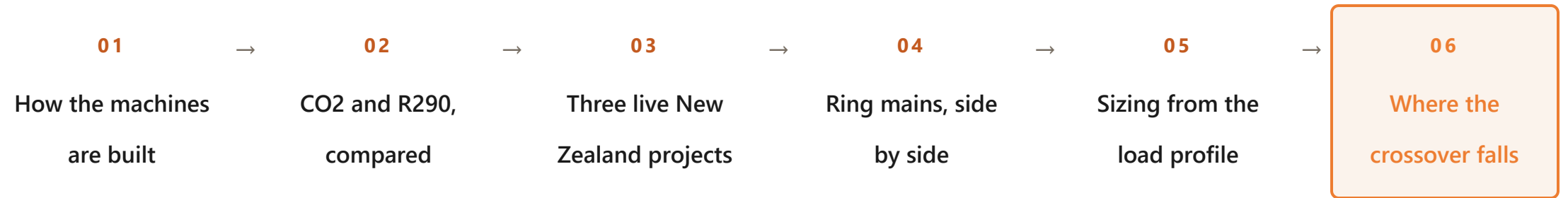
STATUS

Educational · v1

OVERVIEW

Where we are going

R290 or CO2, for a commercial hot water system: how do you decide, and which features of the application make the call?



Finding the critical ratio that determines the optimal refrigerant choice

PART ONE

Heat pump water heater fundamentals

Understanding heat pump components, commercial design variants,
distribution systems and refrigerants.

01

FUNDAMENTALS

Introduction to heat pump water heaters

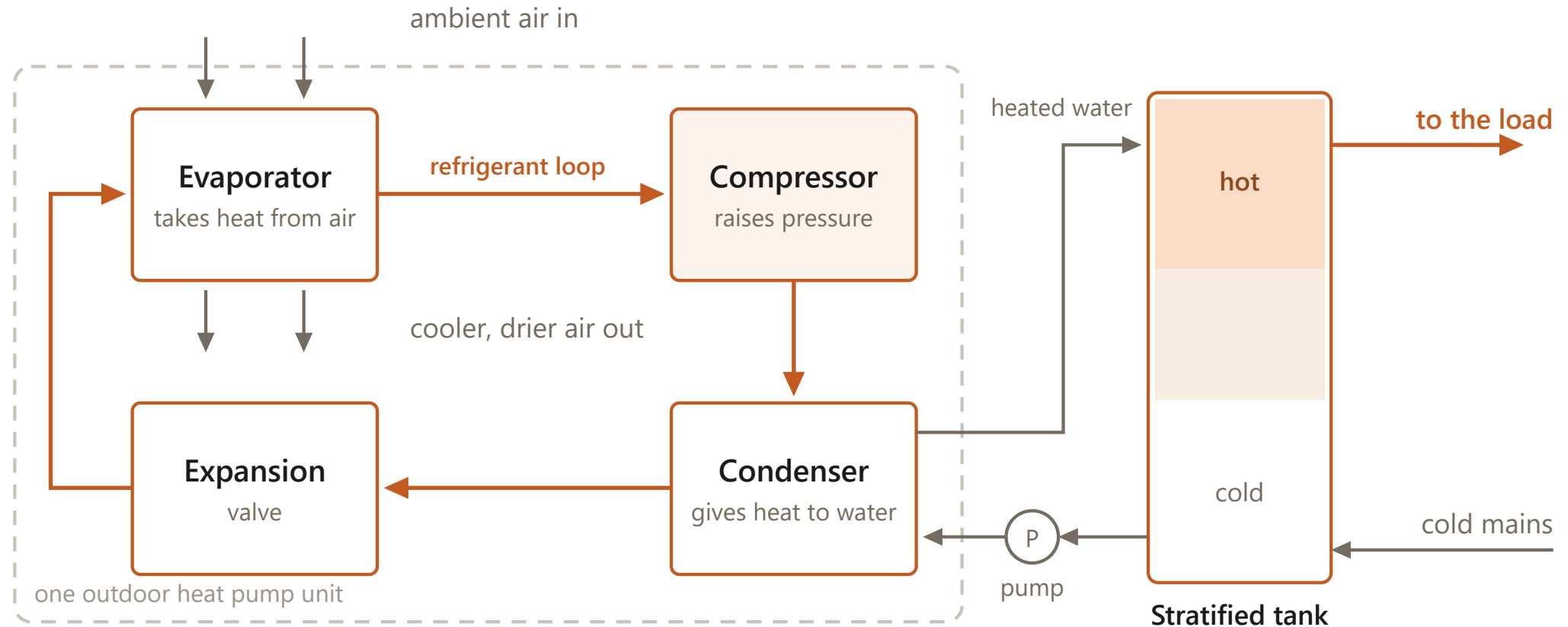
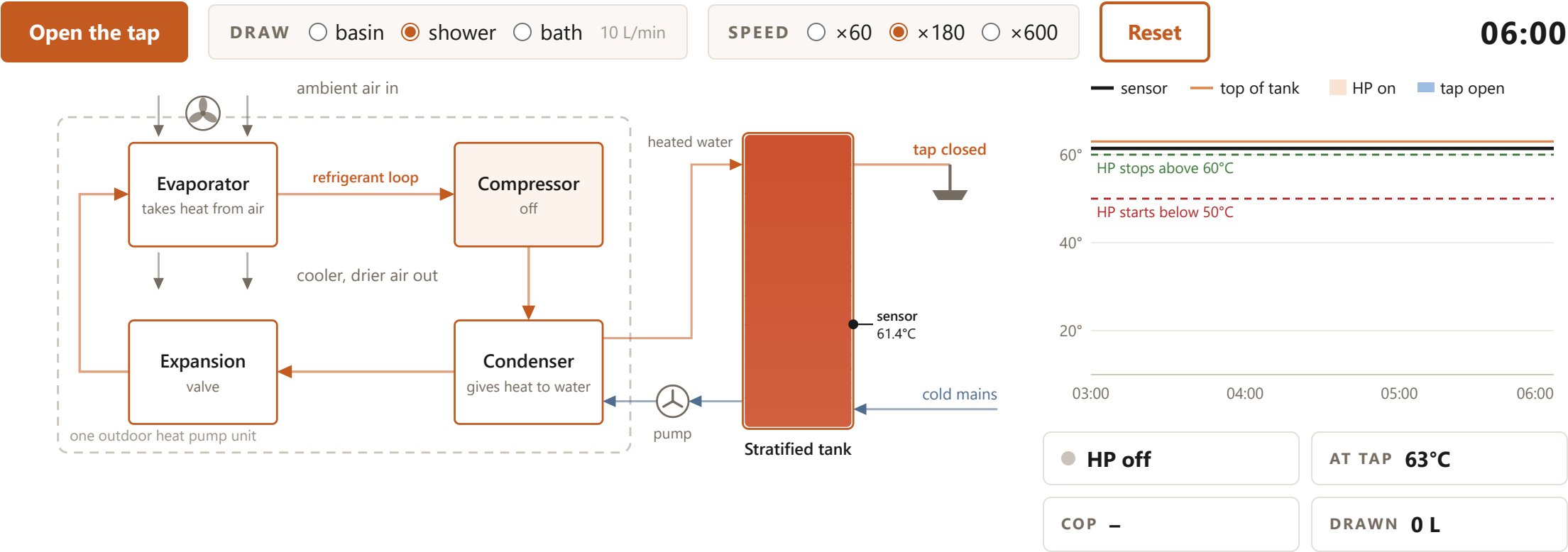


Figure 1. Basic heat pump water heater system.

Watch it run

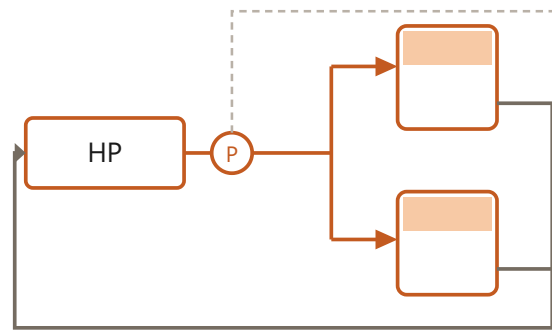


Live simulation, illustrative.

FUNDAMENTALS

Common commercial designs and variants

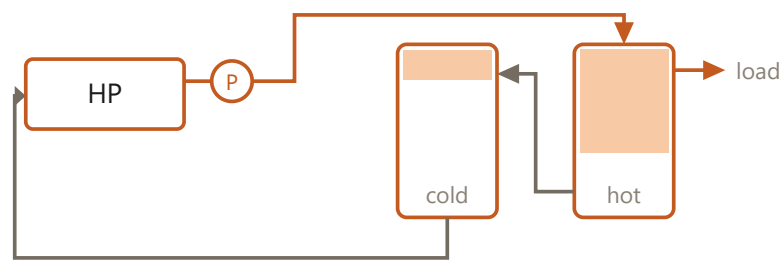
TANKS IN PARALLEL



the pump is told to hold
a fixed flow
a fixed outlet temperature
or a fixed rise across it

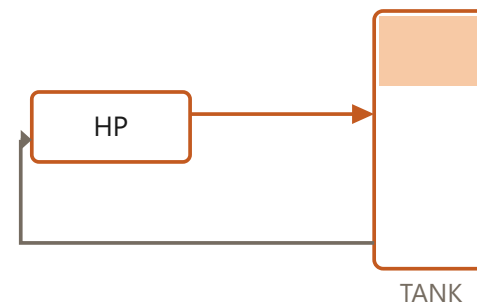
Both tanks sit at the same
temperature. You gain volume,
not a cold end to draw from.

TANKS IN SERIES



Water passes one tank then the next, so the store keeps a cold end
and a hot end rather than one average temperature.

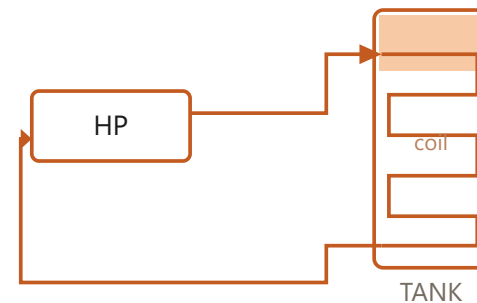
DIRECT



The stored water is the water
that goes through the machine.

Simplest, and the machine sees
exactly what the tank holds.

INDIRECT



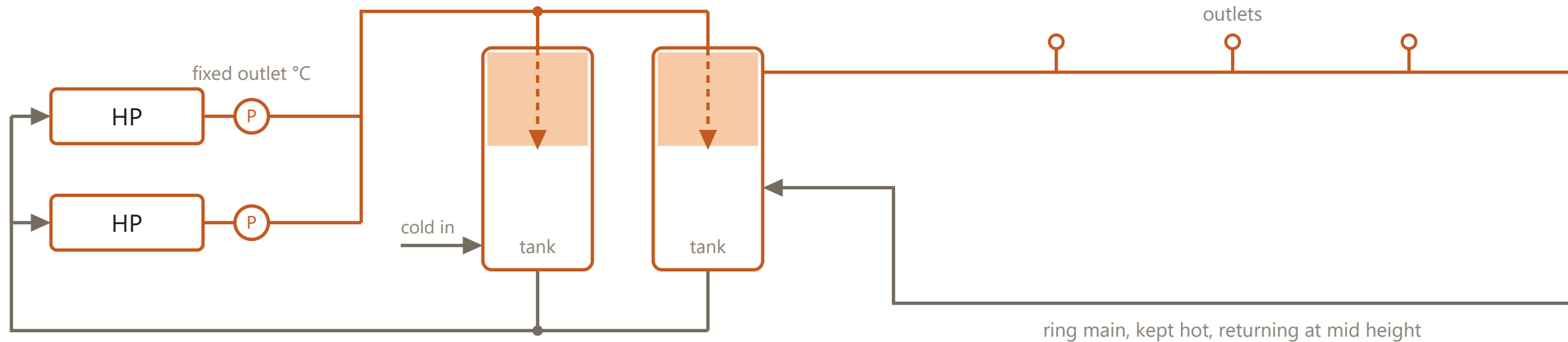
A coil keeps the two waters apart.

The coil can sit on the heat pump
side, as drawn, or on the load side
where it heats water on its way out.

Figure 2. Commercial design variants.

Build the arrangement

HEAT PUMPS ☐ 1 ☒ 2 ☐ 3 always parallel	TANKS ☐ 1 ☒ 2 ☐ 3	TANKS ARE ☒ parallel ☐ series	COUPLING ☒ direct ☐ coil
MACHINE ☐ single pass ☒ multi pass	DISTRIBUTION ☐ dead leg ☒ ring main	PUMP HOLDS ☐ flow ☒ outlet °C ☐ rise	



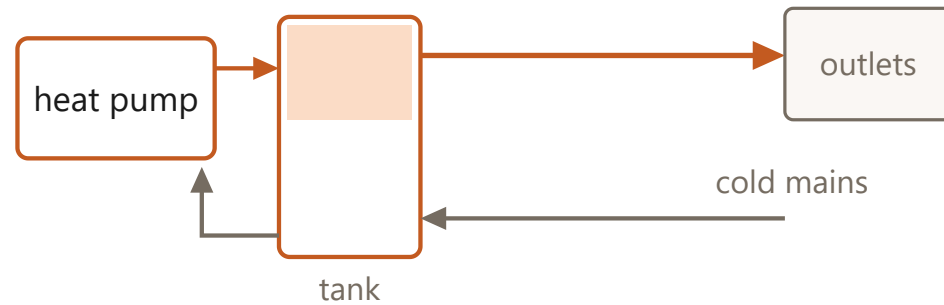
Multi pass: the same water goes round many times, a few degrees each pass, so the store drifts toward one average temperature.

Figure 3. Build your own commercial system schematic

FUNDAMENTALS

Dead-leg and ring-main variants

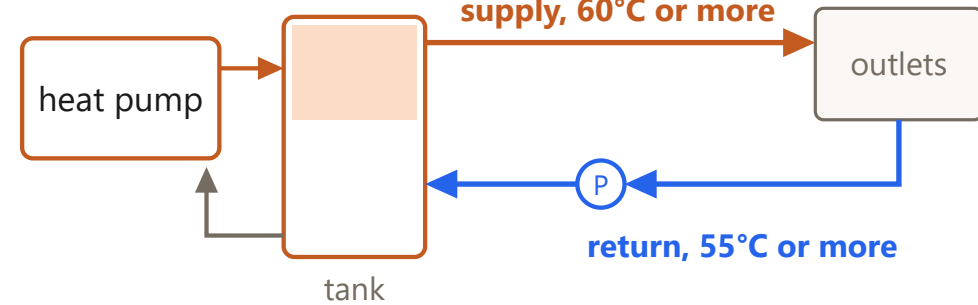
DEAD LEG



Every litre drawn is replaced by cold mains.
Nothing circulates, so there is no standing loss
and no loop to keep hot.

Cost: a long wait at a distant outlet.

RING MAIN



Hot water circulates continuously so every outlet
runs hot on demand. The loop loses heat all year
and hands warm water back to the plant.

Cost: a standing load, and a warmer tank.

Figure 4. Dead-leg vs ring-main

FUNDAMENTALS

Natural refrigerants in commercial water heating

Refrigerant	GWP	Flammability	Toxicity	Water temperature
Propane R290	3	A3 highly flammable	Low	To about 75°C
Carbon dioxide R744	1	A1 non-flammable	Low	Up to about 90°C
Ammonia R717	0	B2L lower flammability	B toxic	To about 80°C

Against the synthetic refrigerants:

- Very low GWP, so no phase-down pressure
- Good upper temperature range: 75°C and above
- Each has a safety issue: R290 flammable, ammonia toxic, CO2 high pressure

FUNDAMENTALS

Synthetic refrigerants in commercial water heating

Refrigerant	GWP	Flammability	Toxicity	Water temperature
R-32 difluoromethane	677	A2L mildly flammable	Low	To about 65°C
R-513A blend	573	A1 non-flammable	Low	To about 60–65°C
R-1234yf / ze HFO	< 1	A2L mildly flammable	Low	To about 65–70°C
R-134a	1,300	A1 non-flammable	Low	To about 65°C
R-410A blend	1,924	A1 non-flammable	Low	To about 60°C

Against the natural refrigerants:

- Less flammable and less toxic, so easier to site
- Higher GWP, and above about 700 being phased down
- Lower maximum water temperature: few go much past 70°C

PART TWO

Three New Zealand case studies

Real systems implemented in NZ

02

CASE STUDY · CHRISTCHURCH

Aged care decarbonisation, Christchurch

BEFORE

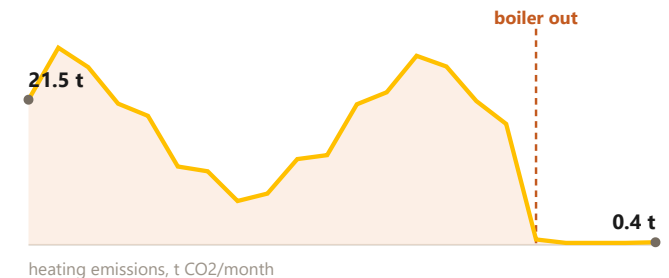
- 400 kW boiler on a 20% biodiesel blend
- 8,000 L thermal store, 100 kW of resistance elements on off-peak
- Erratic outlet temperatures, and outages through winter 2022

AFTER

- Hot water on a single-pass heat pump module
- The ring main has its own dedicated reheat heat pump
- Space heating: 4 × 90 kW variable-flow heat pump water heaters
- R-32 throughout, plus 25 kWp of solar PV



The space heating machines as installed. Photo from the published report.



Heating emissions, monthly: fell 97% after the boiler came out.

George Manning, Heritage Lifecare. Project by Decarbonised Energy Solutions; solar PV by Sunshine Solar; report published by EECA, June 2023.

CASE STUDY · SOUTH CANTERBURY

A hospital that split by duty

DOMESTIC HOT WATER → CO₂

- 120 kW nominal, into cylinders
- Electric elements for backup and Legionella cycles

SPACE HEATING → R-410A

- 450 kW, delivering 65°C to the existing radiators
- Holds output down to –2°C ambient

Timaru Hospital. Two 6 MW coal boilers replaced. 2,280 t of coal and 2,000 t CO₂-e saved a year, NZ\$4.56M. Consultant DETA Consulting, installer Airtech; case study published by RACE for 2030. The report states the refrigerants were chosen for their thermodynamic fit to each duty.

CASE STUDY · AUCKLAND TO CHRISTCHURCH

Aged care on R290, Auckland to Christchurch

BEFORE

- Gas instantaneous units coupled to storage vessels
- Plant at end of life; a carbon target to meet
- Existing sites short of electrical capacity

AFTER

- Multi-pass R290 heat pumps, about 30 facilities
- 65°C storage, no electric boost
- One plant covers draw-off, recovery and maintenance
- More storage, slower recovery: sized to the amps



Two of the R290 units at one of the sites. Photo from the published project page.

Aged care rollout, about 30 facilities. Heat pumps supplied by Waterware, who published the write-up (June 2024). No measured energy or COP published.

CASE STUDIES · COMPARED

Three projects, three answers to the ring main

	Christchurch aged care	Timaru Hospital	Aged care rollout
Hot water refrigerant	R-32	CO2	R290
Hot water machine	Single-pass module	CO2 heat pumps into cylinders	Multi-pass, 65°C storage
Ring main	Its own reheat heat pump	Not published	Carried by the same plant
What is published	Measured emissions, part-year	Project outcomes, not monitored	Supplier write-up, no data

The question this session answers: give the loop its own heat pump, or choose a primary machine that can carry it.

Sources: EECA (2023); RACE for 2030 (2025); Waterware (2024).

PART THREE

Comparing R290 and CO2 system architectures

Understanding how refrigerant choice impacts system design

03

ARCHITECTURES

The R290 reference system

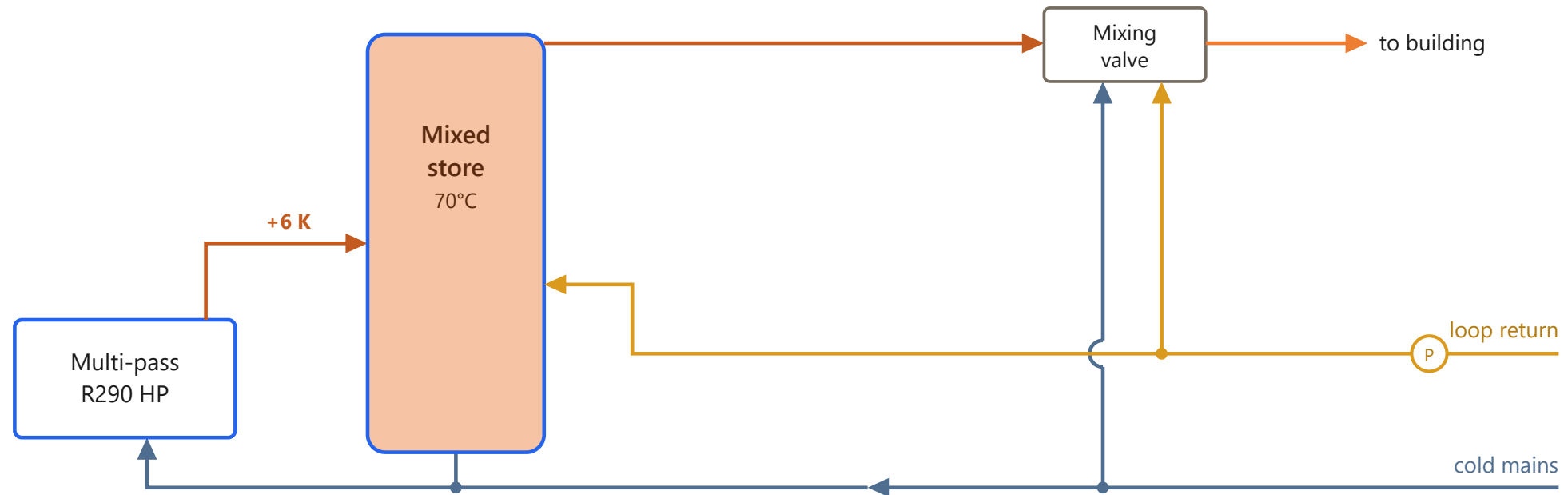


Figure 6. Multi-pass R290 on a ring main. The loop return goes straight into the mixed store.

The CO2 reference system

LOOP RETURN ○ 1 into the store ○ 2 swing tank, series (modelled) ○ 3 loop tank, element ○ 4 loop tank, R290 heat pump

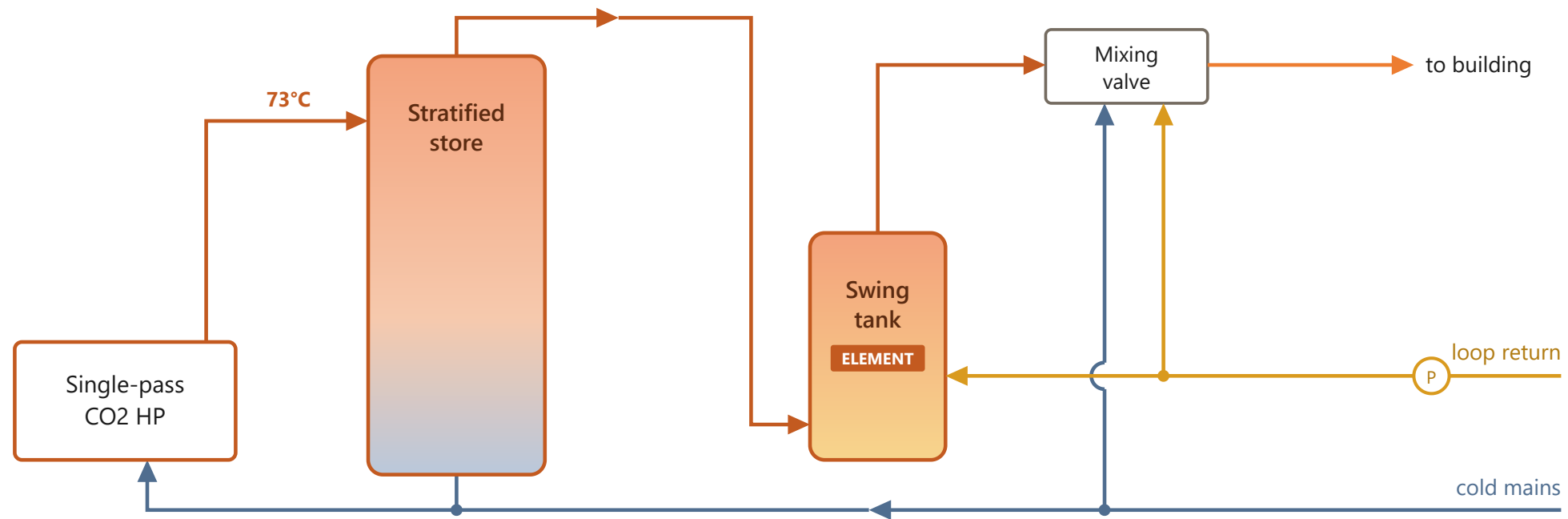


Figure 7. Option 2: a swing tank in series, and the arrangement the simulations use. The draw carries heat from the store into the swing tank; its element holds the loop when nobody draws.

ARCHITECTURES

R290 or CO2: pros & cons

R290

subcritical, multi
pass

PROS

- + Cheaper equipment, China-sourced
- + Low GWP
- + Good COP at high entering water
- + Easy to service

CONS

- Flammable: charge limits, outdoor or ventilated plant
- Outlet ceiling ~70–75°C
- More storage on large loads

CO2

transcritical,
single pass

- + High temperatures easily: 65–90°C
- + Non-flammable, non-toxic, GWP 1
- + Strong in cold climates

- Needs cold inlet water
- Ring main: swing tank plus element
- High pressures: specialist service

Comparing test data for R290 and CO2 systems

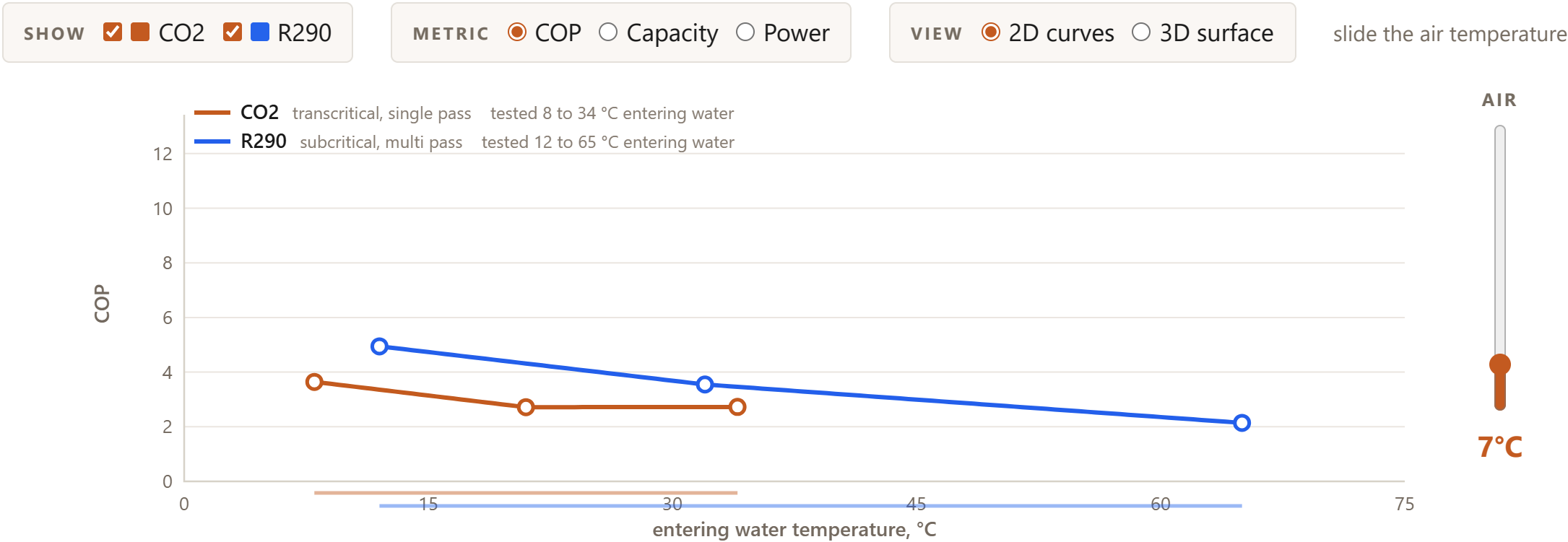


Figure 8. Comparison of performance data for two typical R290 and CO2 systems.

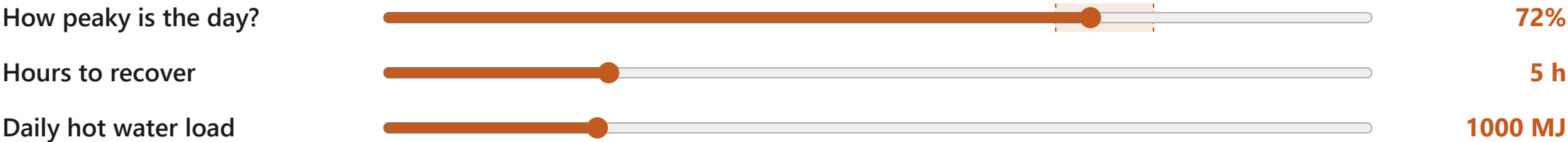
PART FOUR

System sizing principles

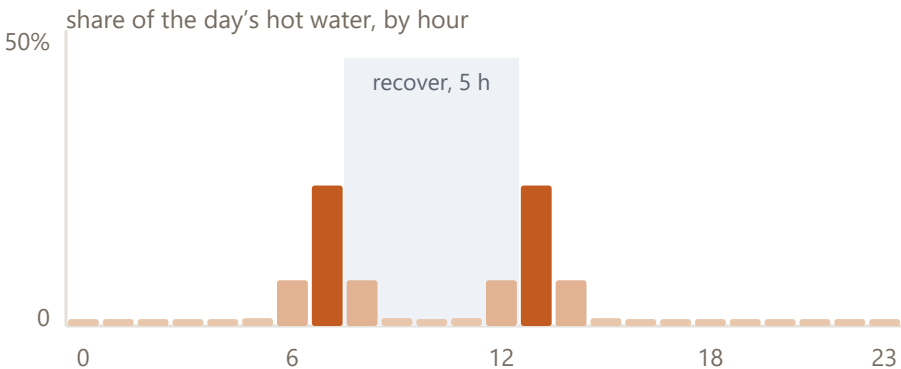
Peak draws set the storage. The time between peaks sets the machine.

04

System sizing principles



peak hour is 24% of the day · ring main assumed: +35% on the day's energy for loop losses



1570

STORAGE, LITRES

set by the peak draw

75

HEAT PUMP, KW

set by the day's volume

1430

RECOVERY, L/H

formula 16.6

Peakiness moves the storage and leaves the machine alone. The recovery window moves the machine and leaves the storage alone.

Figure 9. Basic sizing method: size the load → storage volume → heat pump capacity.

PART FIVE

Simulation of ring-main systems

Understanding the factors that trade off between R290 and CO2 in commercial hot water.

05

THE HYPOTHESIS

Factors that influence heat pump performance

THE PHYSICS

CO2 is best on cold water and cold air

A big lift in one pass. Warm inlet water costs it heavily.

R290 copes with warm inlet water

A small lift, many passes. Most other conditions favour it.

WHAT THE TANK GETS BACK

Load dominates

loop return

cold mains

Plenty of cold make-up.

CO2 runs on cold water and stands out.

loop losses ÷ hot water delivered

CO2 favoured

R290 favoured

a crossover somewhere in between
(the next slides find it)

Losses dominate

55–60°C return

cold mains

CO2 can't use it: an element tops up at COP 1.

R290 runs on it, with little element.

WHAT MOVES IT

Ring-main size

Longer, bigger loop: more standing loss

→ **towards R290**

Thermal load

More hot water delivered: more cold make-up

← **towards CO2**

Climate

Colder mains and air: CO2's best conditions

← **widens the CO2 side**

Figure 11. The hypothesis, before any numbers: what the tank gets back decides which machine wins, and the building sets that balance.

Which one is cheaper to run

CLIMATE

cold

warm

Auckland 15.8°C mains

DAILY LOAD

800 MJ/day

RING MAIN

150 m

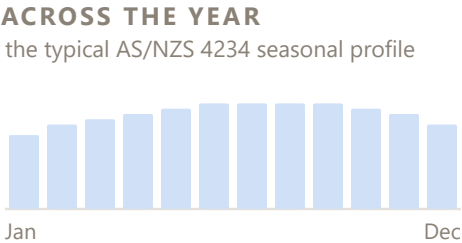
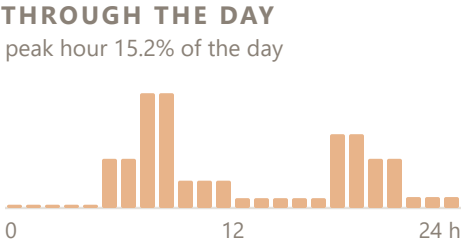
DAY SHAPE

☐ flat

☐ aquatic

☒ apartment

flat to peaky



ANNUAL ELECTRICITY

0 to 126.9 MWh

CO2

heat pump

40.3 MWh

R290

heat pump

39.3 MWh

This building: ring-main loss ÷ hot water delivered = 0.34

R290 uses 2 percent less

CO2 on a swing tank; R290 takes the loop straight back.

Dark: the heat pump. Pale: resistance element at COP 1, on CO2 the swing tank holding the loop, on R290 backup in the store.

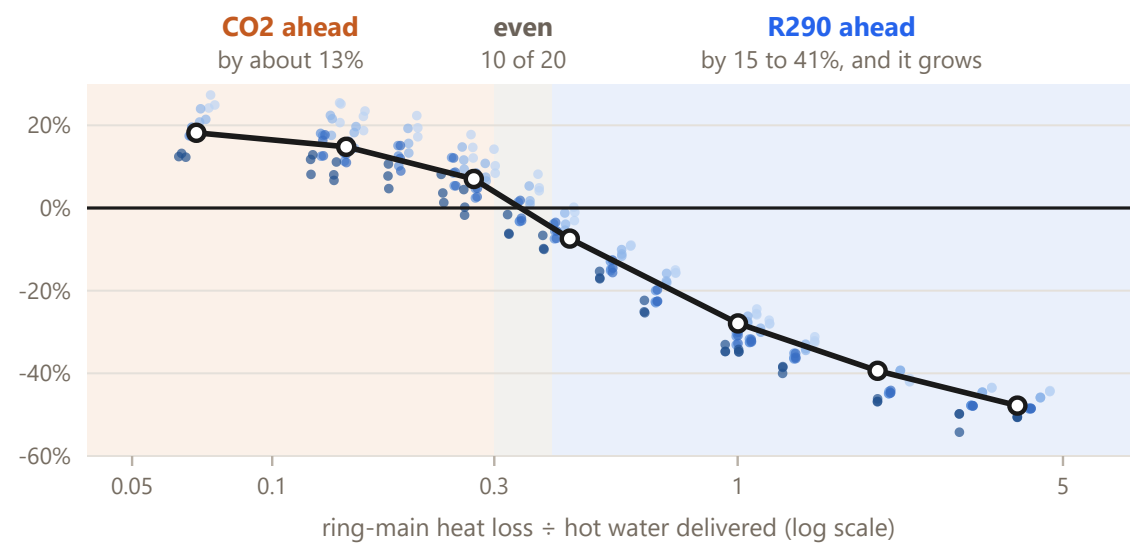
THE PLANT EACH ONE NEEDS

	CO2	R290
Heat pumps	1 x 30 kW	2 x 24 kW
Storage	2 x 700 L	6 x 700 L
Tanks piped	in series	in parallel
Entering water, median	32.1°C	63.1°C
Plant utilisation	35%	52%
System COP	2.57	2.83

CO2 adds a 700 L swing tank with its own element on the loop return. R290 takes the return straight back into its tanks.

THE ANSWER

The critical loss-to-load ratio



below 0.30	n = 88	CO2 wins 87 of 88
CO2 cheaper by 13.1%		spread ±6.4 points
0.30 to 0.40	n = 20	CO2 wins 10 of 20
within 0.3%, sign is a coin flip		spread ±5.8 points
0.40 to 1.0	n = 48	CO2 wins 1 of 48
R290 cheaper by 15.3%		spread ±9.3 points
above 1.0	n = 84	CO2 wins 0 of 84
R290 cheaper by 40.7%		spread ±7.8 points

EACH POINT COLOURED BY CLIMATE, COLD TO WARM MAINS

Dunedin	Canberra	Melbourne	Auckland	Sydney
10.9°C	12.1°C	14.5°C	15.8°C	17.7°C

Colder mains moves the crossover right: 0.43 in Dunedin, 0.26 in Sydney.

The crossover loss-to-load ratio is 0.3–0.4, higher for cold climates. **Note:** this result would change with different equipment, sizing decisions, or system design, but illustrates the principles directionally.

CONCLUSION

What to take away

- Energy modelling earns its place on commercial hot water
- R290 and CO2 are both suited to it, and neither is the default
- CO2 wins on colder mains and low entering water
- R290 wins once the loop is large enough to need real maintenance heat
- Efficiency is only one part of the equation: capital cost, maintenance, safety and other considerations also influence it

Thank you for listening. Time for questions

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Energy Analysis & Engineering Ltd · HPWH compliance modelling, TRNSYS simulation, scheme registration.

Educational session. Modelled units are anonymised and banded, and comparisons are between thermodynamic architectures rather than between products. Case study material is reproduced from publicly published reports with credit to the parties that did the work.