FROM INCEPTION TO IMPLEMENTATION: HOW PRAGMATIC DESIGN IMPROVES WATER SUSTAINABILITY.

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ABSTRACT

Sustainable measures have been installed at Tauranga City Council's (TCC) new Waiāri Water Treatment Plant (WTP) to reduce energy consumption through plant design and optimization, and to consider sustainable and operator centric buildings. The recently constructed Waiāri WTP provides 30 ML/d capacity with a future design capacity of 60 ML/d using coagulation, clarification, membrane filtration and disinfection (sodium hypochlorite). The WTP is also a zero liquid discharge facility with all liquids either recycled and sludge physically removed from site, a process rarely used in New Zealand. The plant will serve growth in Tauranga over the next 30+ years.

TCC utilised one of the Energy Efficiency Conservation Authority's (EECA's) grant co-funded programmes 'industrial design advice', to develop energy conservation measures to reduce both carbon and power consumption in the final WTP design and construction. The identified energy savings from this assessment were equivalent to approximately 500,000 to 600,000 kWh and 80 to 90 tonnes of CO_2 per year with an estimated payback period of 14 years.

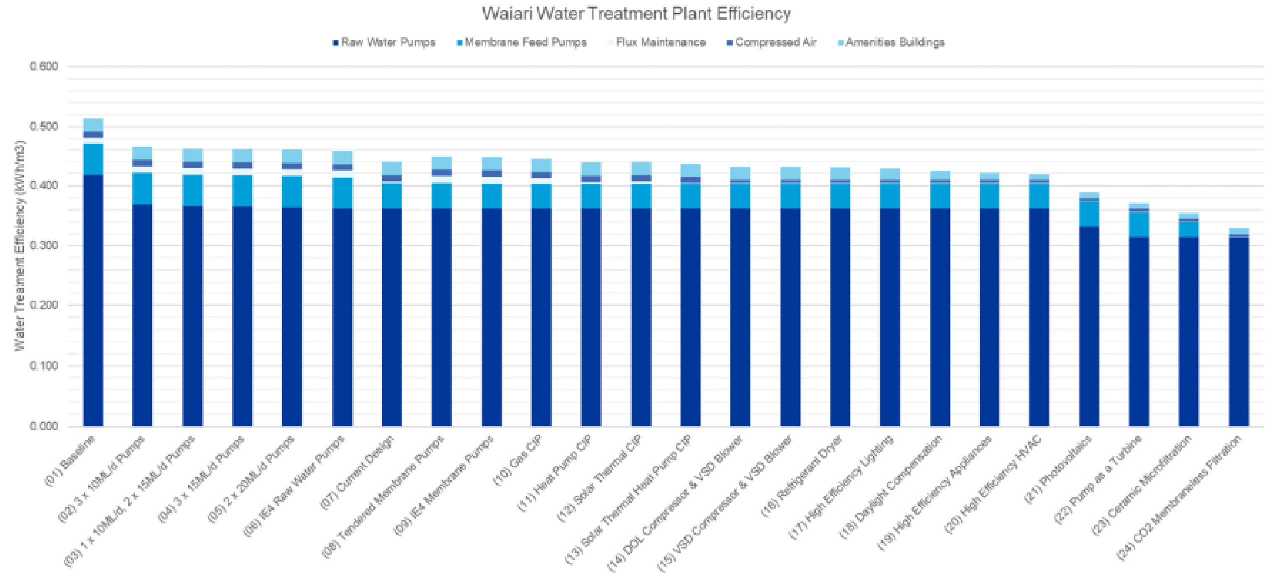

Figure 1: Shortlisted Energy Efficiency Findings

This paper discusses the overall energy approach and final gains achieved from the energy review on the operational Waiāri WTP, how these were included in the design, and the importance of being adaptive and collaborative to maximise energy efficiency outcomes.

This includes designs to reduce intake pumping costs, solar energy, processes to maximise treatment component life and reduce chemical use, alternative heating processes, rainwater capture and water re-use.

This paper then outlines the key metrics being developed and reported on through the WTP control system for energy consumption, and how these will be used to monitor performance and efficiency. These metrics are not commonly used and could be more universally adopted across other operational facilities.

Sustainable materials and construction items were also considered in the early design stages and built into the Waiāri WTP, including permeable pavements and surfacing, and green star building elements. This paper discusses the considerations into these elements, challenges with procurement and design, what was implemented, and lessons learnt to consider for future projects.

KEYWORDS

Energy, Sustainability, Reuse, Water treatment, Efficiency

PRESENTER PROFILE

Scott has been in the water industry for 16 years and has worked in operations, planning and consulting roles. Scott promotes sustainability and efficiency through challenging others and looking to further embed this as business as usual. Scott co-authored the Waiāri energy review and was the process lead and commissioning technical lead for the Waiāri Water Treatment Plant.

INTRODUCTION

Sustainable measures have been installed at Tauranga City Council's (TCC) new Waiāri Water Treatment Plant (WTP) to reduce energy consumption through plant design and optimisation, and to consider sustainable and operator centric buildings. The recently constructed Waiāri WTP provides 30 ML/d capacity with a future design capacity of 60 ML/d using coagulation, clarification, membrane filtration and disinfection (sodium hypochlorite). The WTP is also a zero liquid discharge facility with all liquids either recycled and sludge physically removed from site, a process rarely used in New Zealand. The plant will serve growth in Tauranga over the next 30+ years.

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This paper discusses the overall energy approach and final gains achieved from the energy review on the operational Waiāri WTP, how these were included in the design, and the importance of being adaptive and collaborative to maximise energy efficiency outcomes.

Sustainable materials and construction items were also considered in the early design stages and built into the Waiāri WTP, including permeable pavements and surfacing, and green star building elements. This paper discusses the considerations into these elements, challenges with procurement and design, what was implemented, and lessons learnt to consider for future projects.

ENERGY EFFICIENCY REVIEW

The Industrial systems design advice scheme (through the Energy Efficiency & Conservation Authority (EECA)) advisory service was utilised for the Waiāri WTP. This scheme has specific objectives to assess opportunities to improve efficiency and reduce carbon emissions associated with the project.

As summarised by EECA:

"The ideal time to make substantial energy savings is when you're investing in new equipment or changing fundamental processes.

When you're creating, changing, or upgrading your systems, you and your team are likely to be under pressure. Products and processes are often picked 'off the shelf' due to time constraints. As a result, you might miss opportunities to fully scope long-term solutions and maximise capital savings.

Sound design advice at this early stage is crucial for maximising and protecting your investment."

The approach of the review was to identify and assess energy conservation measures for their potential savings based on whole of life costs.

ENERGY CONSERVATION MEASURES

Individual energy conservation measures (ECMs) were identified and then assessed against a project baseline, using the earlier concept design. This assessment was against the relative change of an individual component rather than the system as a whole to allow for assessment of individual measures.

PUMPING ENERGY OPTIMISATION (ECM01)

Water pumping uses the highest energy at the Waiāri WTP. The review focused on the main pumping sources:

- **Raw water pumps** – vertical turbine pumps in wet well, up to 400 kW each. Pumps operate to convey water to the WTP. Each pump has been selected to allow for operation at their best efficiency points (BEPs) across a range of flows.
- **Membrane feed pumps** – Pump from the clarified water balance tank, through the membranes to the treated water reservoir.

PLANT LEVELS

Refinements to the earlier concept design have been made to achieve both energy and capital cost reductions. The location of the WTP has been shifted from the original concept to reduce the overall pipework length and situate the WTP and reservoirs at a lower level. This resulted in a lower static head of 2m for the raw water pumps and 3m head for the membrane feed pumps, an overall reduction of static head of approximately 5%.

MOTOR EFFICIENCY

Changing from a premium efficiency motor to a super-premium efficiency motor for the intake works and for the membrane system, provides a saving of approximately 0.8% of the total pumping energy across the WTP. For more continuous operation, a payback period of 10 years, less than a typical design life of 20 years, is achieved.

OPTIMAL UTILISATION OF STORAGE CAPACITY

The Waiāri treated water reservoir provides buffering storage for the WTP operation, particularly at low demand periods. The 10,000m³ storage volume allows for the WTP to operate at a fixed energy efficient flow for a sustained period (~4 to 12+ hours) depending on the selected flow. This capacity is adequate to allow fixed speed pumping at 15 ML/d (or 30 ML/d) with a daily demand range of 5 to 30 ML/d, with only 1 start per day typically and with a minimum reservoir operating level of approximately 60%.

PUMP SELECTION

The whole of life costs was calculated for various pump combinations for raw water pumping (*Table 1*) and membrane feed pumping.

Parameter	Pumping Combination			
	3 x 10,000 m³/day	1 x 10,000 m³/day, 2 x 15,000 m³/day	3 x 15,000 m³/day	2 x 20,000 m³/day
Average energy use (kWh/m³)	0.371	0.366	0.363	0.359
Average energy cost ($ / annum)	$393,000	$387,000	$384,000	$380,000
Total Energy over 25 years (GWh)	46.0	45.3	45.0	44.5
25-year NPV ($)	$(4,350,000)	$(4,310,000)	$(4,235,000)	$(4,160,000)

Table 1: Raw Water Pumping assessment summary

The use of 20 ML/d pumps provides the highest energy efficiency. However, this capacity is excessive relative to demand. Pumps with a BEP between 15 and 20 ML/d were selected to match the typical plant flows, while still being suitable for forecast demands to the end of the pump life.

A mix of 10 ML/d and 15 ML/d pumps were considered to provide additional operational flexibility, however the operation of pumps with different impeller sizes would be challenging to maintain peak efficiency, with the combinations of speeds to maximise energy efficiency varying as pumps wear.

The sensitivity on the selected flows is important and plant flows were ultimately set to maximise pumping efficiency unless there was a need to operate at lower flows. For example - operating a 15 ML/d pump at reduced speed at 11.5 ML/d approximately matched the 10 ML/d pump BEP efficiency. This shows the benefit of the higher efficiency of the larger pumps, and that a level of operational flow variability can be achieved with a single size of pumps.

Operation of the raw water pumps at fixed flow rates corresponding to the BEP configurations of the installed pumps provides the greatest overall plant efficiency. Allowing for this through plant controls to set a raw water flow such that the largest energy component can be optimised was implemented.

MEMBRANE OPERATION (ECM02)

Membrane vendors are continuously developing their products and operation to reduce energy costs and chemical consumption.

The membrane filter surface is subject to build up and fouling from foreign materials in the raw feed water such as suspended solids and organic matter which accumulate on the membrane over the course of normal filtration through the filter modules. The build-up of material and fouling of the membrane raises the pressure drop across the filtration system which in turn increases the power consumption of the filtration process. This is managed through backwashing and chemical cleaning (and chemical re-use) and is best considered holistically than by just looking at energy.

Membrane chemical cleaning processes require heating of the cleaning solution to a temperature of 30°C to 35°C to reduce chemical consumption and improve chemical cleaning effectiveness. Heating of the system can be achieved by electric, gas, heat pumps or solar thermal (heat pumps or electric heating). The overall assessment for the Waiāri WTP was that heat pump heating alone had the lowest whole of life costs, followed by solar thermal with heat pump as a back-up. This showed that for the Waiari application the additional energy for the heat pump compared to solar thermal is not enough to offset the capital cost of solar thermal water heating.

COMPRESSED AIR (ECM03)

Waiāri WTP's compressed air needs are for:

- Pneumatically actuated equipment
- Membrane integrity testing (MIT)
- Membrane air scour/backwash

An outline of typical pressure ranges and initial daily demand estimates for these services are given below.

Service	Typical Pressure Ranges	Approximate Daily Demands
Pneumatic Valves Equipment	5.5-6.5 bar	140 Nm^3
Membrane Integrity Testing	2-2.5 bar	20 Nm^3
Membrane Scour Air	2 bars	250 Nm^3

Table 2: Air Pressure Ranges

Compressed air demands across the plant fluctuate frequently and hence significant power savings could be made through the use of a variable speed compressor. Fixed speed compressors have a lower capital cost and work more efficiently than VSD controlled compressors under constant demands. However, under variable loads higher losses are incurred due to the cumulative blow off and unloading losses during start up and run down. The use of a variable speed compressor can reduce the number of start/stop cycles and can provide power savings of up to 35% compared to a fixed speed compressor and also reducing maintenance costs.

Air demand will fluctuate at the Waiāri WTP, particularly with larger volumes required for air scouring and integrity testing. Sizing of a fixed speed compressor would need to meet the peak air demand and then require multiple stops and starts per day.

The size of the air receiver considers the working pressures and required air storage based on site air demands. To achieve the same working volumes a higher pressure allows for a smaller receiver to be used for the same available air volume reducing its capital cost, however over-compression is less energy efficient. A reduction of 1 bar at the compressor translates to approximately 7% in energy savings.

The required increase in air receiver size to operate at lower pressures is dependent on the pressure differences. A drop of pressure from 2 bar above the control setpoint to 1 bar would require a receiver to increase in size by 100% to maintain the same minimum volume of air above the pressure setpoint while maintaining the same volume of air for control.

The key findings of this assessment were:

- A VSD compressor for the low-pressure air demand and a VSD Compressor for high air pressures was assessed to provide the maximum energy savings. With the staged increase in capacity of the WTP, savings form the use of VSD compressors at higher pressures is expected to have a limited payback. On this basis, a VSD controlled compressor was used for the low pressure air scour and integrity testing, and a fixed speed compressor used for the plant air.
- Matching the air demand to the required pressure, with air scour and MIT air being supplied from a separate compressed air system can have a significant energy saving.
- Refrigerant dryers are suited for the installation, being the most energy efficient option, and adequate to meet the duty.

HEAT RECOVERY OPPORTUNITIES - VSD WASTE HEAT (ECM04)

Reuse of the heat generated from heat sources throughout the WTP were considered, however many challenges were identified including intermittent operation, part load operation reducing the amount of useful heat available to be recovered, and a demand for heat where the reclaimed energy can be used.

A large heat source is thermal losses from VSDs which are approximately 2 – 3% of the total motor load (depending on the size of the VSD), and this is often discharged into the electrical room.

Instead VSDs were selected with direct air cooling on large VSDs greater than 50 kW with the discharge air directed externally or into another plant room depending on the room temperature. This significantly reduces cooling requirements in the MCC room while providing the opportunity to warm adjacent plant areas.

EMBEDDED GENERATION (ECM05)

Roof mounted photovoltaic (PV) panels can provide onsite electrical energy generation to offset the electrical energy consumption of the WTP.

The WTP building and roofs are designed predominantly with a slope to the north to maximise potential to allow for the installation of PV panels.

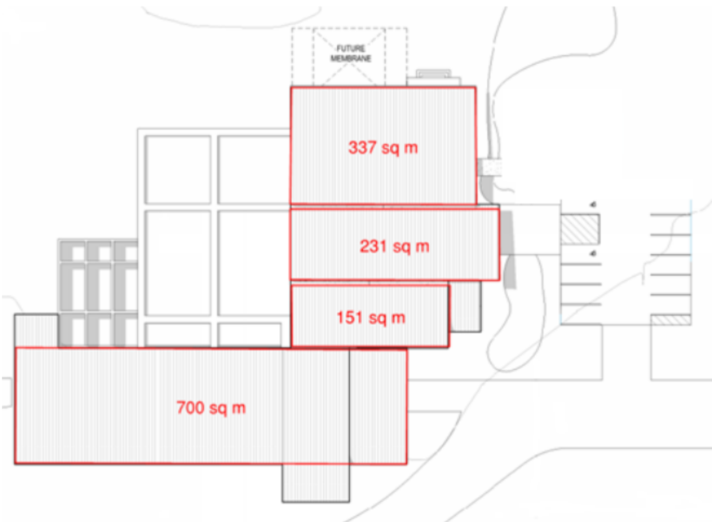

*Figure*2*: Roof Area for Photovoltaic Installation*

*Figure*2 shows the total available area for photovoltaic installation to the roof of the water treatment plant of 1,500m^2 of which approximately 800m^2 is north facing and 700m^2 is south facing. Photovoltaics can be installed to a south facing roof with the appropriate frame to orientate the panels North however the installation will come at a cost premium to installing the panels on the correctly orientated roof.

This analysis assumed panels are installed on the roof at an efficiency of 80% with respect to the total available area with a system efficiency of approximately 15 – 16%. The peak system generation is estimated to be approximately 188 kWp (Kilowatt peak – maximum power during optimal efficiency).

The average annual electrical generation of the installed is estimated to be around 275,000 kWh not including an assumed degradation rate of 0.8% per annum, equivalent to an energy cost saving of around $34,000 per year at an electricity price of $0.125/kWh.

Based on purchase of the photovoltaic system outright, the *Table 3* shows the whole of lifecycle cost of approximately $575,000 (positive) including the maintenance of the panels and replacement of the inverter(s) at approximately 15 years into the life of the panels.

Option	Description	Energy Generation (kWh/ML)	Energy Generation (GWh)	Energy Generation ($)	Total Carbon (tonnes)	Life Cycle Cost ($)
01	Photovoltaic Panels	31.3	6.5	$1,253,020	974	$574,957

Table 3: Photovoltaic Whole of Lifecycle Cost Summary

The financial analysis for the photovoltaic system is provided in *Table 4*. The panels provide a present value of operational savings equivalent to approximately $545,000 which after operation and maintenance costs is equivalent to a net present value of around $37,000.

Option	Description	Indicative Cost ($)	Payback Period (years)	25 Year NPV ($)	25 Year IRR (%)
01	Photovoltaic	$470,000	12	$37,246	6.8%

Table 4: Photovoltaic Financial Summary

The following was provided at the Waiāri WTP:

- Photovoltaic panels were installed on the roof of the plant building, generating 115 kW of power (inverter capacity).
- A power purchase agreement with the electricity supplier to maximise the benefits of the solar generated.

Other opportunities include to consider future 'field' mounted installation to extend and increase generation capacity for the WTP.

AMENITIES BUILDING (ECM06)

The use of efficient lighting, appliances, water heating and HVAC were considered and assessed. These elements, while seen as standard practice, were noted to have an energy saving of approximately $100,000 of the 25-year assessment period.

ENERGY AND WATER METERING (ECM07)

Flow and energy monitoring was considered for process control requirements and also for ongoing energy and performance monitoring throughout the plant, including:

- The use of ethernet I/O for variable speed drives to obtain power metrics.
- Power sub metering to show the energy used and generated across the site.
- Location of flow meters and pressure transmitters for process control and also for monitoring pump efficiency.
- Including energy metrics against individual equipment within the plant control system

ENERY RECOVERY TURBINE (ECM08)

There is an opportunity to install a turbine to generate electricity where pressure control valves or pressure reducing valves are used. This was identified on the treated water pipelines entering the downstream reservoirs, however the power demand at the turbine location is low and cost to connect for export to the power grid high.

Option	Description	Energy Efficiency (kWh/ML)	Total Energy (GWh)	Total Energy ($)	Total Carbon (tonnes)	Life Cycle Cost ($)
01	Turbine	18	2.2	$297,000	325	$20,000

Table 5: Turbine Whole of Lifecycle Cost Summary

NEW TECHNOLOGIES INVESTIGATION (ECM09)

Any new technologies in water treatment processes, even with significant reduction in energy intensity for the particular process will only have a limited impact on the overall energy consumption of the Waiāri WTP due to the significant energy consumption of the raw water pumps.

Newer technologies were provided for information including ceramic membranes (starting to be considered more widely now – largely for their robustness), and membrane-less filtration using CO_2, understood to still be at a lab scale.

ENERGY FINDINGS

Figure 3 below shows an estimate of the average energy efficiency of the WTP ranked according to each ECM.

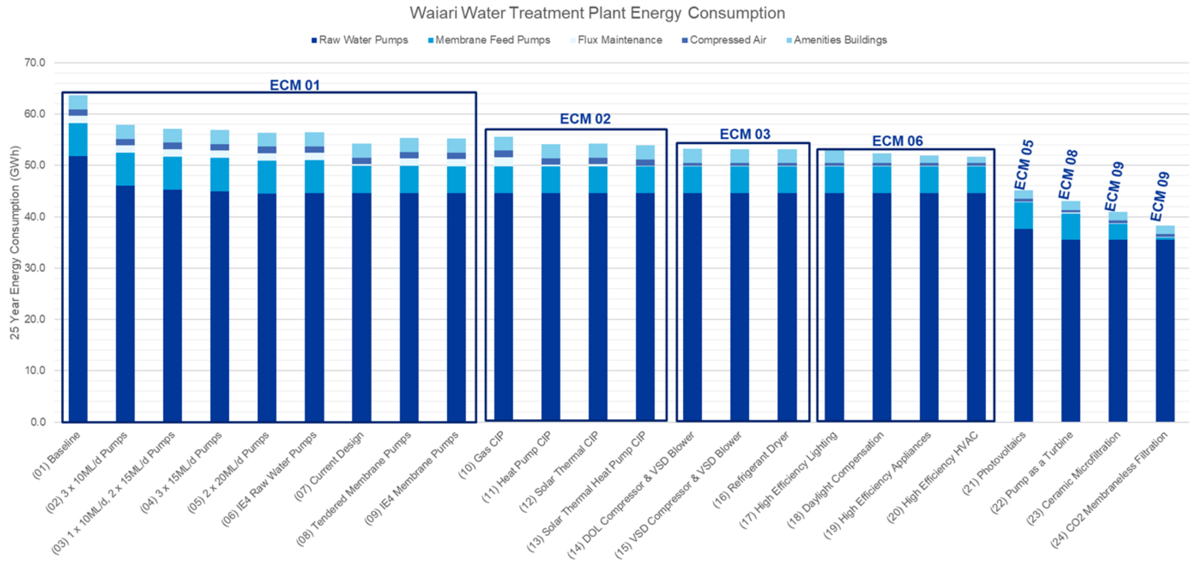

Figure 3: Waiāri WTP Energy Efficiency

The estimate of the WTP energy efficiency above is averaged across the first 25 years of the plant operation which will have a varying energy efficiency across this period. For example, during the initial years of the WTP operation, the flow through the membrane filters will be low and therefore the pressure drop and relative energy consumption is less than when the plant is operating at its full capacity. On the other hand, initially, the amenities buildings will represent a high proportion of the overall WTP energy consumption but over time will drop as the volume of treated water through the plant increases. Only the main process energy consumption at Waiāri has been included in the above estimate of the WTP efficiency and therefore the actual efficiency is likely to be slightly worse than shown here. The renewable energy generation is shown as an offset on the raw water and booster pump energy consumption which will be the main consumer of any embedded generation located at Waiāri. The pump as a turbine will be remote to the site and therefore will be exported to the grid in that location. The increased energy efficiency is shown here for simplicity.

ENERGY SAVINGS REDUCTION

Figure 4 below shows the relative energy consumption of each implemented energy review action as a cumulative reduction from the baseline concept design.

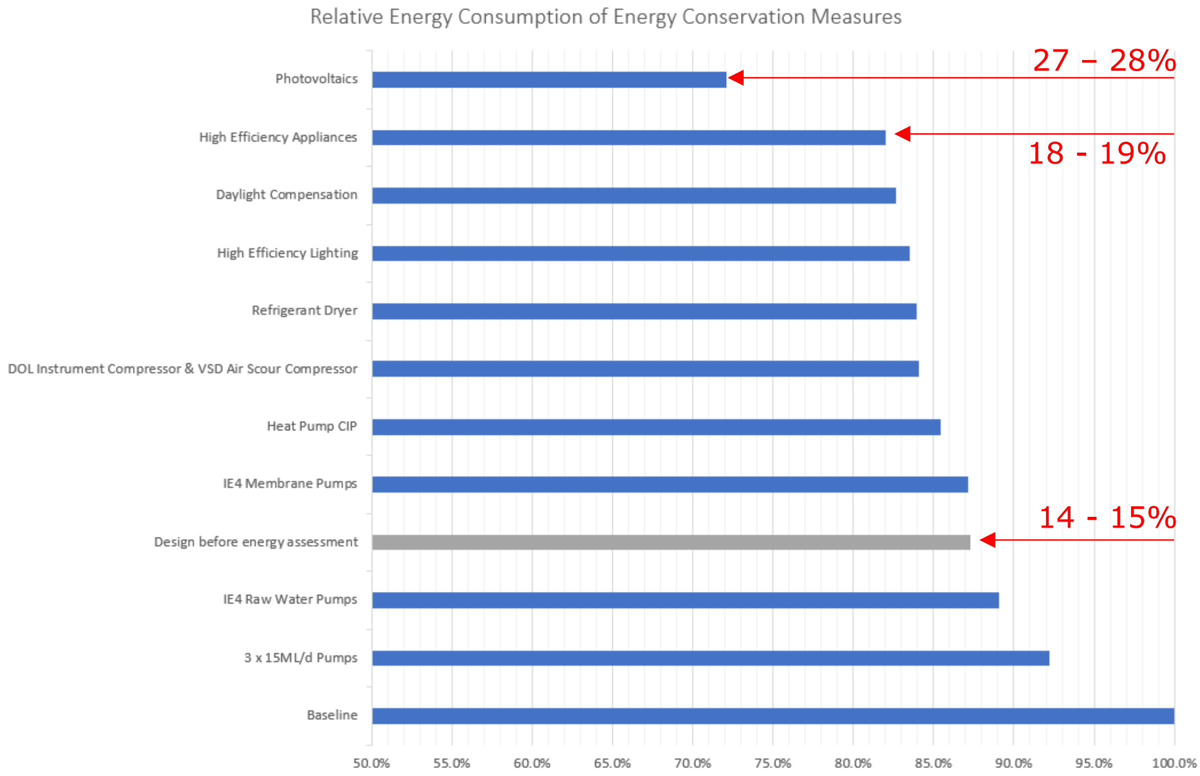

Figure 4: Waiāri WTP Energy Savings

The design for the Waiāri WTP at the time of the energy review, provided approximately a 14% energy saving against the original baseline estimated energy consumption. Further opportunities were implemented to offer another 4 – 5% energy savings overall, with embedded generation utilising photovoltaics further reducing the energy by up to an additional 14%, providing in total up to 28% reduced power use from the original concept.

ENERGY SUMMARY

This section summarises the financial performance of each energy efficiency opportunity with a base assessment period of 25 years for the analysis.

We note that the Energy Conservation Measure options which have some plant replacement at year 25 can be significantly disadvantaged within the analysis. This is because the depreciated value of existing assets is not a consideration in the analysis.

- **ECM 01: Water Pumping Energy Optimisation:** The proposed pump combination shows a positive return on investment across the anticipated economic life of the pumps.
- **ECM 02: Membrane Opportunities:** Based on the financial analysis, heat pumps provide the shortest payback of 8 years compared to electric heating as the baseline option. There is also an opportunity to consider complementing a heat pump with solar thermal panels which also show a

positive return on investment, albeit at a slightly lower rate than the heat pump on its own.

- **ECM 03: Compressed Air Systems:** Variable speed drives options for compressed air provide a negative NPV due to the systems being sized for the maximum treated water volume but initially operating at a low initial water volume.
- **ECM 04: Heat Recovery Opportunities:** The only opportunity selected for analysis was for the heat recovery from the VSD waste heat which does eventually provide a payback.
- **ECM 05: Embedded Generation:** Based on installation costs of purchasing a 180 kW PV system at $2,500 per kW installed the energy generated will provide a positive return on investment and provide 'free' energy for the second half of the photovoltaic system's life.
- **ECM 06 Amenities Buildings and Process Area:** Energy efficient lighting and daylighting for the process area provides a positive payback
- **ECM 08 Pump as a Turbine Energy Recovery:** This opportunity might offer a payback but is dependent on the capital cost to install this system as well as the grid price for the energy generated.

The following energy charge rates have been used:

- Electricity: $0.125 per kWh
- Natural gas: $0.04 per kWh

The payback periods have been compared based on the following calculation while taking account of typical rates of inflation:

- Payback Period (in years) = Initial Investment Cost / Annual Operating Savings

Note that the following considerations have been allowed for in these calculations:

- An annual 2.1% inflation increase.
- An annual 3.4% energy inflation increase.
- A 6% discount rate has been assumed.
- Maintenance costs have been excluded (assumed equivalent between the options under consideration)

A summary of the financial analysis is provided in *Table* below. The identified energy savings are equivalent to approximately 500,000 – 600,000 kWh and 80 – 90 tonnes of CO_2 per year.

Description	25 Year Cumulative Total			Financial Performance Indication			
	Energy Savings (kWh)	Cost Savings ($)	Carbon Savings CO2	Indicative Capital Cost ($)	Payback Period (years)	25-year NPV ($)	25-year IRR (%)
Water Pumping Energy Optimisation	1,641,000	$362,000	258	$(44,000)	10	$62,000	11.2%
Membrane Flux Maintenance Operations	1,322,000	$285,000	193	$(89,000)	15	$3,000	6.3%
Compressed Air Systems	713,000	$144,000	107	$(40,000)	18	$(13,000)	0.9%
Heat Recovery Opportunities	46,000	$6,000	9	$(30,000)	18	$(23,000)	4.3%
Embedded Generation	6,490,000	$1,253,000	974	$(470,000)	12	$37,246	6.8%
Amenities Building	1,886,000	$374,000	283	$(65,000)	13	$27,000	7.3%
Energy and Water Metering Systems*	3,152,000	$674,000	473	SCADA included in Baseline Design			
Pump as a Turbine	2,170,000	$297,000	325	$(60,000)	14	$20,000	8.0%
New Technology Investigation	3,121,000	$445,000	468	Technologies not available for this project			
Total (excluding ECM 07 & 09)	**14,268,000**	**$2,721,000**	**2,148**	**$(798,000)**	**14**	**$142,246**	**6.8%**

Table 6: Comparison of Energy Efficiency Opportunities

The findings are as follows:

1. Raw water pumping is approximately 85% of the Waiāri WTP energy consumption. A 1% increase in either pump hydraulic or electric motor efficiency for the raw water pumps provides approximately 500,000 kWh in energy savings at a value of approximately $100,000 across a 25-year period. The raw water pumps should be controlled for the highest possible hydraulic efficiency and operated at the Best Efficiency Point (BEP) for as much of its operation as possible. Treated water storage can provide a buffer to enable operation at the BEP at all times as well as taking advantage of Time of Use electricity prices for operational savings. Super high-efficiency (IE4) motors are used for both the raw water and membrane feed pumps to provide the maximum energy savings. Three 15 ML/d nominal capacity raw water pumps provide the greatest benefits in terms of energy and control.
2. A heat pump hot water heater provides the most cost-effective heating option for the membrane cleaning heating.

3. Variable Speed Compressors are recommended for the compressed air systems although due to low initial water volume through the plant the payback is initially quite slow. The use of a refrigerant air dryer, being considered adequate for the purpose and more energy efficient than the alternative desiccant air dryer.
4. There are limited heat recovery opportunities at Waiāri. Ducting VSD and compressor waste heat into the plant areas over winter is provided to re-use some waste heat.
5. Roof mounted Photovoltaic Array provides a significant contribution towards the operating costs of the WTP. An array of 115 kW is installed. At an assumed cost of $2,500 per kW installed, the normalised cost of energy from the photovoltaic array is approximately equal to 7.2c/kWh at today's prices or more than 40% less than the power price baseline of $0.125 /kWh used in this assessment. Hence this is considered economic and is recommended for consideration.
6. While the amenities buildings are only estimated to contribute 2% of the overall energy consumption there are some opportunities to save energy through passive design of the building envelope, high efficiency heating and air-conditioning systems as well as high efficiency lighting and daylight harvesting in the process area building.
7. The energy saving benefits of the energy and water metering systems aren't accounted for in the total estimated savings as these systems prevent excess consumption and provide the operators the tools to identify when operational efficiency is declining, rather than save energy when compared to a baseline. Process optimisation using a control system which is continuously monitoring the plant operation and providing operational information on actual real time energy use will assist with running the WTP at its peak efficiency throughout the lifecycle of the operation.
8. There is an opportunity to operate a pump in reverse as a turbine to generate electricity at the inlet to the Poplar Lane or the Eastern Reservoirs, and for the Joyce Rd WTP.

New technologies are either in development or exist for water treatment however neither Ceramic Microfiltration (commercially available but currently cost-prohibitive) or Membrane-less CO_2 filtration (research only) are available in the context of this project.

ONGOING MONITORING

Ongoing monitoring and optimisation of the Waiāri WTP is still under development by the TCC operations team. The following are yet to be implemented:

- Provide kWh/m³ metrics on pumping equipment.
- Generate low priority alarms for equipment that is not performing compared to a baseline.

- Monitor compressor run hours against plant flow, as an indication there may be leaks in the system.
- Connecting and linking the electricity spot price into the control system metrics.
- Manage plant operation to be outside of peak electricity tariff periods where applicable, both having a lower spot price and a reduced likelihood of non-renewable power being used.
- Maximising the generated solar energy, versus operation during lower tariff periods at night.

The above metrics will allow further optimisation of the plant energy use and allow for proactive maintenance to occur on larger equipment.

ADDITIONAL PROJECT SUSTAINABLE MEASURES

The following sustainability related measures were provided with the Waiāri WTP

CHEMICALS

Chemical use for membrane cleaning is re-used up to four times before being discarded and removed from site, reducing the amount of chemicals required, and reducing the waste removed from site. To enable this, additional membrane cleaning infrastructure was required, with the inclusion of an acid tank, an alkali tank, and a hot water tank.

WATER RE-USE

Rainwater is captured from the roof over the amenity and membrane hall areas for WC flushing requirements.

BUILDING FEATURES

While a relatively small component for the overall power use, the benefits of the wellbeing of the people working on site should be considered, particularly with larger plants where there will be multiple staff working full time at the site.

TCC made the pragmatic decision early on in the design of the Waiāri WTP to design to greenstar building standards but without the intent to apply for certification.

The following elements are included in the completed WTP:

- Smart DALi lighting throughout the site to enable lighting to be controlled and configured as required.
- Provide the remote switching of heating, allowing control of the building management system with the plant control system.
- Environmentally preferable Insulation
- Low VOC paint
- Low VOC carpet
- Low VOC adhesives and sealants
- Low VOC ceiling tiles
- Formaldehyde minimisation

- Timber partitioning / framing – maximise use of timber framing in lieu of steel to reduce embodied carbon.
- Sustainably sourced timber
- Environmental Choice Products: Specify environmental choice certified products where appropriate.
- Enhanced glazing system and thermal performance – Double glazing with good g-value and Low-e coating
- Airtight seals around new windows and glazing systems to reduce unwanted infiltration.
- Provide appropriate window / wall ratios to provide balance between thermal, visual and view requirements (25-40% for east and west faces / 30-50% for north and south faces)
- Provide fixed external solar shading where required to help manage peak solar loads, improve summer comfort, and reduce cooling requirements.
- Provide insulation above code requirements.
- Reduced thermal bridging.
- Utilise exposed thermal mass to manage temperatures.
- Maximise passive ventilation.
- Provide air-to-air heat exchanger on outdoor air supply in the amenity area. Air conditioning systems are split systems with occupancy sensing and temperature set-back functions.
- High level windows with actuated louvers that open to extract hot air and promote natural cross ventilation.

CONCRETE

Many options are now available for the reduction from carbon from concrete, including:

- Low carbon concrete,
- aggregate substitutes (using plastics, pumice, perlite, recycled aggregate, or recycled glass)
- Cement substitutes (pulverised fly ash, ground granulated blast-furnace slag, silica fume, limestone fines, pumice)

The Waiāri WTP required the use of a mix of fly ash of up to 30% in the concrete mix.

OUTDOOR SPACES

Outdoor areas were considered to have more natural stormwater management, reduced run off and low maintenance. The following are included at Waiāri.

- Reduced grass areas for reduced mowing (more gardens)
- Permeable pavement, reinforced grass, and Low Impact Design stormwater philosophy
- Pavement design focuses on minimising maintenance and extended design life in high use areas and low impact pavement in low use areas i.e., permeable paving about reservoirs.
- Onsite wastewater treatment system to provide irrigation to landscape areas where possible.

CONCLUSIONS

The design and implementation of the Waiāri WTP has been a long journey with energy efficiency and sustainable practices largely integrated as business as usual. With any project there are always some learnings, and below are the key takeaways from the sustainability and energy efficiency journey for the Waiāri WTP.

- **Start early –** thinking the right way at the start of a project integrates thinking into a project, rather than trying to add it on to an existing design. Thinking across a project will allow you to focus on the big-ticket items, but also allow smaller details to be considered.
- **Understand and move with the current market –** There are differing levels of maturity with regard to some methods, e.g., permeable paving and low carbon concrete. Involve a contractor early or understand the market and availability and reality of low carbon products.
- **Grasscrete –** Although the design intent of reduce**d** run off while allowing for vehicle traffic achieves sustainability objectives, the construction method is labour intensive, and utilises plastic formwork that is then melted away by a blowtorch after the concrete has set.
- **Natural light –** maximise this in any plant design. It creates a much more pleasing environment (and cheaper) than artificial light.
- **The value of monitoring –** a lot of effort went into the ability to monitor equipment and power use, and the ability to maximise operation of the WTP during low power periods.
- **Background power use –** a large plant has a considerable baseline power usage, particularly for continuous water sampling, multiple remote I/O cabinets, ventilation, and lighting. When the WTP is operating, the baseload power is close to 20 kWh.
- **Smart lighting –** is great in principle but make sure that users have the required training to set up, configure and manage. When things don't quite go to plan, the lights cannot be turned off! We recommend that the system has a superuser from the wider operations team.
- **Building management systems –** these systems have become complex, highly intelligent and connected. Make sure that that users have been trained, that the right level of complexity for the application is selected, and that the pros and cons of web based interfaces are considered in the context of cybersecurity. Typical approaches are to have a standalone building management system, and this is often left up to the Contractor to select. Other TCC teams may have had familiarity or preferences around these systems that could have been implemented. A lot of the smart features in the amenity area are controlled through this system, and while it can be controlled through the plant control system via a web browser link, it is not likely a priority to optimise this from a plant operations perspective – particularly when someone can just open a door or a window!

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