DECARBONISATION AND ENERGY EFFICIENCY STRATEGIES

ENERGY IN EXISTING BUILDINGS

EECA
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ENERGY EFFICIENCY & CONSERVATION AUTHORITY

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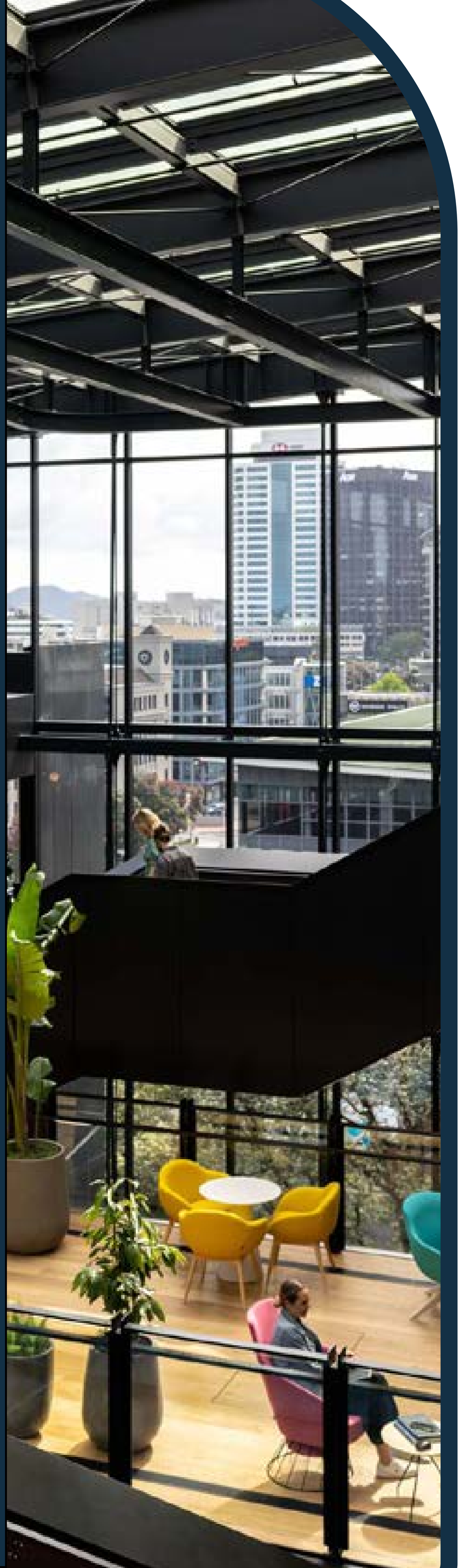


INTRODUCTION & BACKGROUND

PURPOSE AND TARGET AUDIENCE

Decarbonisation and Energy Efficiency Strategies: Energy in Existing Buildings is intended to provide information and raise awareness about initiatives that can help property owners and managers reduce energy costs and cut emissions for their buildings.

This handbook aims to identify initiatives that are not mandated in the current New Zealand Building Code (NZBC), helping to promote best practice energy performance in the existing property sector.

The initiatives outlined in this handbook will encourage building owners to be more ambitious about the energy performance of their buildings, helping to reduce costs and position their assets for a low carbon future.

This handbook is also intended to help the market adapt to the rapid and continuous changes to technology and industry practice. For example, in the past 5 years LED lighting and EC (electronically commutated) fans have leapt from the fringe to standard practice in many buildings. Solar photovoltaic systems have also reached a tipping point, with the number of large-scale installations planned to have increased rapidly over the past 12 months.

The initiatives in this handbook have been grouped in a way that acknowledges the specialised design professionals required to design and incorporate them in practice.

THE DOCUMENT'S INTENT

This handbook is intended to guide the selection of possible initiatives. It provides advice of a general nature and should not be used as a substitute for specialist project-specific advice from building industry professionals. In particular, this handbook does not attempt to address:

- Variability in energy pricing – consumption charges vary with location, organisation size and level of consumption, and some customers are subject to peak electrical demand charges.
- Variability in the upfront cost premium – costs vary with location, and even between one contractor and the next.

HOW THE INITIATIVES WERE SELECTED

The initiatives contained in this handbook are typically those which:

- Have been demonstrated as technically viable at commercial scale;
- Are not prescriptive requirements of the New Zealand Building Code (NZBC);
- Are applicable at building scale (rather than precinct or fit out, for example); and

NDY's experience has informed the guidance that this handbook provides regarding upfront cost premium, payback period, resilience and complexity.

IMPROVEMENTS TO BUILDING CODE

The New Zealand Building Code Clause H1 specifies the minimum energy performance standards applicable to building works in New Zealand, covering requirements for both building fabric and building services.

These apply to both new buildings and works within existing buildings. In existing buildings, it is generally expected that full compliance with the current building code is not required, only that new or modified elements, components or systems within the building achieve the minimum performance requirements, and do not cause any other elements, components, or systems to be less compliant than they were prior to the works. The recent update to Clause H1 in 2021 significantly expanded the scope of elements, components and systems regulated by the code. Review of potential future updates to the code are currently underway and are likely to include a focus on whole-of-life carbon.

GOVERNMENT EMISSIONS REDUCTION PLAN

New Zealand's Emissions Reduction Plan (released in 2022) established the reduction of operational emissions as a key objective for the building and construction industry with improved energy efficiency and reduced reliance on fossil fuels targeted as the primary mechanisms for achieving this.

These will undoubtedly be incorporated in future updates to building regulations and the Building Code, among other statutory instruments.

As part of the Emissions Reduction Plan's objective to reduce reliance on fossil fuels, the government has commenced work on a Gas Transition Plan as part of its broader Energy Strategy. The Plan will focus on actions through to 2035 for the fossil gas sector to reduce emissions and support the transition to a net zero carbon economy by 2050. This will include steps to reduce reliance on fossil gas, while still providing for some fossil gas use in 2035. Lifecycle replacement of fossil gas heating plant in buildings with equivalent electric sources is expected to be strongly encouraged in the short term.

NABERSNZ AND GREENSTAR RATING SYSTEMS

NABERSNZ and Greenstar are both formal rating tools that provide normalised indexes of performance and enjoy international recognition. NABERSNZ rates the measured energy consumption over 12 months, while the Green Star rates a range of attributes including energy.

NABERSNZ is more readily accessible, but still requires that metering is appropriately located to categorise energy flows. Meters, both gas and electric, must be certified to energy-retail standard. Some buildings present complications, for example a single heating water system serving 2 buildings, or a single heating water system serving both office and retail tenancies, cannot be rated under NABERSNZ rules. An initial assessment to determine the feasibility of NABERSNZ rating is necessary to determine the scope of work required.

Green Star is a voluntary environmental rating system for the built environment administered by the New Zealand Green Building Council (NZGBC). Four rating tools exist which can be applied to buildings of all types at different stages of the building lifecycle, two of which are applicable to existing commercial buildings.

Green Star Design & As Built can be used for buildings either when built (new construction) or subject to major refurbishment (see below) to rate the building design attributes at 4-star (New Zealand best practice), 5-star (New Zealand excellence) or 6-star (world leadership).

Green Star Performance can be used for all existing buildings to rate the operational performance from 1-star to 6-star. Points are awarded for exceeding minimum benchmarks against a range of environmental attributes in nine key categories (Management, Indoor Environment Quality, Energy, Transport, Water, Materials, Land Use and Ecology, Emissions, and Innovation). Minimum requirements exist in some categories that must be achieved to be eligible for a certified rating.

Major refurbishment is generally considered to comprise of the upgrade of either or both of a building's fabric and services with the aim of enhancing the building's ability to attract tenants, improve rental growth and maximise market value. In order to do so, the building, or a portion of the building, is vacated and withdrawn from stock for the purpose of the refurbishment.

Building owners interested in understanding how the initiatives detailed in this document may assist in meeting the objectives of either Green Star Design & As Built or Performance ratings, or in seeking formal certification against either rating tool should consult with a Green Star Accredited Professional (refer to the register at the NZGBC website: https://www.nzgbc.org.nz

As at the time of writing, the existing Green Star Design & As Built rating tool is currently in the process of being updated to the Green Star Buildings rating tool. Green Star Accredited Professionals will be abreast of the changes and will be able to advise on the implications of this change to potential building ratings.

As of January 2021, all government-occupied office buildings are required to achieve minimum energy performance standards based on NABERSNZ ratings, and to publicly disclose their performance. Mandated government agencies entering a new lease or renewing an existing lease for total net lettable area (NLA) above 2,000 m² should target a base building NABERSNZ rating of 5-star and must achieve a minimum rating of 4-star (a whole building rating is acceptable where base building and tenancy energy consumption cannot be separated), and all occupied premises must be rated by December 2025. This places a significant onus on the owners of government-occupied buildings to rate their premises, and to improve their rating particularly if less than the minimum 4-star rating threshold.

The introduction of a mandatory energy performance rating system for commercial, public, industrial, and multi-unit residential has been announced by government in proposed amendments to the Building Act. Changes are expected to take effect from sometime after mid-2024, with requirements for different building types introduced progressively.

DECARBONISING: WHERE DO WE START?

Reducing energy usage and decarbonising existing commercial buildings is not an easy task! Building's services within them can be extremely complex and vary greatly from building to building, with no silver bullet to solve it all.

Each building needs assessing on its own merits and many challenges arise when considering decarbonising a building. These include:

- Legislative mandates
- Plant exchange logistics, tenant leasing constraints
- Electrical utility capacity
- Spatial challenges
- Equipment selection and sizing
- Change of use of building since construction
- Modern standards and NZBC compliance
- Refrigerants and remaining life of plant

These are just some of the aspects that need to be considered and often contribute to the final outcome.

LED conversions of existing lighting can provide easy wins, with low capital outlay when compared to removing fossil fuel usage. However, larger energy savings are generally achieved through adjustments to or electrification of a building's heating, ventilation and air conditioning (HVAC) systems or domestic hot water (DHW) generation. Changes to existing commercial buildings needs careful consideration by qualified building services engineers to support the asset owner and a strong understanding of the existing systems and building constraints.

CONVERSATIONS WITH TENANTS ABOUT ENERGY USAGE

Tenants need to play a part here too and understand they may have to give up some comfort conditions to realise a greater sustainability outcome.

Mature conversations with the intent to reduce energy usage are required between landlords (or their representatives), and their tenants. These discussions must note the implications of meeting current lease conditions and the potential reduction of their office climate conditions. For example, discussions may be required to widen HVAC temperature setpoint "dead bands" (the range either side of the actual temperature setpoint, without active heating or cooling) or delay the building warm up cycle in an effort to reduce overall energy usage, which may affect the building's leasing grade.

This conversation then cascades down to the tenant's facility managers communicating to their occupants that this change is accepted by their business, which will likely result in an increased level of temperature-related complaints from occupants.

CONSIDERATIONS FOR TENANTS

Tenants are somewhat limited on the changes that they can introduce without support from their landlord. For example, minor changes within tenants fit outs, such as DHW generation at kitchenettes or toilets may be addressed with the introduction of electric instant water heating units at the source of use. Again, this has implications to available electrical capacities from the tenant's distribution board (DB) and needs checking with the current leasing arrangements.

CONSIDERATIONS FOR FACILITY MANAGERS & ASSET OWNERS

Facilities managers and asset owners need a strong understanding of their buildings and the services within them.

Plant space and logistical access to exchange plants, play a large part of what can be offered to improve HVAC plant replacement options. Plant rooms and external equipment yards are often designed for the original equipment, which limits potential changes. Converting these existing spaces for retrofitting with alternative equipment may be constrained by their position, access, servicing and available adjacent spaces. Plant rooms are often at roof top, mid-level or basement level, which limits options for change and constrains the ability to move away from like-for-like equipment exchanges.

Considerations of the existing equipment's expected remaining life span affects what can be accepted within projected CAPEX plans by asset owners. For example, a newly replaced boiler system providing building wide heating, may reduce options to upgrade a failed cooling only chiller with a modern heat pump chiller, as the asset owners want the life from the previous boiler investment returned before considering alternative heating options with the chiller replacement strategy. This then limits the chiller upgrade options or requires the business to plan operational changes in a more holistic manner when compared to like for like exchanges.

Ultimately, the ideal time to target a holistic decarbonisation strategy for an existing building is at mid-building life. This allows plant exchange to be paired with other significant investments to improve the lease-ability and market targeting such as facade replacement or structural improvement.

CAPEX planning should be aligned with well thought through replacement strategies. It is important for facility managers, aided by engineers, to keep track of the existing plant life and understand the scope for the inevitable projected replacement or exchange needs of the building.

It is also important to note that a replacement process may involve temporarily relocating occupants, at least partially, to accommodate the disruptive construction required to implement the changes.

ISSUES WHICH MAY LIMIT COMMERCIAL BUILDING ELECTRIFICATION OPTIONS

Electrical supply capacity to buildings may limit electrified decarbonisation options. Careful consideration is needed to understand the capacity constraints of the electrical utility supply, (transformers etc.), and the building's main switch board (MSB) and risers. Should upgrades be required, early conversations with the local lines company are recommended.

In addition, upgrading electrical infrastructure supply capacity to a building can be a very expensive and a lengthy exercise, and may constrain what can be electrified and the timeframe. MSB capacity is also often limited to the buildings original design intent and may also need replacing to provide sufficient capacity to electrify building wide heating or DHW generation. If the MSB needs replacement to meet new capacity demands, it must meet modern NZBC compliance. This may require a new MSB room to be constructed to house the new configuration. This work needs modern compliance and fire engineer's reports, must be built to current building codes and with local council building consent, which adds further cost and complexities.

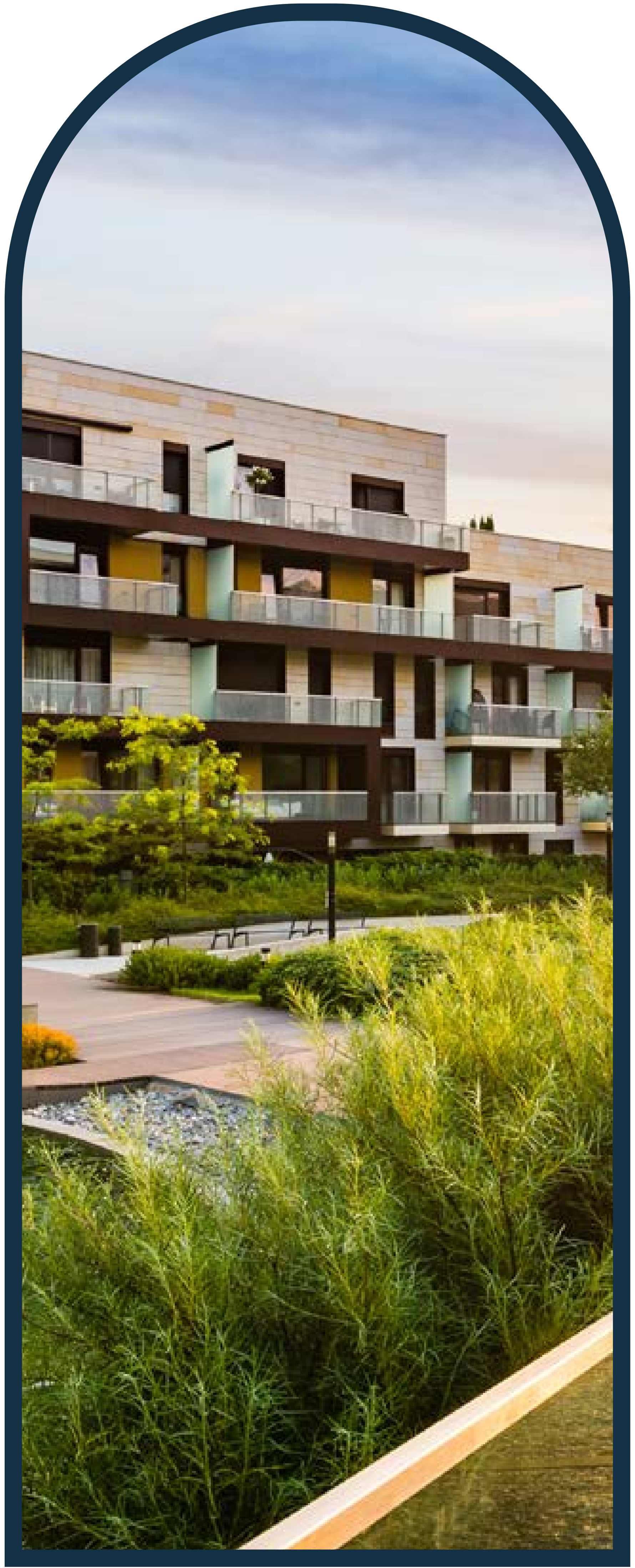
A simple example of adding electric vehicle (EV) chargers to an existing carpark basement may be limited by these capacity constraints. It may be mandated to "load shed" EV circuits when the building reaches maximum electrical demand, for example during the peak of summer during maximum demand cooling loads from chillers. This may limit EV charging availability and capacities at certain times of the year.

UNDERSTANDING YOUR EXISTING BUILDING'S HEATING AND COOLING ASSETS

A sound understanding of your HVAC system is a critical component to determining which replacement equipment might work best for your situation. We include a section further in our report on the challenges of understanding your existing HVAC systems and its importance (page 13).

HVAC systems are typically ducted mechanical systems that facilitate the circulation of fresh air and maintain climate control within buildings. These systems employ a variety of methods and equipment, which collectively impact the volume of air transfer and the conditioning of the internal climate. They are designed to achieve specific temperature setpoints, to ensure comfortable and targeted environmental conditions for the building's occupants.

HVAC systems vary in terms of their air usage, with some systems consuming more air than others. Certain systems offer recirculation options or energy recovery mechanisms within the airflow path. These features help reduce the energy needed to heat or cool air supplied to specific areas, resulting in improved efficiency.



Building-wide heating can be provided in many ways and varies from building to building. One commonly used heating source is traditional gas fired boilers. These supply heating hot water (HHW) for building wide heating through a variety of means such as centralised or distributed heating systems to align with the specific equipment selections on office floors.

In a centralised system, HHW can be used to primarily heat incoming outdoor air prior to distribution to the equipment on the office floors, using heating coils in AHU to supply equipment such as chilled beams or dual duct systems. Alternatively, distributed heating of the outdoor air can be utilised at each office level at branch ducts, using variable air volume (VAV) units fitted with heating coils, or fan coil units (FCUs) fitted with heating coils, located in the area of the specific office zone that they are servicing.

CONSIDERATIONS WHEN REPLACING BOILERS

It is important to note that boilers cannot be easily replaced without also considering associated components. For instance, the comparison between an older-style high-temperature boiler operating at 80°C and a modern condensing boiler operating at 60°C. These two types of boilers require different heating coil sizes, pump flow rates, and riser sizes in order to achieve the same heat transfer. All of these elements must be taken into account when making any changes to the boiler system. In this example, it is crucial to replace the HHW risers, circulation pumps, and coils to ensure that the overall heating capacity remains uncompromised while transitioning to lower temperature HHW generation with higher flow rates.

Additionally, the placement of heating coils in the air handling units (AHU) or within the ducting on each floor level as VAV heating coils, can have implications on the size of the heating coils required. The quantum of in-duct heating coils may be so large that it may cause the exchange to a lower temperature, higher volume coil to be highly costly. This will increase costs when considering alternative heat sources, making boiler conversion less attractive for certain asset owners. Alternatively, replacing boilers with electric heating elements located in on-floor ducting may face limitations due to insufficient electrical capacity from the existing electrical supply, as previously mentioned.

OPTIONS TO MANAGE YOUR BUILDING'S HEAT LOADS & SOLAR GAIN

To reduce a commercial building's energy consumption, it is crucial to address the reduction of heat loads and solar gain in buildings by exploring various options. This includes:

- Enhancing facades through the use of high-performing glazing
- Installing solar shading to limit sunlight penetration
- Improved insulation at spandrels and roof level
- Mitigating the permeability of the facade

These measures lead to decreased heat loads, minimised heat losses, and improved operational efficiencies.

CHANGES TO THE BUILDING OVER TIME

Buildings change over many years of occupancy, resulting in altered heat loads. Even changing to LED lights alters the buildings mechanical heat load profile. Over time, the building may have a very different electrical, heating and cooling demand from its original design. Like-for-like equipment exchanges by building incumbents often ignores this and can result in wrongly sized chiller machines, heat pumps and boilers replacements. Asset owners and facilities managers should look to their building services engineers to review and calculate the actual current or projected building heat load, to ensure the new equipment is sized correctly and designed for the actual loads.

When considering replacing your chiller or heat pump it is important to note that they generally use a refrigerant in their process. In some cases, these refrigerants have been removed from the market due to their damaging effects to our planet's ozone and their potential to contribute to global warming. This may leave some asset owners with machines that may not be serviceable upon failure, such as a refrigerant leak, which is a significant risk to their business. This could contribute to early chiller exchanges allowing further decarbonising works to advance earlier than its asset life indicates.

NEW TECHNOLOGIES

Modern equipment is continuing to be developed by suppliers with improved operational efficiencies to replace older equipment. Heat pump chillers that provide either simultaneous heating and cooling or reversable heating and cooling options are now entering the market with a proven track record to replace gas fired boilers. Equipment capacities are also improving all the time to meet market demand.

While heating and cooling machines with higher output temperatures are advancing, there is still currently no straightforward replacement for existing equipment.

UNDERSTAND YOUR BUILDING SERVICES

HVAC - HEATING AND COOLING

This section describes the various types of Heating,Ventilation, and Air Conditioning systems sufficiently to establish a context for discussion of relevant energy efficiency measures.

The following descriptions attempts to summarise some of the advantages and drawbacks of the major system types. There are many VAV systems in the NZ building stock, and they deliver energy efficiency, comfort and long life, with the advantage also that most maintenance activities are outside the tenant's space. Despite these advantages other systems are popular for the advantages of increased net lettable area, or for the ability to be applied as retrofits to building structures that were not designed to accommodate large ductwork.

Central Plant Systems

Central plant systems, including constant air volume (CAV), variable air volume (VAV) and dual duct (DD) circulate conditioned air from a central plantroom to the occupied spaces and are typically able to change all the air in the occupied space eight times every hour. The temperature of the conditioned air is varied by the central plant from warm to cool as appropriate to maintain comfortable conditions, and this conditioned air is generally a mix of outdoor air and recirculated air.

A VAV system varies the rate of air supplied to each space according to the needs of that space. A CAV system delivers air at a constant flow rate, as may be required for air quality and pressure control in health care facilities. A DD system supplies hot air in one duct and cold air in another, to be mixed at the point of use to meet the needs of the space served. An efficient system should incorporate optimised start and stop, economised outdoor air ratio, and night purge.

Central plant systems are economical of refrigeration energy but use fan power throughout all operating hours. The energy efficiency of the central plant system is offset by the need for more space within the building, requiring greater investment and more embodied carbon in the building's structure.

Distributed Plant System

Temperature control equipment is distributed throughout the building, and the high rate of airflow necessary to control space temperature is restricted to local circulation. These systems include fan-coil units (FCU), variable refrigerant flow (VRF) (also known as variable refrigerant volume or VRV), hydronic packaged air conditioning units (hydronic PACs) and chilled beams (CB). Energy for temperature control is distributed by water or refrigerant pipes, and these are much more compact than the air ducts used in central plant systems. These systems work in conjunction with a dedicated outdoor air supply (DOAS) system, which distributes outdoor air from a central plantroom throughout the building.

The DOAS distributes 100% outdoor air at rates which meet ventilation requirements, typically in the range 1/6th – 1/5th the air flow rate handled by a VAV system. Duct size and fan power is much smaller than for central plant systems, but they do not have the ability to circulate high rates of outdoor air and to use this for cooling without refrigeration, commonly referred to as “free cooling”.

Chilled Beam Systems

Chilled beam (CB) systems can be either passive, active, convection-only, or convection-plus-radiant.CB systems are temperature-control items that are distributed throughout the occupied space and supplied with energy by a water pipe network, all as for the distributed plant systems described above, but the primary air that drives active chilled beams is conditioned by central plant and is supplied at a rate 2 – 3 times higher than that needed for ventilation alone.

CB systems require indoor relative humidity to be limited to 50% RH to avoid risk of condensation on the beams. While this adds an energy cost during warm weather it has the benefit of providing a more comfortable environment, and 24˚C in a CB system is as comfortable as 23˚C in a VAV system. This is relevant to the use of a wider dead band. Active chilled beams also provide effective and comfortable heating using low temperature water, and so are compatible with heat pumps.

Other Systems

Radiant systems work by heating or cooling surfaces surrounding the occupied space, reducing the need to move air through the space. These systems work well when the radiant surface is large and operates at a temperature that is not much different to the space air temperature. For example: a radiant floor (underfloor heating) provides good comfort even in tall spaces that are otherwise hard to heat. Radiant ceilings can provide effective cooling if the chilled panels are large. Radiant systems are economical to operate, primarily because radiant energy has a direct effect on the human body and avoids need to condition large volumes of air. This is particularly valuable, for example, in a double-height foyer or circulation space, where a heated floor will provide comfort without the need to circulate heated air throughout the whole volume.

Displacement ventilation provides cool air directly to the occupied space at low level, and exhausts used air from high level. The need for low level ducting and diffusers limits application to certain room types, for example auditoria and foyer space, and heating must be by some other means. Displacement ventilation provides excellent air quality and high energy efficiency.

Chillers

Chillers are commonly used to remove heat from a building and transfer that heat to the atmosphere, much like your fridge does. Effectively, chillers are generally cooling only, 2-pipe type non-reversible heat pumps for cooling only purposes.

Each chiller type uses various iterations of compressors to manage the condensing of refrigerant to extract and then transfer building heat to the atmosphere. The chillers are effectively removing heat from the building’s air using chilled water coils, transferring it to a water condensing circuit and require cooling towers to then discard that heat from the condensing water to the atmosphere. This type of equipment is often termed “water sourced” machines as it uses water as a condenser medium to transfer the heat from the chilled water circuit to the atmosphere, via a water condenser circuit. As a result, these machines cannot recover heat from the atmosphere. To do this we need to look to heat pumps, known as air sourced machines. Heat pumps do not require the cooling towers like a chiller does, as it uses the reverse process to recover heat from the atmosphere via an array of on-board condenser coils and fans.

Due to the nature of the process, it requires compressing the refrigerant, therefore most chillers require lubricating oils to be mixed with the refrigerant to service the machines parts and maintain machine efficiency.

Chillers with mag-lev bearings do not require lubricating oil to be circulated with the refrigerant and consequently have better heat transfer performance. These chillers can operate efficiently over a wide range of loads, providing a highly efficient solution that is economic when long run-hours are required (e.g. 24/7 operation).

Compressors within chillers, vary from machine to machine and have different characteristics with regards to how they operate and the loads they can operate to meet. Screw, scroll and reciprocating compressors are the most common arrangements and can limit how low a cooling load a machine can be turned down to, to meet lower building heat loads. Often a building may be fitted with a smaller “low load” chiller to maintain the conditions through most of the year when ambient conditions allow, and a larger “high load” machine to operate in peak cooling season (peak of summer) and generally not operating through the majority of the year.

Refrigerants

Refrigerants are chemicals used within chillers and heat pump systems by way of expansion and evaporation to capture and transfer heat. Refrigerants used in commercial chillers and heat pumps are now known to contribute negatively to climate change and have been defined under the Montreal Protocol as ozone depleting substances (ODS). Refrigerants are commonly defined as compared to a ratio of the equivalent to C02, known as global warming potential (GWP). A GWP of 1 notes the refrigerant is equivalent to CO_2. Inversely a GWP of say 4000, notes the refrigerant as 4000 times as harmful to the planet at CO_2. Some refrigerants carry a very high GWP and require immediate ceasing of use, or mandates of no further sales or manufacturing, and others are lower GWP and are now promoted by suppliers. Chillers and heat pumps are design for specific refrigerants and substitution of other refrigerants is very limited and must be supported by the manufacturer.

Certain refrigerants have characteristics that may make some more toxic or flammable than others, some operate at higher pressures, and they vary in their ability to transfer heat at different temperatures. Considerable development by machine manufacturers is continuing to develop improved options and machine characteristics to allow for lower GWP and meet the needs of higher temperature machines to replace older boilers and alike.

Heat Pumps

A commercial-scale heat pump will extract heat from cold air and put that heat into warm water, using electricity as a fuel. This technology allows heating fuel to be switched from gas to electricity. Even when electricity costs are higher than coal, oil, gas or biofuel options, investing in high-temperature heat pumps may still be commercially viable due to their high efficiency and coefficient of performance (COP) of 3. Fuel costs are no more than that of gas, on-site CO_2 emissions from the building’s heating system are eliminated, and as the nation’s electricity supply moves towards zero-carbon generation this electricity becomes progressively more sustainable. Heat pumps are available as:

- 2-pipe heating or cooling
- 4-pipe heating and cooling
- 4-pipe heating and cooling with heat recovery
- 6-pipe water-sourced heating and cooling

The heat recovery machine will transfer heat from the atmosphere to the heating system, and/or from the cooling system to the heating system, when necessary, using some energy from both sources simultaneously. This provides a very efficient solution for heating and cooling a building. 2-pipe machines can be arranged in banks to provide simultaneous heating and cooling from a group of machines.

- An air-cooled chiller takes heat from the water circuit that runs through a building's air handling units and rejects that heat to atmosphere. Heat is discharged to atmosphere via coils using air medium to remove heat without the need for cooling towers.
- An air-sourced heat pump is a "reversed" chiller, taking heat from cold air and putting it into the water circuit that runs through a building's air handling units
- Typically, an air-sourced heat pump includes a reversing valve making it capable of either cooling or heating.
- A 2-pipe heat pump will either heat or cool, and it delivers this energy through the same pair of pipes. This might be connected through a single piping circuit to air handling units that deliver either heating or cooling, depending on the mode of operation selected, and change-over from one mode to the other will incur delay of several hours or a day.
- Alternatively, with additional valving in the pipe circuit, the 2-pipes from the heat pump might be connected to a building's separate heating and cooling circuits, changing from one to the other as the mode changes. This arrangement allows a bank of 2-pipe heat pumps to serve a building's simultaneous heating and cooling requirements.
- A 4-pipe heat pump can transfer heat from the pair of pipes dedicated to cooling to the pair of pipes dedicated to heating. This provides heating and cooling simultaneously and efficiently.
- A 4-pipe simultaneous heat recovery machine can transfer heat from the cooling to the heating pipes and at the same time transfer heat to or from the atmosphere. This type of machine is able to meet a building's cooling and heating demands as they vary through the day and the season.
- A 6-pipe heat pump is similar to the 4-pipe heat pump with the requirement to use cooling towers to remove the building's heat in place of air sourced transfer. Unlike the machine above it uses condenser water to remove the heat from the machine, which then needs to be removed by the way of cooling towers. It has the ability to transfer heat from one circuit to another and vice versa allowing it to recover the heat and transfer it to other building areas. As it does not have the atmosphere to draw heat from, it has the challenge that it cannot service a building's warm up without an additional heating source to draw from. A warm-up source would be required to provide initial heat to the building prior to occupants arriving or equipment and electrical loads rising.

So, heat pump technology provides an efficient means of using electricity to heat a building even in the depth of winter, and heat recovery technology accomplishes transfer of heat from the sunny side of a building to its shady side for very efficient operation in the spring and autumn conditions. The combination of these abilities delivers a high "seasonal efficiency", that is, the efficiency measured over year-round operating conditions.

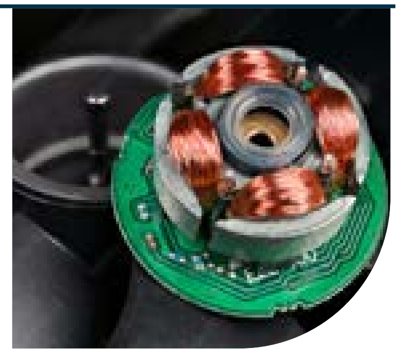
A drawback of heat pump technology, in its current form, is that the heating water is delivered at 45˚C or, for more recent machines, at 55˚C. A new installation can be designed to operate effectively at 45˚C, and many buildings are now operating with this form of heating. The higher temperature of 55˚C that is available from many machines using refrigerant R32 is a close match to the 60˚C used as the design temperature for condensing gas boiler system, making direct retrofit of such systems possible.

Direct retrofit to the older gas-fire systems, designed for the conventional 80˚C, remains a difficult challenge. Options include:

- Adjusting the entire building's heating infrastructure to align with the lower heating temperature available from heat pumps operating commonly at 55 ˚C. This may mean that pumps, heating coils, pipe risers and controls need to be replaced to ensure the same heating transfer rates are achieved. Whist costly, this may align with a full plant upgrade to improve lease-ability at mid-life of the building.
- Heat pump booster units. These will deliver the higher temperature but add investment and operating cost.
- De-superheaters. This is a long-established technology that will deliver a small percentage of the heat pump's output at a high temperature.
- Machines with alternative refrigerants. Alternative refrigerants currently available include:
- Ammonia. This has been used since the invention of refrigeration so is well proven but is limited by its toxicity to industrial applications.
- Carbon dioxide. This operates at a very high pressure, so is best applied in self-contained proprietary systems. It works over a wide temperature range, making it well-suited to heating domestic hot water, but not well suited as a retrofit for conventional gas boilers. It can be applied as a heat source for multiple systems including low and high temperature, such as domestic hot water, underfloor heating, and air heating coils, though this is a complex system.

The refrigeration industry is developing rapidly in response to the challenges of replacing conventional gas boilers and minimising global warming potential, so a heat pump that can replace conventional gas-fired boilers may yet be introduced.

EC Motors



EC motor technology can reduce the electrical demand of small motors, such as those in fan-coil units (FCUs). These reductions are individually small but apply to hundreds of units within a building to become collectively significant.

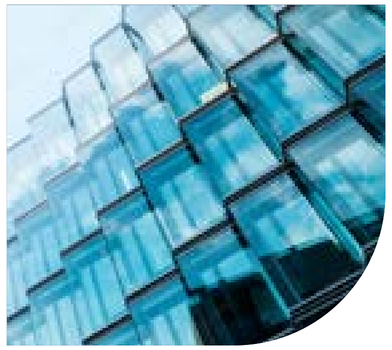
EC motor technology applied to a multiple-fan FCU gives that unit the ability to respond to different demands in several rooms, improving precision of control and reducing energy consumption.

Matching Plant Efficiency to Load Profile

"Load profile" refers to the variation in heat load capacity required to meet the building's operation over the full annual range. For example, chillers must be sized to meet the cooling demands of hot days in January and February but spend much of time operating at low loads; in fact, chillers serving VAV systems in the Wellington climate spend much of the year sitting idle. It is the "seasonal efficiency" of this plant, which is important, more than the efficiency at peak load.

Optimum system efficiency, and high reliability, is in many applications achieved by provision of a small chiller for low-load and long run hours paired with a large chiller for peak load duty and short-term use.

Building Upgrade – Façade Replacement



Building owners should understand that today's low-energy targets require the building envelope to be well-insulated, so that a building which requires replacement of conventional gas boilers is also likely to require substantial upgrades to or even replacement of the façade. An improved façade helps to lower heat demand and therefore makes it easier to convert gas boilers to heat pumps.

No matter how efficient the HVAC system might be, ultimately it is the quality of the building envelope which determines whether the highest standards of energy efficiency can be achieved. As well as reducing HVAC energy costs, improved façade performance delivers a more comfortable interior.

Upgrade of single-glazed facades has been achieved using reflective film applied to the glass and insulation to the spandrel panels. This is an economic approach well worthy of consideration. Façade replacement is a major cost that can be contemplated only in the context of a total building refit, often in conjunction with seismic strengthening. Modern facades combine double glazing with glass which is tinted and coated to selectively control transfer of heat and light. Thermal break technology is becoming available to reduce heat transfer through the structure of the façade.

Plant Upgrade

Main plant has a limited economic life, and the need to replace plant provides an opportunity for adopting new technologies that will reduce energy consumption and other environmental impacts.

The value of replacing plant with more efficient technology is highest when that plant must be replaced anyway.

The economic life of main plant items is: air cooled chillers 15 years, water cooled chillers and cooling towers 20 - 25 years, jet pressure burners 15 years, conventional boilers 30 years, condensing boilers 15 – 20 years, fans and pumps 20 – 30 years, electrical switchboards 20 – 30 years (all subject to individual conditions and the level of maintenance applied). To avoid loss of service due to breakdown, with associated risk of loss of rental income, a prudent building owner will plan for replacement based on age. Planning for replacement should include consideration of the opportunity to adopt sustainable technologies.

HVAC - OUTDOOR AIR

A reliable supply of outdoor air is necessary to maintain air quality in each occupied space, and the flow rate should be appropriate to the number of occupants and the activities of those occupants.

Depending on weather conditions this outdoor air may demand energy for heating it or for cooling it, or it may contribute to the cooling effect necessary for comfortable temperatures and so avoid energy use in refrigeration plant.

Plainly there is potential for tension between the objectives of air quality and energy efficiency. While the various HVAC systems have different means of controlling the outdoor air supply, for all of them there is a need to balance the competing objectives of energy efficiency and air quality. The best result will be achieved by use of real-time information on occupancy, air quality, weather conditions and HVAC performance.

Economised Outdoor Air Supply

During cold and hot weather VAV and CAV system should operate on minimum outdoor air ratio to avoid need for cooling or heating outdoor air unnecessarily.

During moderate weather these systems can make use of high rates of outdoor air to cool the occupied spaces; this is typically known as "free cooling" because it avoids need to run the refrigeration plant, and the system is known as an "economiser". The high rate of outdoor air may be seen as a benefit to indoor air quality. An economiser is operated by sensors that compare the condition of air returning from the occupied spaces with that of the outdoor air, applying an algorithm to determine the optimum ratio and moving control dampers to alter the mix as required. The air "condition" may be assessed according to temperature alone, or by a combination of temperature and relative humidity; the latter "enthalpy control" provides a better result. Economised outdoor air control is standard technology, but tuning requires input of appropriate labour and expertise.

Air Quality Control

Air quality monitoring is highly recommended, for the benefits of confirming the effectiveness of ventilation and to contribute real information relevant to concern about infection risks.

A common example is complaints of uncomfortable temperatures may have been addressed by changes that appear to address the issue at the time, but which cause related issues:

- A temperature sensor that is located above or otherwise outside of the occupied area that it controls will not deliver comfort; adjusting its setpoint may appear to address the issue in the short-term but the real solution is to re-position the sensor.
- Main plant, chillers and boilers, are typically initiated by feedback from selected sensors. If one or more of these have been adjusted incorrectly to address a local comfort issue then it has potential to call in main plant when it is not justified, running big motors for little value.
- "Incorrect adjustment" in this context includes a dead band range that is too tight, and/or control functions that attempt to be too precise. Temperature control should be "proportional" and should not include "integral" or "derivative" algorithms.

Measures of air quality include:

- Temperature
- Relative humidity
- Carbon dioxide level
- Particulate matter
- Volatile organic compounds

Night Purge

It is common for temperature in occupied spaces of a multi-storey office building to rise after the HVAC plant has been switched off, as heat stored in the structure radiates into the space. When this heating effect persists through to the start of the next day then it will be effective to flush the building with cool air shortly before sunrise. This uses similar principles, equipment, and software to optimised start. Again, tuning requires input of the appropriate labour and expertise.

Hotdesking With Senser Control

Monitoring of actual desk occupancy provides management with valuable information to assist with planning the development of facilities. It can also be interfaced with the outdoor air control system to tailor actual outdoor air supply to demand. Existing buildings with aged BMS and control systems will require an upgrade to incorporate hot desking sensor control.

Heat and Energy Recovery

The technology to transfer heat from one airstream to another has become much more economical, supported by large European manufacturers. Transfer of heat from exhaust air to incoming outdoor air not only reduces energy costs but also reduces the size of heating plant. Heat recovery equipment includes:

- Run-around coils
- Heat pipes
- Plate heat exchangers with impermeable cores
- Plate heat exchangers with semi-permeable cores
- Rotary wheel heat exchangers

Plate heat exchangers with semi-permeable cores and rotary wheel heat exchangers transfer both latent and sensible energy and so are properly termed "energy recovery" devices while the others transfer sensible heat only and so should be called "heat recovery" devices. The energy recovery devices promise higher efficiency, but the plate heat exchangers can be applied to toilet exhaust with confidence that there will be no cross-contamination, and in many buildings, this results in a higher rate of heat recovery.

ELECTRICAL

The electrical energy requirement of a building will primarily depend on comfort and health and safety factors.

Lighting, first by development of fluorescent technology and more recently by widespread change to LED, now uses substantially less electricity than 20 years ago. This reduces heat load into occupied spaces and so reduces the need for air conditioning capacity. Lighting is important to allow the occupants to work safely with mandated lighting levels. The amount of energy that lighting requires depends on the lighting control and lighting technology implemented.

The amount of electrical energy imported from the grid into the building can be reduced by introducing renewable energy such as solar PV and battery energy storage systems (BESS). This reduces the building's carbon emissions by using less imported grid energy which tends to have a larger carbon footprint at present. The solar PV and BESS systems can also be used in power outages to cover some basic lighting and small power after earthquakes and storms for example.

Light Fittings – Replacing Common Office Fluorescent Light Fittings with LED Light Fittings

Replacing fluorescent light fittings with LED light fittings could mean energy savings of up to 50% can be achieved. Also, the lifetime of quality LED's can be significantly longer than for fluorescent tubes and compact fluorescent lamps, reducing maintenance costs due to end-of-life lamp changes.

There are many different types and sizes of both fluorescent and LED light fittings. Replacements of fluorescent light fittings with LED light fittings will depend on many factors, such as light output, lamp colour rendering, glare, macadam steps, aesthetics and environmental factors.

The replacement specification for LED light fittings and lamps can be easy if it just a matter of identifying a replacement for a compact fluorescent lamp or more difficult if replacing an office light fitting and ensuring that the replacement LED fitting complies with lighting standards.

Good practice - It is recommended that a lighting designer by engaged where lighting standard compliance is required. Also, that a licenced electrician is engaged for any installation replacement light fittings and associated electrical work. The estimated costs, energy reductions, resilience and payback times will change depending on the light fitting replacements used. Two examples are shown below as a guide:

- where LEDs are replacing an optimal LFL installation, paybacks are in the region of 15+ years.
- where LEDs are replacing sub-optimal LFL installations, paybacks can be as low as 5 years.

Key factors in a sub-optimal lighting installation are over-illuminance and poor control. The use of integrated daylight sensing on new LED luminaires (as opposed to zone control) is also a factor which can lower the payback period for replacement.

Open Office Space Lighting Control – Occupancy Sensing and Daylight Harvesting

Existing open office space lighting with basic lighting control such as timers and manual switching could include some automatic light switching control to switch off areas of the open office space that are unoccupied periodically. This will save on the electricity used for the office.

Occupancy switching – This type of switching is ceiling mounted and monitors areas of workstation clusters. They sense people occupying these areas and switch on and off as the occupancy requires. Can be cost effective if implemented with a light fitting upgrade.

Daylight harvesting switching – This type of switching is ceiling mounted and monitors areas of workstation clusters near windows during the daylight hours. They sense daylight available in these areas and switch on and off lighting if the daylight if the light in the area is stronger than the light from the light fittings.

Can be expensive when added to existing lighting and payback times maybe prohibitive. Some cost effectiveness if implemented with a light fitting upgrade can reduce electricity consumption by 5%.

Measuring Electrical Maximum Demand – Electric Vehicles (EV) Charging Installations and Building Electrification

An electrical engineer will be required to assess the building's electrical maximum demand to determine and compare the spare capacity values with any proposed new heat pump and electrical vehicle loads.

This requires an assessment of the building's electrical maximum demand. If historical information (3 years or more) is at hand, then the cost will be slight. If measurements are required to attain the maximum demand value this could add to the cost.

Good practice/resilience - The building has historical maximum demand main switch board digital metering data for 3 years or more stored in the buildings BMS system.

Maximum demand data can be attained from utility billing (usually half hourly measurements) but not as accurate as digital metering at the main switch board.

Knowing the building's maximum demand at any time can prevent overloading of the building's electrical infrastructure when additions such as heat pumps and EV charging are considered.

A maximum demand calculation may highlight the requirement for 'load shedding' in some instances especially during the 'peak maximum demand summer months' when the building's cooling systems are on full load. This might mean that EV charging for example is load shed during these periods to prevent the building's main switch board being overloaded and switching off.

Solar PV – Grid Connected Only

This requires design work to understand if using solar PV in a building will be economically feasible to install. Licenced electricians and structural engineers are required for this work.

Costs for roof mounted solar PV for a typical commercial office block are estimated around $2700 per kWp installed (1) and are dependant of roof accessibility and connection to the main switchboard.

Payback times vary between 10 – 12 years based on an average 80% usage of Solar electricity by the building. This is also, dependant on the quality of PV modules and other equipment.

Good practice/resilience - Dependent on good quality PV technology being used. Good technologies such as heterojunctions (HJT) can have a service life well over 30 years.

Note: Grid connected only systems will not provide any energy to a building during power outages. Battery storage must be used if the energy is to be used during power outages.

Good design using optimised PV solar energy installations can offset 50-80% of grid electricity use.

Ethical PV solar manufacturers will provide 'Modern Slavery'(1) statements.

(1) There has been government concern around the use of forced labour in supply chain of imported goods into New Zealand. The PV solar industry is of particular concern due to the silicon feedstock (the raw material used to make solar cells) being made with forced labour in some instances.

(2) Based on a 80kWp system cost of $2,700kWp (q1 2023)

Solar PV – Grid Connected With a Battery Energy Storage System (BESS)

Installing PV Solar if designed optimally can reduce the building's requirement for importing electrical energy. If a BESS is installed with the PV Solar, it can further reduce the requirement of importing electricity. Also, a BESS can be used to supply small electrical loads for short periods of time after events such as earthquakes if the mains supply is lost.

A Battery Energy Storage System (BESS) is fundamentally like a small power bank with the purpose of storing energy for future consumption. BESS consist of rechargeable batteries that are charged by electricity generated from renewable sources such as solar PV.

New installations of BESS will require a dedicated room to store the batteries and can require large spaces to meet the energy requirements. At present, BESS is an expensive option, but is expected to become much cheaper in the near future.

Good design using optimised PV solar energy installations and BESS can offset 80% of grid electricity use.

Payback times will vary between 10 – 15 years (1) depending on total electrical energy import offset energy based on an average > 80% usage of Solar electricity by the building.

Good practice/resilience – Dependent on good quality batteries and PV technology being used. During power outages caused by natural disasters BESSs can power small loads such as lighting for few hours, which could replace diesel generators for this period.

All BESS systems come with elevated maintenance costs due to limited battery life and charge cycling limitations. Lead acid battery life is often limited to 5 years prior to full replacement being required and this interval can be further reduced to meet critical business needs. Advances in battery technology to solid state or flow cell type batteries are continuing to be developed allowing for extending battery life, however these types are not yet commonly available in New Zealand for commercial installations.

(1) Based on 15kWh BESS at $1000/kWh (Q1 2023)

PLUMBING

Demand Control Domestic Hot Water System

The energy usage of domestic hot water (DHW) systems in commercial facilities is often overlooked. Demand-type hot water recirculating systems also known as instantaneous water heaters, can save water and energy without much alteration to an existing central hot water plant. The system operates without the use of a storage tank. This presents an opportunity for system improvement and energy savings by measuring the hot water delivery system and peak demand patterns to understand building peak loads, and seasonal impacts. Most central hot water systems have recirculation loops that operate continuously, even during periods of low or no use. This results in continuous circulation pump electricity consumption, as well as wasted energy to constantly reheat water as it circulates through the building.

Both in natural gas and electricity use, savings can be achieved by altering or introducing a control system with the hot water plant to operate the hot water system at the right peak demand periods and therefore reduce the pump run time, energy consumption, plant life extension, and energy losses through the reticulating loop.

Economiser Hot Water

Basically, a heat exchanger system that can transfer heat in most cases from HVAC heat reject via a heat exchanger. The heat exchanger transfers energy from heating sources over a period of time into storage tanks to meet peak demand requirements.

The system is best suitable as a preheat system on a central hot water plant, to reduce the overall energy consumption to raise the incoming cold water to 65°C by increasing the incoming cold water from 1°C up to 25°C. The usage of water-to-water heat exchangers can save up to 80% of water heating.

Domestic Hot Water (DHW) - Heat Pump Hot Water Cylinders

For domestic hot water (DHW), CO_2 heat pumps hot water systems can have up to 75% energy savings compared to traditional electric hot water cylinders or gas boilers. Heat pump systems, although effective, have certain limitations to consider. They require ample plant space and should be situated in close proximity to the storage tanks. Additionally, their performance can be affected by extreme high or low outdoor temperatures. Heat pumps are generally not designed to handle high peak demand loads efficiently, and the recovery rate for hot water can be relatively low. Booster units are available to raise the temperature of heating water from that produced by a heat pump to that of conventional boilers, but these do incur additional cost, occupy more space and reduce energy efficiency.

Domestic Hot Water (DHW) Generation Options Instantaneous Electric

Electric on-demand units are designed to deliver a steady stream of heated water to sanitary fixtures. The system has a higher energy efficiency than gas, an electric hot water cylinder and in some cases heat pumps. Does not require storing hot water or maintaining temperature so no thermostatic mixing valve is required, no circulating losses, less complex distribution. Requires three phase power for high demand areas and temperature delivery can fluctuate when demand changes drastically.

BUILDINGS ARE BECOMING INCREASINGLY SOPHISTICATED, WITH INTEGRATED SYSTEMS THAT COLLECT, ANALYSE, AND USE DATA.

DATA AND CONTROL

Building upgrades must be based on real information that establishes a baseline of performance and identifies areas for improvement. Substantial investment may be required to obtain this information, and while it does not provide an immediate return on investment it is an essential input to the process of mapping out the upgrade path.

Buildings are becoming increasingly sophisticated, with integrated systems that collect, analyse, and use data. Data can be collected from various components and users can only gain valuable insight if this data is used. With the increased volume of data collected from systems, it becomes difficult and overwhelming to analyse and make sense of that data.

Building managers and owners need to rely on technologies to analyse, simplify, and report on the data collected. These technologies are generally referred to as “proptech” (property technology). The proptech solutions that have emerged in the recent years have revolutionised the way buildings are viewed and should in return change the way we control our buildings. This was prompted further by the current trends of work from home and offices becoming more of a collaboration and social space rather than the traditional work. Facility managers and owners need to ensure data collected is validated and correct to ensure that the information that gets populated from the different systems are valid. The main driver for data collection, analyses and reporting of building data tends to be around building operation and sustainability. Understanding how the building is operating can enable many benefits including increased comfort and productivity of occupants, improve energy efficiency, reduce maintenance and repair cost, increase the safety and security of the building to retain and attract quality tenants, and extend the lifespan of plant and equipment.

Commercial buildings often have a building management system (BMS) to control the building’s equipment and hours of operation. These systems are generally bespoke to the building. Commonly these systems are largely considered the realm of the incumbent technicians to manage the building’s operation of AHUs, boilers, pumps etc. Often these systems can add much more value to the facility manager or asset owner. Understanding the value of these base BMS systems and the data they can yield is critical to getting the best performance from the building. Monitoring over a given time-period through the correct use of trending data will allow facilities managers and incumbents to maintain efficient building operation and monitor improvements or degradation. Often the trending information is not well setup, and it is simple a system to control the building’s operation, missing the real value it can add. The BMS can be developed and supplemented with additional software (both bespoke or proprietary), to provide much more value to the asset owners. Opportunities to add complimentary software to the BMS, can greatly improve the building's operation and performance. Live energy monitoring, air quality monitoring, fault diagnostics, and equipment life management are some examples that can help facilities managers with things like CAPEX projections, planned plant exchanges, building improvements, air quality monitoring, energy monitoring, NABERSNZ ratings etc.

Technology is advancing quickly in this space and opportunities to elevate the BMS capacities should be considered. As an example, introducing embedded electrical metering to the buildings electrical distribution boards automatically reporting to the BMS, can provide real-time data on energy used to allow monitoring of the building's energy performance and ease the workload to determine a NABERSNZ rating.

Without a base line of data, we cannot measure ongoing improvements. The value of a good BMS with supplementary systems should not be overlooked.

Building Management Systems (BMS)

As the building management system ages, it reaches its End of Life (EOL) within 12 to 15 years. The EOL could be due to the fact that components are now obsolete, the system has high level of failure of components, performance issues or simply, the system does not deliver the performance required, or the maintenance and support does not meet requirements.

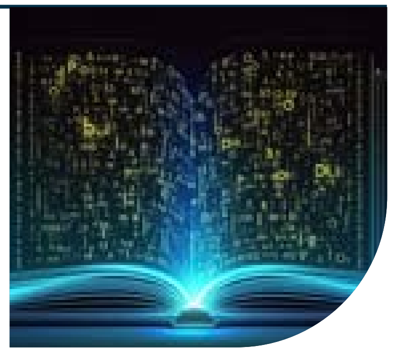
For example:

- The operating system (OS) may no longer being supported
- The system may not provide for remote access via web connection.
- The supporting agent's business may have been discontinued
- The system may not have capacity for additional sensors required to report air quality from multiple locations.

This is when the building owner needs to consider a replacement option. In most instances, the upgrade is like-for-like that uses existing infrastructure and cabling. It's important to think of what modern technologies are out there and what simple changes that can be made to add value to your BMS upgrade. This is also the time that control strategies should be scrutinised and revised for various plant ensuring greater building optimisation and performance. Opting for a like-for-like upgrade may seem more cost-effective initially, but it may not deliver enough advantages to justify the investment. On the other hand, a developed upgrade would undoubtedly enhance a building's long-term worth but will require a higher budget upfront.

An effective BMS that can be interrogated remotely is essential to management of the facility. Fault-finding and tuning an HVAC system requires specialist expertise, and this can be deployed economically if the Facilities Management team has remote access to the BMS of multiple buildings.

Asset Energy Management



Proactive monitoring and management of building energy performance is a critical step towards improvement, and this can be done using any available data.

We recommend convening an energy management forum, including facilities management personnel and maintenance contractors as a minimum, responsible for:

- Reviewing monthly energy performance data
- Maintaining a register of suggested energy performance improvement actions
- Reviewing holistically any proposed and anticipated changes to building operation

An individual shall be nominated to chair the forum, and this person shall have overall responsibility for managing energy performance, subject to KPIs, to assure ongoing accountability and engagement.

This action represents a substantial investment in skill and is most economically applied to a portfolio of buildings.

The quality of data available to many buildings in New Zealand, particularly of the older stock, is not high, nevertheless this action should not be delayed in anticipation of upgraded data systems. More extensive, higher resolution and better-quality data will assist but is helpful only if being used to inform operational, maintenance and lifecycle decision-making and actions. The management structure to accomplish these actions is the key element.

Note: implementation of this option is likely to require a full BMS, it is unlikely to be suitable for standalone controllers in small packaged plant or similar.

Energy Management Systems (EMS)

An energy management system (EMS) is a software-based system that monitors, analyses and reports on the energy consumption of a building. A building's energy consumption includes electrical, gas and water services. The EMS uses data collected via meters, sensors, and other equipment. An EMS tends to be integrated into the BMS but can also be standalone. The main functionality of the EMS is to provide real-time energy usage information to building users, allowing them to make informed decisions about energy use and cost-saving measures. EMS configuration in multiple buildings e.g. hospitals, university campuses are connected to each other with central operating systems to allow smooth operation among the buildings and increase efficiency. Increased cooperation among different buildings, through the EMS allows for additional increased energy management and measuring as functions of the different buildings can be coupled or calculated automatically.

The effectiveness from an EMS is highly dependent of the how it's designed and setup. To gain maximum benefit from the EMS and reporting of the data need to be easy to read and understand. The use of virtual meters (meters that don't exist in the field, but the manipulation of the data already gathered (example the addition/subtraction of one meter from the another) can aid in better understanding the data presented. Reporting should be mapped to an energy model such as NABERSNZ or Green Star. Once the data is understood, organisations can identify areas of high energy consumption, track energy performance over time, and implement energy-saving measures to reduce their energy bills and carbon footprint.

Fault Detection and Diagnostics (FDD) and Data Analytics

Fault Detection and Diagnostics is a technology that uses data from sensors, meters, controllers, and other sources to identify issues within the various systems and equipment within the building. The FDD analyses that data, using statistical and computational methods to identify patterns and relationships. The FDD then identify faults, anomalies, and inefficiencies in the operation of those systems and equipment. The goal of FDD is to identify issues early so that they can be addressed before they lead to more serious problems or system failures. This is different from the alarms that are raised via the BMS where alarms are raised regardless of other factors such as sensor failure or out of range.

In the context of FDD, data analytics is used to process the large amounts of data generated by building systems and equipment and assist in identifying patterns and anomalies that may indicate faults or inefficiencies in their operation. By combining FDD with data analytics, building operators and maintenance teams can gain a better understanding of the performance of their building systems and equipment, and take proactive steps to address issues before they become more serious problems.

An example is a preset routine activated at the start of the heating system to drive all heating valves full open and measure the effect, using sensors already available, of downstream HHW temperature or the coil air-off temperature. If an open heating valve doesn't result in a heating effect then it is flagged for maintenance attention. Fault detection systems result in better service to tenants at an economical cost.

Full Dynamic Control

Full dynamic controls refer to a system that has the ability to adjust various building parameters in real-time to optimise the performance of building systems such as HVAC, lighting, and security. The system uses data from a variety of sources (both internal such as sensor data or external such as weather forecast) to make adjustment to the systems and equipment to maintain a comfortable environment but ensures that the system operates as efficient as possible.

Examples of full dynamic controls:

- While the system will have capacity for outdoor air appropriate for the fully-occupied building, people-counters within the various spaces served, (such as desk occupancy sensors), might be used to reduce this air flow rate in response to the actual occupancy, as determined on an hour-by-hour basis.
- The heating and cooling plant capacity can be selected according to the weather forecast; on a day forecast to be consistently cold there will be no need to make the chiller plant available.
- When plant is operating the set-point can be varied according to weather forecast; on a day that requires low cooling capacity the chilled water temperature can be set to a higher level, reducing power demand.

Dynamic control strategies must be tailored to the actual systems and equipment installed into any given building, and when designed correctly, will reduce energy costs, improve occupant comfort, and extend the life of building systems by reducing wear and tear.

Asset Record Information

The availability of current and complete record as-built documentation for a building is essential to correctly understand the basis of the original design, how a building is intended to operate, and any subsequent changes. In the absence of complete information, it becomes more likely that changes and modifications to a building will undermine the intended operation and reduce efficiency. As building systems become more complex and integrate newer technologies this risk increases. As-built and record information should be consolidated into a digital repository to provide reliable as-built records, including as-built drawings, operation and maintenance manuals and control's function descriptions as a minimum. An industry-standard platform such as Aconex is worth considering for the version control and search functions it provides, but a sharable cloud file storage platform, e.g. Dropbox or OneDrive, would be sufficient to make the consolidated information generally accessible.

Building Retuning

This is an ongoing process of monitoring and reviewing performance of the various aspects such as changing occupancy numbers and densities, temperature control throughout the building, fan and pump performance, main plant operation, and energy consumption. Review will typically identify adjustments to settings and control algorithms that will improve performance and reduce energy consumption. Seasonal alterations may be appropriate to provide year-round optimisation.

HVAC Optimised Stop & Start

This is an automated means of starting the HVAC system to bring the occupied spaces to a comfortable temperature just in time for the agreed start of occupancy. On a cold morning plant starts earlier than on moderate mornings. Similarly optimised stop shuts down the temperature control equipment before the agreed end of occupancy, allowing temperature to drift but not so much that it goes out of the comfort range.

Optimised start and stop is achieved by reading temperature sensors for the occupied space and the outdoors using a self-learning algorithm that takes account of building thermal mass.

Optimised start takes place prior to the agreed start of occupancy and so plant can operate and under many conditions should run with the outdoor air damper closed. Optimised stop takes place before the agreed end of occupancy and so the ventilation equipment should continue to operate even though temperature control equipment has been shut down.

Optimised start and stop are generally standard features in a Building Management System (BMS) so should be implemented readily, but the system may require tuning to get these controls to work effectively through the full range of operating conditions. Tuning requires input of the appropriate labour and expertise.

HVAC Control Dead band Settings - Wider Dead Band Settings

This is an ongoing process of monitoring and reviewing performance of the various aspects such as temperature control throughout the building, fan and pump performance, main plant operation, and energy consumption. Review will typically identify adjustments to settings and control algorithms that will improve performance and reduce energy consumption. Seasonal alterations may be appropriate to provide year-round optimisation.

DECARBONISING OPPORTUNITIES

The process of reducing energy in existing commercial buildings can be complicated, expensive and challenging, however some options offer improvements with lower complexity or capital outlay than others and can be implemented with less disruption to tenants.

For example, items such as LED conversions of office lighting can be progressively implemented after hours and offer shorter payback periods, depending on the condition of the existing lighting when compared to more complex strategies.

Below are some items that could be implemented to buildings either in part or whole to reap early sustainability gains and energy savings with reduced payback periods.

SUMMARY OF OPTIONS

	SYSTEM TYPE DESCRIBES THE SYSTEM TYPE	COST INDICATES UPFRONT COSTS BASED ON TYPICAL UPGRADES IN METRO AREAS	PAYBACK INDICATES THE PERIOD IN WHICH THE INVESTMENT IS RETURNED	COMPLEXITY INDICATES HOW CHALLENGING THE SYSTEM MAYBE TO BE INTRODUCED	ROBUSTNESS INDICATES THE RESILIENCE OF THE SYSTEM
DATA	Asset record documentation (as-builts)	$	< 5	✓	✓✓✓
	BMS upgrade	$ $	< 10	✓✓	✓✓
	Asset energy management	$	< 5	✓	✓✓✓
	Energy management systems	$ $	< 10	✓✓	✓✓
	Fault detection – diagnostics and data analytics	$ $	< 10	✓✓✓	✓✓✓
HVAC	Building retuning	$	< 5	✓	✓✓✓
	Optimised stop start	$	< 10	✓	✓✓✓
	Wider dead band settings	$	< 5	✓	✓✓
	Air quality monitoring	$	< 10	✓	✓✓✓
	Full dynamic control	$	< 10	✓✓✓	✓✓
	Sensing control for hot-desking	$ $	< 10	✓✓	✓✓
LIGHTING	LED upgrade	$	< 10	✓	✓✓✓
	Open office space lighting control – occupancy sensing and/or daylight harvesting	$ $	< 20	✓✓	✓
SOLAR	PV	$ $ $	< 20	✓✓	✓✓
	PV with BESS	$ $ $	< 20	✓✓✓	✓✓
DHW	Instantaneous electric	$ $	< 10	✓	✓✓
	Demand control	$ $	< 10	✓✓	✓✓✓
	Economiser system	$ $	< 10	✓	✓✓
	Heat-pump hot water cylinder	$ $	< 10	✓✓	✓✓
FAÇADE	Replacement	$ $ $	< 20	✓✓	✓✓✓
	Insulation additions	$ $	< 10	✓✓	✓✓✓
	Glazing films	$ $	< 10	✓	✓✓

COST

Indications of upfront cost premium have been assigned based on typical current costs of implementation for the ugrade of existing buildings in metro areas.

- $ <$100k
- $ $ $100k - $1mil
- $ $ $ >$1mil

PAYBACK PERIOD

Indications of payback period have been assigned based on cost vs savings = payback outlay. Typical metro area energy prices and maintenance costs have been taken into consideration. Only simple economic payback has been considered – different internal rates of return and consequent net present values have not.

- <5 Short term
- <10 Medium term
- <20 Long term

COMPLEXITY

This indicator is used to describe how challenging the proposed changes maybe with regards to engineering design, constructibility or system control.

- ✓ Low complexity
- ✓✓ Medium complexity
- ✓✓✓ High complexity

ROBUSTNESS

The ability of a system to recover from a fault and maintain persistency. A system is considered resilient if it can adjust its functioning prior to, during, or following faults

- ✓ Low resilience
- ✓✓ Medium resilience
- ✓✓✓ High resilience

HOW DO WE PROGRESS?

Decarbonising existing commercial buildings is complex and can be overwhelming to some.

WHERE DO YOU START?

Well, we start with data, data, data and more data. We need to start with compiling information of the building's equipment, its lifespan, its usage and its energy used to measure our current building's performance. Is the building operating efficiently? How old is the equipment? Has my use of the building changed since its inception?

The building management system (BMS) generally fitted to most large commercial buildings, to control the internal systems, can be used or adapted to build a data profile of the building, its energy usage and assets coming to their end of life. Additional software such as energy monitoring software can be integrated into your BMS to live monitor and trend use. Asset registers and as-built information needs to be up to date.

All this data starts to build a picture of what in the building is using excess energy and when, what is nearing replacement and generally what is your building's needs? This information coupled with good professional building services engineer's consulting advice, can assist asset owners and facilities managers with building up a replacement strategy for their equipment, and allowing improved CAPEX planning, with informed positions on their specific systems and processes.

ADDITIONAL READING

There is a wealth of other information available compiled by a variety of other organisations. The following is a small selection of resources that have come to light during consultation with peak industry bodies and leading private sector building owners. They may be of interest to those targeting best practice on their projects.

- NABERZNZ - www.nabersnz.govt.nz
- NZGBC - www.nzgbc.org.nz
- Carbon Neutral Government Programme - www.environment.govt.nz
- Building for Climate change programme - www.building.govt.nz
- Nationally Determined Contribution of NZ - www.environment.govt.nz
- ASHRAE publication: Energy Efficiency Guides for Existing Commercial Buildings - www.ashrae.org
- CIBSE publication: KS12: Refurbishment for Improved Energy Efficiency: An Overview - www.cibse.org (note 2008 publication date)

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