Practical Electrification

What Goes Wrong and How to Fix It

Jacksons Engineering

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Decarbonisation

Building Automation Systems

Climate
daptation

Existing Buildings

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Electrification

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Change

Heat Pumps

ESG Reporting

Solar PV

Demand Management

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Operational Performance

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Energy Efficiency

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Legacy Systems

Green Star
NABERS

HVAC

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Carbon Accounting / Offsets

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Heat Pumps

Refrigerants

Smart Buildings

Battery Storage

Grid Capacity

Our Focus

Decarbonisation aka 'Existing Building Electrification'

1. New buildings can be designed around electrification from day 1
2. Existing Buildings already have a personality:
    - Existing tenants
    - Existing operating patterns
    - Legacy systems (AHU's, Chillers, Boilers, heating coils etc)
    - Existing electrical infrastructure
3. Many of these things put limits on Decarb options

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Why

Building electrification matters in NZ

Electrification allows buildings to:

- Reduce carbon emissions – esp. fossil fuels are used for heating
- Take advantage of NZ's highly renewable electricity grid
- Reduce / eliminate fossil fuel infrastructure – e.g. natural gas
- Improve long-term building resilience to support ESG objectives
- Improve NABERSNZ performance

Why

Building electrification matters in NZ

- Replace end-of-life energy plant such as boilers and chillers
- Create opportunities for operational efficiency:
  - Modern heatpump systems
  - Controls upgrades
  - Replacement of legacy / inefficient plant e.g. EC Motors

Electrification is often the most practical pathway towards decarbonising existing commercial buildings

Why Existing Buildings Are Different

New Build

- Clean sheet of paper
- Designed for low temp systems
- Coordinated approach from the outset
- Planned electrical infrastructure for all electric
- Unified strategy for systems
- Spatial and structural planning from the outset

Existing Building

- Legacy constraints
- Existing systems likely high-temp
- Unknown operational history, changes and system interactions
- Existing electrical system capacity limitations-Gas as a heating source
- Layered modifications over decades
- Space & structure challenges, Resource Consents

Electrification is easy in theory…

Making existing buildings work afterwards is the challenge

- Some buildings are more **'Electrification ready'** than others:
- They may already have:
  - Low temp heating systems
  - Upgraded controls / BMS
  - Spare electrical capacity
  - Available plant space
  - A good thermal envelope (Double glazing *etc*)

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Electrification is easy in theory…

Making existing buildings work afterwards is the challenge

- More commonly, buildings throw up challenges, making them ‘less Electrification Ready’
  - High temp heating systems
  - No spare electrical capacity
  - Limited riser space
  - Poor/aging controls
  - Limited available plant space
  - Structural challenges
  - Tenant sensitivity

Case Study

The 80°C Heatpump That Couldn't Heat the Building

A decarb project can look technically impressive on paper

… but fail spectacularly if the building systems are not well understood!

This project will demonstrate:

- Why existing hydronic systems matter?
- Why VAV reheat systems are tricky?
- Why return water temperature is critical?
- Why "headline temperatures" can be misleading?
- Why operational reality beats theoretical performance.

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Case Study

The 80°C Heatpump That Couldn't Heat the Building

A decarb project can look technically impressive on paper

Decarbonisation is not just about replacing the heat source.

It's about ensuring the entire system still works afterwards!

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Case Study

The Proposal

Picture an existing building – Quality design and installation.

Large central plant VAV (Variable Air Volume) systems.

The fundamental aim: Replace aging gas fired boilers with CO_2 based heatpumps.

Legacy 80°C heating water temperature.

Retain existing infrastructure (VAV AHU's and VAV boxes throughout).

Case Study

The Proposal

A typical “Replace fossil fuel heating source with electric heating:

- Replace ageing gas fired boilers
- Install CO_2 Heatpumps
- Deliver 80°C water
- Reduce emissions
- Improve NABERSNZ rating
- Reuse existing infrastructure

Discussion:

At first glance…

What sounds good about this?

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Case Study

Why CO_2 Heatpumps Are Attractive

CO_2 Heatpumps:

- Can generate high temperature water
- Zero ODP
- Have extremely low GWP =1 (Negligible)
- Are excellent for:
  - Domestic Hot Water systems
  - Process heating
  - Applications with cold return water

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Case Study

How conventional refrigerant based heatpumps work

Traditional Heatpumps utilise latent heat of evaporation & condensing to transfer energy over small temperature differences.

- Standard heatpumps, typically air sourced, operate to provide heating hot water at 45 – 50°C under normal operating conditions.
- Where higher water temperatures are required – typically as direct replacement of a traditional heating boiler, a two-stage strategy is required.

Case Study

How conventional refrigerant based heatpumps work

- The Stage 1 heatpump is: Air source
- Extracts heat from the surrounding ambient air
- Produces heating water up to 45-50°C
- Expected return water temperature of 35-40°C.

Case Study

How conventional refrigerant based heatpumps work

- The Stage 2 machine is: Water source
- Extracts energy from the stage 1 heating loop
- Reduce that loop temperature by approximately 10°C, before returning it to the stage 1 machine for reheating.
- The heat extracted from this loop is boosted via the refrigeration cycle to circa 80°C
- Supplies hot water directly to legacy heating coils.
- Cooled return water recirculated back to the stage 2 machine.

Case Study

The Critical Concept - CO_2 (R744)

CO_2 systems are transcritical

CO_2 refrigerant does not condense into a liquid when cooled by the water it is trying to heat - it remains in a fluid state.

No phase-change "plateau," as per refrigerant based systems

The gas cools over a larger temperature range, typically from ~100°C to ~35–40°C.

For the heat exchange process to be effective, the water temp must also experience a large temperature rise.

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The Critical Concept - CO_2 (R744)

Result - The system generates heating water from ~30°C to ~90°C.

System relies on the very cool return water temperature to efficiently heat the water to 80-90oC

If the water to be heated is returned too warm:

System efficiency rapidly drops, as low temp differences between the water and the CO_2 refrigerant.

System performance and efficiency is therefore reliant on large temperature differences.

Case Study

The Critical Concept

So, what happens if:

The building sends back 65°C water to a CO_2 heatpump?

- The Heatpump output capacity collapses (Low ΔT.)
- The gas cooler rejects heat to cool the water, so efficiency drops
- Heatpump COP collapses
- Plant derates massively
- Efficiency we sought to gain is lost

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Case Study

The Building factor

What is the application for this 'case study' CO_2 heatpump?

- Large commercial office building
- VAV (Variable Air Volume) system
- Hundreds of VAV boxes with terminal hot water reheat coils
- Original heating system design based on:

  80°C flow temperature, 67°C return temperature

Case Study

The Building factor

VAV systems are required to deliver cool air
(other than during morning fast-warm-up cycle)

The perimeter and central zones reheat locally, so the VAV reheat coils dominate heating load

Those heating coils were designed around high-temperature hot water (80°/ 67°C)

Case Study

Lessons

At face value, the heatpump was theoretically large enough…

Until the existing building system was connected to it.

- The problem is not the nominal capacity of the heatpump
- It is that the building cannot provide a sufficiently low return-water temperature to allow the CO_2 heatpump to deliver its rated capacity.
- i.e. it is inefficient at warm return water temperatures

Case Study

Lessons

Issues:

- The design of the VAV box heating coils was based on a 13°C temperature split.
- The coils will not achieve their rated output with a 50°C temperature split
- As a result, the building cannot be effectively heated.
- The existing system cannot realistically return 35–40°C water.
- At the required 67°C return water temp, the CO_2 heatpump performance will be significantly reduced.

Case Study

Results

So why can’t we just slow the water flowrate down to increase ∆T?

This would result in:

- Lowering the mean coil temperature (and LMTD)
- Significantly reduced heating output from the reheat coils
- Inability to maintain zone heating requirements, particularly for perimeter zones
- Loss of comfort for the building tenants
- = Complaints, lost time, service cost increases

Case Study

Results (Continued)

Estimated performance drops were:

Building peak heating demand	1,600 kW
Proposed CO_2 Heatpump nominal capacity	2,000 kW
Estimated capacity at actual predicted higher return water temps	~1,250 kW (62% of claimed performance) COP drop from ~3+ to < 2
Additional capacity reduction due to winter defrost operation	-10% to -20%

Case Study

Results (Continued)

Likely real winter performance	Potentially ~1,000–1,100 kW (!,600 Req’d)
	62 – 68% of required performance
	50 – 55% of claimed performance
	Energy use ~ 50% more than anticipated

The building cannot be sufficiently heated!!

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Case Study

Lessons Learnt

Existing systems matter!

- Not all heatpumps are suitable for direct replacement of boilers – it is application specific

  High temperature does not always ensure compatibility

  - The advertised supply temp is not the full story

  Return water temperature is critical

  - Especially for CO_2 systems

Case Study

Lessons Learnt

Whole-system thinking matters!

- Terminal units (VAV Boxes in this case), Control systems
- Air and water flowrates, Electrical infrastructure
- Thermal loads & occupancy patterns all matter.

Decarbonisation is operational engineering and it is system specific

- It is not just equipment replacement
  – even at increased capacities!

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Case Study

The use of New technology

This does not mean CO_2 heatpumps are poor technology!

They're excellent for:

- Domestic Hot Water systems – where high ∆T's are the norm
- Industrial heating systems – where high ∆T's can be designed for
- Systems specifically designed with low return water temperatures

Electrification projects fail when we replace the plant…

but forget to account for the design requirements of an existing system

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Electrification projects fail when 'systems thinking' is missing!

Practical Realities

1. Electrification Changes the Entire System

Replacing a boiler with a heatpump is never a “like-for-like” replacement.

Discussion Points

- Conversion from gas to single stage electric heatpumps requires additional electrical capacity and related infrastructure
- Water flowrates will increase due to lower operating temperatures
- Control strategies must be upgraded to suit new heatpumps
- Additional spatial and structural requirements

Successful projects are typically based on a whole-of-system approach.

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Practical Realities

2. Heatpumps need stability

Heatpumps are less tolerant of unstable hydronic systems than boilers. Be kind to them!

Discussion Points

- Low water volume will cause short cycling, compressor stress, nuisance trips and premature failure
- Heatpumps require greater system volume than boilers, careful staging, hydraulic separation & stable flowrates
- Buffer tanks are often underestimated.
  Typically, 7–14 litres/kW for chillers - x2 for heatpumps.

Practical Realities

2. Heatpumps need stability

Discussion Points

- Defrost cycles are inevitable in cold climates
- The temporarily remove heating capacity
- Systems relying on high outside air quantities are critical to heating continuity and are vulnerable during defrost cycles.

When the outdoor coil is full of ice – something's gotta give!

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Practical Realities

3. Temperature Still Rules Everything

Existing HVAC systems designed for 80 / 70°C.   45°C won’t cut-it.

Discussion Points

- Legacy systems commonly designed around 80°C flow / 70°C return
- Many modern heatpumps operate most efficiently at 40–50°C
- Lower temperatures reduce coil output/reheat capacity & warm-up performance
- Problem areas include AHU heating coils, VAV reheat coils, plate heat exchangers and radiators / convectors.

Practical Realities

3. Temperature Still Rules Everything

Discussion Points

- High-temperature Heatpumps exist, but:
    - Efficiency drops
    - Complexity increases
    - Capital cost increases
    - Economic life expectancy reduces

The challenge is not making 80°C water…
it is making it efficiently and reliably!

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Practical Realities

4. Successful Electrification Requires a Master Plan

Electrification is usually a staged transition, not a single project

Discussion Points

- Existing buildings often require enabling works, staged upgrades, temporary hybrid systems and future-proofing
- Sometimes the first step is to upgrade the controls, the electrical infrastructure, thermal storage and heating coils
- Building envelope improvements should be considered early to avoid over sizing plant
- The heatpump itself may be the easy part!

Practical Realities

4. Successful Electrification Requires a Master Plan

Discussion Points

Example:

- AHU Existing legacy hospital system consists of gas fired steam boilers, feeding steam / water plate heat exchanger, to supply 80°C heating water the AHU heating coils.
- *Stage 1* – Add 45°C heatpumps, add supplementary duct electric heaters to make up shortfall in capacity.
- Retain existing aging ’s for 3-5 years. Decarb stage is complete, but some compromise on energy efficiency.

Practical Realities

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4. Successful Electrification Requires a Master Plan

- *Stage 2* – Replacement of aging AHU's utilising larger low-temperature heating coils and install a complete low-temperature hydronic heating system.
- Full energy efficiency potential is finally realised.

Good electrification projects often take several years to achieve the master plan outcomes.

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Timing Matters

Master planning

Electrification works best when aligned with asset lifecycle planning

Discussion Points

- Electrification rarely stacks up financially as a standalone replacement of functional plant
- However, when existing boilers, chillers, AHUs, controls, or cooling towers are already approaching end-of-life, the business case changes significantly

Timing Matters

Master planning

Electrification works best when aligned with asset lifecycle planning

- Existing capital replacement budgets can often absorb part of the transition cost.
- This creates stronger owner buy-in, improved ROI, and a clearer pathway toward long-term decarbonisation.

If major plant already needs replacing…
why reinstall fossil fuel infrastructure again?

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Avoiding Stranded Assets

Poor sequencing, isolated upgrades, expensive dead-ends.

Electrification should be viewed as a long-term asset management strategy

Discussion Points

Without a master plan, projects can accidentally result in:

- Replacing a boiler today that becomes obsolete in 5 years
- Replacing coils twice to transition to low temp sustainable heating water
- Under sizing or duplicating electrical infrastructure
- Installing temporary solutions that later restrict future upgrades

Avoiding Stranded Assets

Poor sequencing, isolated upgrades, expensive dead-ends.

Electrification should be viewed as a long-term asset management strategy

Without a master plan, projects can accidentally result in:

- Oversized or inefficient plant due to lack of long-term planning
- Good master planning allows staged upgrades, future-proofing, coordinated electrical and mechanical infrastructure,
  and a smoother transition toward low-temperature sustainable heating systems

Electrification projects fail when today's upgrade prevents tomorrow's strategy

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