# HOSPITAL PASS

# CASE STUDY: ENGINEERING CLIMATE ACTION

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This document provides a summary of the webinar by Jack Young, a mechanical engineer and energy specialist.

Jack is a Senior Energy Engineer at Energy New Zealand. He specialises in industrial energy management and sustainability. He enjoys optimising mechanical and thermal systems, and working with teams to solve complex industrial and engineering problems across the industrial sector.

In this webinar, Jack discusses how the heavily regulated and change-adverse health care sector has begun to drive transformational change to tackle the task of energy transition. He then discusses how the lessons learnt can be applied to other industries.

# 1: INTRODUCTION

In New Zealand, almost all large hospitals use large amounts of fossil-fuel energy, which is due to the requirements and services hospitals need to meet.

Hospitals are buildings that have huge heating, ventilation, and air conditioning (HVAC) systems. Hospitals also use significant amounts of potable hot water, where steam is used to sterilise surgical equipment and reusable materials. These systems must run continuously. Other services further add to their energy use.

There are numerous reasons for hospitals to transition to a low-carbon future. Not only are District Health Boards (DHBs) internally and externally mandated to address their emissions from energy use, but the pricing and availability of fossil fuels like natural gas is also a significant factor. The use of fossil fuels is no longer financially viable in the long term, due to their increased costs and their fluctuating availability which greatly impacts the operating costs, risk and resilience of the hospitals.

There is also strong public sentiment and a government mandate to reduce emissions. Although new hospitals can be built, the cost and time required to build new facilities – rather than upgrading existing ones – is too great. Therefore, transitioning existing hospital infrastructure is more viable.

# 2: DESIGN

The goal of this project was to **understand** energy use and the complex systems at the hospital. The project first sought to identify future projects that **reduced** energy use. The project then identified projects that **eliminated** the use of natural gas.

### UNDERSTAND

- Energy mapping; submetering data and calculations
- Where, when and how energy is used, transformed and rejected

### REDUCE

- Optimise existing systems
- Eliminate waste
- Displace fossil fuels

### ELIMINATE

- With new low-carbon equipment and systems.

## MODELLING

Our study sought to understand energy use across the site. To understand how the system could be improved, we had to first understand where energy is used and any inefficiencies in the system.

Understanding the difference between energy quantity (kWh[1]) and rate (kW[2]) is important as it can often be confused. Energy use depends on temperature, timing (day/season), and efficiency[3] and should be clearly understood.

Modelling was conducted for due diligence. This included a top-down approach using revenue data and a bottom-up approach using observations, measurements, and submeter information and calculations for specific pieces of equipment.

### KEY INSIGHTS

#### Sterilisation services only account for a small fraction of the total steam energy

Natural gas is used by the main steam boilers to make steam, which has a couple of end users, such as the Primary Central Sterile Services Department (CSSD), which refers to the steam sterilisers for surgical

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[1] https://en.wikipedia.org/wiki/Kilowatt-hour

[2] https://en.wikipedia.org/wiki/Watt

[3] https://en.wikipedia.org/wiki/Energy_conversion_efficiency

equipment. We wanted to calculate how much steam the CSSD used, overall and per cycle. When looked at from a bottom-up approach, the CSSD accounted for only a small fraction of the total steam energy. This investigation further showed that much of the energy used by the steam boilers is wasted as baseload losses.

### Ventilation results in a large amount of energy waste

The hospital for this case study utilises an HVAC system that is once-through, meaning that there is 100 per cent fresh air supplied to every area, all the time, to meet ventilation requirements. The recycling of air in the hospital was not possible with existing equipment, and even if it was it may not be used due to the presence of COVID-19 (a respiratory virus), resulting in a significant amount of energy in the HVAC exhaust air being rejected to atmosphere.

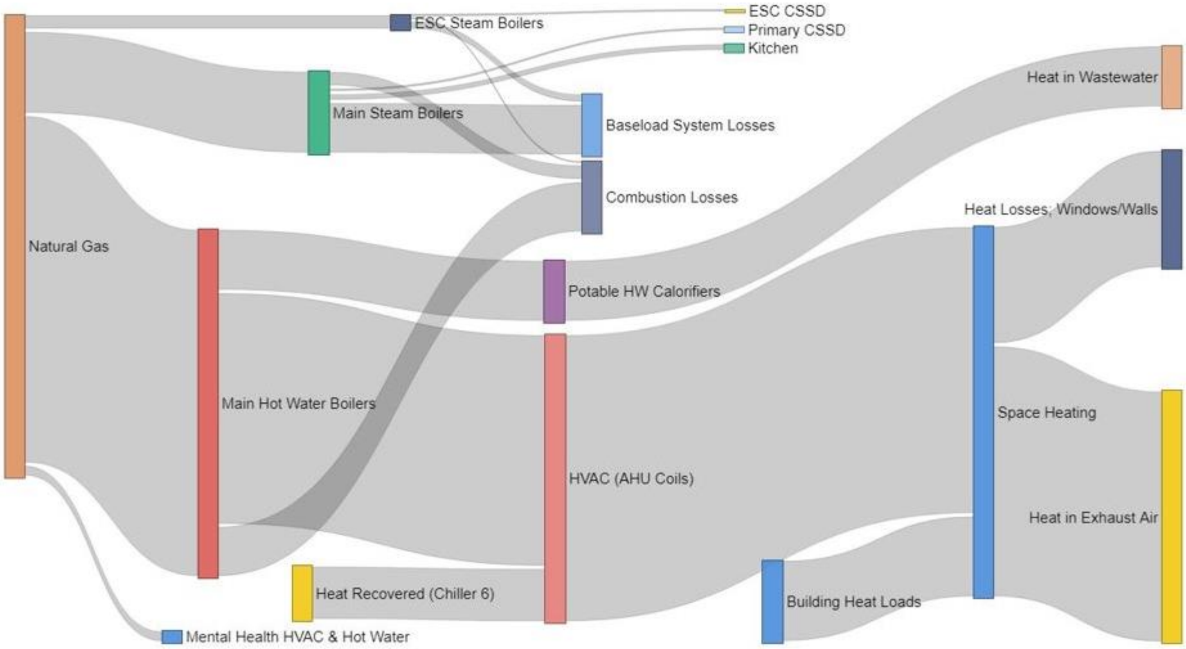


*Figure 1: Current energy flow (Source: EnergyNZ[4])*

Figure 1 is a scale diagram showing an output of the initial investigations of the energy flows and transformations through the hospital describing natural gas and annual energy usage.

### Hospital chillers use a small amount of electricity to move large amounts of heat energy

Hospital chillers use a small amount of electricity to move large amounts of heat energy, and the HVAC exhaust air contains a large amount of recoverable heat energy in the form of air at about 23°C. This is another potential source for recovering wasted energy if upgraded to a useful temperature using a heat pump.

[4] https://www.energynz.com/

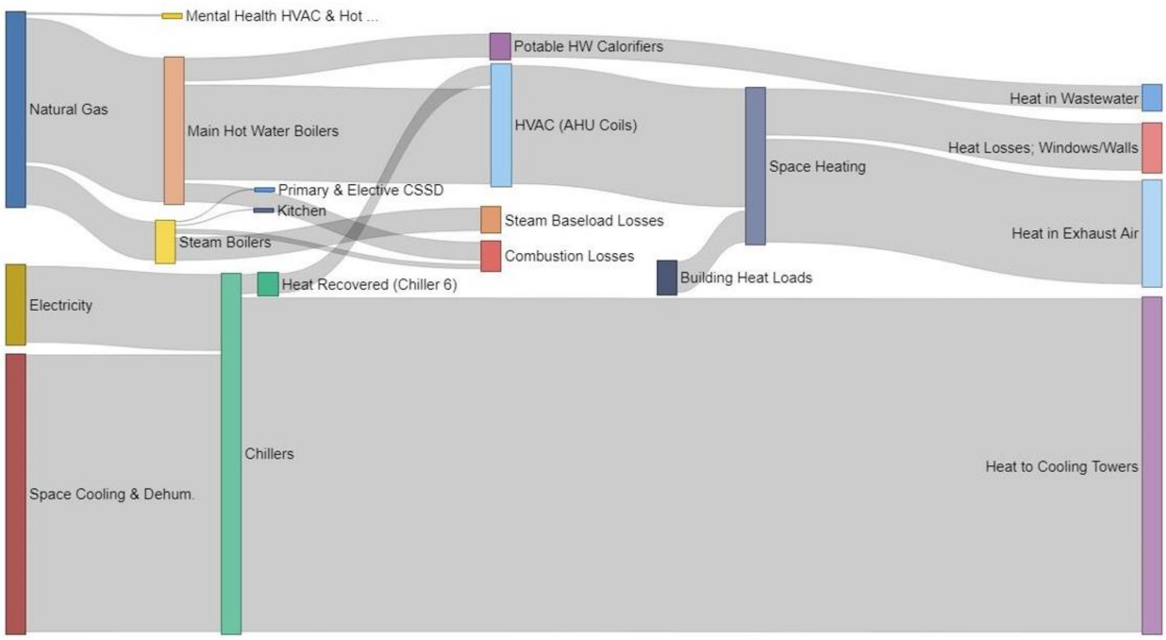


*Figure 2: Hospital chiller energy usage*

Figure 2 is a scale diagram showing the natural gas energy used for thermal systems and the electricity used for the hospital chillers.

# EXPLORING IDEAS

Once we better understood the energy usage from the data collected, we could start to suggest projects to increase efficiency. These ideas include:

- hot water heat pumps
- electric steam boilers changing for direct electric power equivalents
- biomass hot water boilers
- window films
- wastewater heat recovery
- backup generator set heat recovery.

Key considerations the study looked at for identifying and quantifying these projects involved:

- the emissions associated with their ongoing operations
- the project capital cost, fuel costs, and the maintenance costs
- the resilience and reliability of these hospital systems (as statutorily required)
- the capacity of the existing transformers, switchboards, and non-essential supplies and the electrical distribution on site.

# CO-BENEFITS

Finding emissions reduction projects that add co-benefits to solve existing problems were important to consider. Several solutions had important co-benefits that were looked at, in order to:

- reduce maintenance burden
- reduce operating costs
- improve resilience
- improve safety
- reduce water and wastewater.

# CONSULTATION

### Tendency to focus on problems and roadblocks

Once the projects had been identified, a stakeholder idea discussion was initiated. This was a vital step in the process. There was a positive engagement at all levels, indicating that people wanted positive change. The difficulty here was that it is really hard to challenge the 'business as usual' mindset, which makes it very easy to focus on the problems and roadblocks for why things cannot happen.

Often, large-scale change can be an uncomfortable idea. Time, discussion, and comfort need to be considered when approaching these ideas, as it cannot just happen within one meeting. As engineers, we can use those reasons to understand challenges for moving forward and improve our decision-making process.

### Key shift: understand the end service provided by fossil fuels

A key shift that helped the project through was making sure that the end services currently powered by fossil fuels were well understood. Understanding exactly why fossil fuel is being burnt, how efficient that system is, and what service is being provided at the end user (i.e. a CSSD steriliser) is essential. The key requirement of a possible project was to provide the same or better services without the use of fossil fuels.

### Imagine: a hospital without fossil fuels – what steps are needed?

It also helped the project to consider, from the start, a future world without fossil fuels. What would hospitals do? It helps to start joining the dots between our current state and the ideal future state. Once we understand the difference, it can avoid heading in the wrong direction.

# ROADMAP OPTIONS

The stakeholder discussion found steam boilers could be removed and replaced with Electric CSSD (sterilisers) and electric kitchen equipment.

All remaining natural gas at the hospitals is used for hot water. However, this could be reduced with hot water heat pumps that can upgrade waste heat at a low temperature. Hot water heat pumps require a waste heat source, which is why it was key to identify, quantify, and understand the profiles of the chillers. The chillers and the HVAC exhaust are waste heat sources.

Once we addressed the hot water requirement, we were left with a fraction of the current gas usage still needed for winter peak heating loads. There are options to eliminate this, including air source heat pumps, or a winter boiler that is just needed on those coldest days and that could be fuel-fired temporarily.

# ROADBLOCKS

A roadblock for this project was that a CSSD (sterilisers) replacement project was already in progress with the hospital. During the project, it was discovered the sterilisers were at the end of their life, and their replacements were ready but had not yet been sent.

Urgent investigations then occurred to change the purchase order to electric equipment, which turned out to be slightly cheaper. Investigations on capacity upgrades were then quickly scoped and priced as the electricity needed for the electric equipment is substantially more than the steam-heated equipment.

Because of the project’s urgency, conservative assumptions were made around the peak loads needed and the capacity needed. Those assumptions influenced the pricing of the equipment to provide that capacity, which may have inflated the scope. That wasn’t ideal, but it’s what had to happen at the time.

The extra electrical demand led to a new supply being needed. There was an existing connection to the grid that had capacity, but there was a new transformer needed to get that capacity down to 400 volts. Modifications to an existing switchboard were needed, there was new cabling to a new electrical board for the sterilisers. A new backup generator set was required to provide backup electricity for the electric steriliser. There are a lot of different issues here with complexities.

# NUANCES

There were nuances around the issues surrounding the sterilising equipment. Electric capacity upgrades were being planned anyway and would be needed for future expansions that are planned. An investment would be needed to maintain existing steam systems. However, the cost could be avoided by decommissioning the existing steam system, avoiding the need to replace and upgrade components in that system. A new kitchen upgrade was happening anyway, so the ability was there to replace that equipment and electrify.

However, as discussed earlier, timing was a key issue because the new equipment had to be ordered and in service by a certain date, and that was the critical path. It transpired there was no way to get the electric capacity upgrades completed within that critical path time frame. **This is why the project felt like a hospital pass.**

# 3: IMMEDIATE IMPACT

Due to the time constraints, the hospital ended up ordering steam heated CSSD (sterilising) equipment instead of the electric equipment this project proposed. The requirement for steam heating locked in the need for steam boilers, which burn natural gas. Electricity upgrades were identified but no closer to happening than before. Many who worked on the project felt like it was a failure.

## RETROSPECTIVELY

Looking at this retrospectively, the project team's work and the range of initiatives put forward in the roadmap really opened the eyes of senior decision makers. It highlighted the range of options available and the trajectory that would be required to meet government requirements and climate change goals.

A key outcome was highlighting that there are viable replacements for the central steam system, which was running very inefficiently. This also presents substantial cost benefits from the reduced maintenance burden for hospital staff and a less complex overall system.

One interesting factor realised after the project failed was that the new CSSD sterilising equipment could be retrofitted to be electric later. Obviously, there is a cost associated with this option, but it is a fraction of the total investment cost. The equipment would not need to be replaced with an electric steriliser. It was possible to retrofit a new steam steriliser to be an electric steriliser. This option was then scoped and priced.

## CURRENT OUTLOOK

Things can move very slowly at large organisations and institutions, including hospitals. However, New Zealand's hospitals are advancing these projects over the next few years, integrating with asset management cycles.

# 4: DISCUSSION

## LESSONS FOR ENGINEERS

### System level understanding is the key to finding opportunities

System level understanding is key to finding opportunities. In this project, if the steam boilers were the only thing that were looked at, opportunities would have been missed.

For instance, the opportunity to electrify the end of the sterilising equipment and the kitchen equipment on its own would have been missed. Alternatives for providing steam into the system without reducing the waste that is inherent in that central system would probably have been looked at instead.

Therefore, system level understanding really is the key to see the big picture.

### Understand both supply and demand

The supply side (in this case the energy used and the utility equipment, like the boilers) is only a part of the picture that needs to be understood. You need to understand the demand side, for example where/ how/ when steam is used, as this can be more complex. It is often hard to measure things on the demand side, but it is one area where you can get most of the way there even with very limited information and some appropriate modelling and assumptions.

This is where good engineering judgement lies. You might gather information by looking at a specific piece of equipment like a steam steriliser and by looking at the datasheet. You can work out exactly how many kgs of steam it uses per cycle. Then, by looking at the number of cycles, the amount of steam it uses can be deduced, which can be compared to the total amount of steam produced. Once you have that type of information, you can begin to evaluate the efficiency and use data to make better decisions.

### Timing – key decisions need to be identified well in advance

Critical to solving complex problems is to identify all the potential solutions and then find the one that provides the best results; moreover, key decisions need to be identified well in advance. That is where we as engineers need to get busy right now because these things can happen slowly. We need to ensure good decisions can happen as soon as possible, otherwise, we risk delaying improvement and carbon reduction.

### Co-benefits matter

Co-benefits are important, especially looking at solving problems around required maintenance. The simpler the system, the better. That comes down to some basic engineering principles about the simplest solution being the most elegant.

Maintenance is a huge headache for these types of organisations, and publicly funded organisations are looking at reducing maintenance costs to reduce the burden.

### Leverage helps

Leverage helps to make sure that comparison is being made on the fairest basis. That comparison will often be what is the continued cost of ‘business as usual’ versus changing the system. In this case, this involved looking at the cost of doing nothing and letting that existing same system keep running. There is the natural gas cost, but there are also associated maintenance costs. Understanding current and future maintenance costs is a really important factor in evaluating the cost of business as usual compared to the cost of change.

# 5: Q&A

**How do you initiate discussion with a client? When dealing with the DHB for example, it can be obvious to an engineer when you're discussing things with another engineer, that these things are a good idea, and they need to happen. But procurement people and CFOs are the hard ones to get over the line. How do you start to initiate those conversations in the first place?**

*It comes down to a team approach that's really effective. One person or group of engineers can be somewhat limited at times in their influence that we can wield. Making sure that you have a team or that the team you are working with that you know that can help you influence decision makers to make the right decision. That might be someone in management who knows what is important to decision makers at the board level or corporate level. That can be key. Then be aware that, that might take time and it might take multiple tries to be successful and kind of exerting that influence.*

*The second thing is communication. In a lot of organisations – and the DHBs is a good example – projects are communicated in a business case which is a fairly standard document. You describe the projects and Google who reads that full description, and then it comes down to what is the key benefits and the financial implications of that decision. So, make sure you understand the key costs of 'business as usual' and the project. This can often help when looking at things from a whole system perspective.*

*One further about communication – these things can really be complex and the simpler you can get your communication the better. The sand key diagrams is one example of this. If we can sit there and talk someone through a sand key diagram it is far more likely to get that understanding across and have people agree with the reasoning that's lead us to certain areas, than it would be to provide them with a table of numbers or a graph with no context. So, looking at what communication is relevant for what specific audience can also help communicate that kind of system levels thinking.*

**Engineers aren't typically good with soft skills and it's often not taught in university and polytech courses. Do you have any recommendations for courses on this? How did you learn to become an efficient communicator essentially?**

*I'm not a perfect example, but there are a number of courses out there on soft skills. There are ones about how to communicate to non-technical audiences and how exert influence without authority, which can be really useful. Also, some people naturally communicate and influence as part of their job. If you can find those people and if you can make sure that on a personal level you can communicate with them effectively, then that's going to help you in that kind of wider company structure. Often these aren't people in management roles, and they might have a little bit more information on what their managers or the people in the approval process are looking for. So lean on your team. Don't just look at developing yourself, although that is a key step, but try and find the most effective people you can work with for results.*

**Is the level of steam wastage you saw typical of hospital systems or is this an outlier?**

*The systems we saw in the hospitals had a relatively high base load system loss. For simplicity, we lumped that into one lump in the diagram here but the key factor with hospitals is that you've got some peaky or spikey demands for steam and relatively high baseload losses. So, with those sterilisers, a large hospital like this would have around four sterilisers and then another four pieces of equipment that work like them, running cleaning cycles every so often and have a really high demand for steam for a short period of time and then a much lower demand the rest of the time. So that's a peaky cycle. The kitchen is the same way. They use a lot of steam for a really short period of time, so you can appreciate the challenge that a design* *engineer would have had sizing that steam plant and equipment and also sizing for future expansion and for potentially an on-site laundry.*

*Other key changes have a large difference on the size of steam and on the size of the steam system. It's really hard to size. Often, the steam borders are oversized for the kind of average loads. Everything tends to average out more in reality than it does on the design table. So, there are a number of key losses there that are compounded by the fact that you've got larger borders than necessary. So, the stuff we've found is typical for a hospital but it's not typical of industrial systems that have a much higher base load and consistent loads those will have. The losses will be a much smaller proportion of the input energy that what we've seen at the hospitals.*

### How much of the base load system losses were as a result of heat loss and the steam loss and condensate recovery? How much was the design load averaging process?

*There was steam-based load loss, which is heat loss in the steam and condensate piping. There was that fixed kind of loss and there's steam traps and improved insulation of other things you can do. Then there was the efficiency of the boilers and meeting that average load and because they're large boilers, you've got two of them for redundancy purposes. So, you've got a hot dirty boiler and a hot standby and they're meeting a very low average load. They're both cycling on and off and purging, so you don't get ideal combustion efficiency and you get all those purge losses, and then there's fixed losses with the steam boiler system. Obviously, combustion loss and blow down and the energy required to heat up new feed water and stuff. There's probably more in-depth discussion but there's a small amount of steam based on losses, which they were not the majority. They were substantial but not the majority of these hospital systems.*

*In most cases there was the waste heat recovery. Systems do not last due to various reasons. One of the main reasons would be when the source is not available, there must be an alternative method to get the same heat recovery etc. how do you mitigate this challenge.*

*I don't know which waste heat recovery systems you're specifically referring to, so the ones we're looking at here are chiller heat recovery – basically heat pump that effectively is a chiller. So, you're putting a heat pump next to a chiller and then you're recovering that heat, and the longevity of that system is it'll last as long as a chiller would. So those are industrial grade systems you'll probably get 20 or 30 years out of those.*

*Other waste recovery systems – if you're talking about things like an economiser on a steam border – that's not what we're looking at there and there's obviously a substantial issue with that sort of thing. But we were looking at heat pumps. There would be exhaust that exhaust air duty. You'd need to put a new coil into the exhaust air system, and that's used for air handling units for the heating and cooling coils that go into those. So again, there's no kind of serious issues with those recovering heat from exhaust air streams – we're not talking about recovering heat from combustion heat from combustion heat streams.*

### Can you tell us a bit more about biomass boilers and do you think that they're a good option for hospitals?

*Yes, they can be a good option for hospitals. It comes down to a few key questions, including fuel availability and potential for on-site storage. I think if you were building a new hospital in certain areas of New Zealand that had good biomass availability, it would be the obvious choice. We were looking at hospitals in parts of the North Island that did not have significant local supply of biomass and so that would have to travel a long distance and we were also looking at existing hospitals which had very limited space requirements on site for the fuel. The fuel is a solid fuel, so it has to travel, and so what that means in practical terms is that it's* *coming on a truck and you need a bunker and a fuel handling system. So, on an existing hospital with limited footprint, in an area that doesn't have excellent biomass availability, it might be possible but it's probably not the best solution. That's why we steered away from that.*

*Another key factor on that option is that at the hospital we're looking at, the boilers are on the roof and there's no good access to replace those with biomass boilers and get the fuel up onto the roof. You would have to look at something on the ground level and real estate is at a premium on existing hospital facilities.*

### Why did you not consider solar power?

*We were looking at stationary energy emissions. With solar power, there are obviously two key technologies in that space. One is solar PV and those are the panels that generate electricity so that would act to reduce this and that can be done. There is a lot of business doing that. It offsets your energy costs as well as your reported emissions from using grid electricity. But at hospitals, most of the emissions are natural gas and so solar PV does nothing to help with natural gas.*

*What you can look at, because a large portion of this natural gas is used for heating hot water, are solar hot water systems, which can work – it's just a case of, 'Are they the best use of funds?' versus the other solutions. It comes down to an economic consideration.*

*There's one other mitigating factor where hospitals might be quite different to a residential house and that is they use most of their hot water for HVAC heating over winter, when the availability of heat from a solar hot water system is at its lowest. So, there's not a great match between the availability of heat from the system and the utilisation of that heat. Projects that can recover heat 100 per cent all year round have a much better return on investment. That's what kind of steered us towards those heat recovery heat pumps – even though they use electricity to power those systems, they can recover so much more heat, and this makes it a more viable project.*

### How practical is direct heat recovery from exhaust air into the intakes by heat transfer at each building, rather than through recirculation? Recognising that air intakes and outlets will obviously be in different places, there are systems available to recover heat from extracted air and residences. How scalable is that in a hospital setting?

*So that's direct air heating heat exchange. I'm very familiar with the options available for residential systems, which can be very effective. However, the infrastructure requirements for hospitals are enormous.*

*If you look at heat recovery using a heat pump at that exhaust location and then moving that heat via hot water, you can have a much more compact system with smaller pipes and pumps. It's probably going to be a cost a lot less overall.*

### What are your thoughts on absorption chillers that are running on steam? So that there are economies of scale?

*Absorption chillers can be effective but need low-cost source of steam generation. The hospitals we were looking at, which are in major urban centers in the North Island, don't have access to biomass, and did not have access to geothermal steam either so the cost of steam would be relatively high. That obviously means that the cost of the cooling that's provided by that absorption chiller is also relatively high.*

*What you really need is a cheap heat source or a heat source that is free to make that a compelling argument. They didn't end up being a kind of suitable technology for the hospitals that we were looking at.*

**DHBs are probably like many other health sector providers: they've got lots of red tape and good intent but the challenge is in delivering. How would you approach other public sector clients in the future?**

*If nothing else changed, we'd probably try things the same way, although try and get it there at an earlier stage than outlined in the sterilising project. I think out approach was good. It was the timing that was bad with that specific one.*

*But I think again, public sector organisations – and private sector organisations to some extent – the whole context for them is changing rapidly. So, if you were paying attention to this area of the Government announcements recently, you would know that the Government has a really big fund of money. There is $220 million for projects to reduce emissions in the public sector.*

*So, the public sector organisations that we work with and that we have spoken to are all keen to find these projects that are going to get them on the path to reducing their emissions, towards that net zero goal. They are keen to find those projects and to apply for funding. That funding really has really greased the wheels of these systems and help provide some more alignment between what management are aware of and what needs to happen to reduce emissions.*

*To a similar extent, that's also happening in the private sector as well.*

*There was an announcement a few weeks ago of a big package of funding for the private sector. So, the Government wants to co-fund projects in the private sector to achieve these same sorts of goals. Again, that's been excellent at greasing the wheels and seeing decision makers more aware of the direction things need to go.*