TAURANGA WASTEWATER - ENERGY AND CARBON FOOTPRINTNG

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ABSTRACT

Council wastewater treatment infrastructure tends to be developed over many years, with guidance for future development developed through a master planning process. While the main driver for future development is typically population growth and discharge treatment quality, it is important to consider energy consumption as part of this process. Reviewing future development plans with a focus on energy and emissions rather than quality and capacity provides an opportunity for an alternative mindset and the introduction of new ideas.

Internationally, many water and wastewater utilities have adopted goals of "energy neutral" or "nett energy positive" for their facilities in order to reduce operating costs and be more sustainable. In New Zealand, Watercare has announced an ambitious target to see its two major wastewater treatment plants become electricity neutral by 2025, and other Councils are likely to follow.

Considering the energy production and consumption of existing assets and future developments facilitates decisions which allow for an ongoing improvement in energy consumption for the facilities over time. This can also be a first step towards evaluating the carbon footprint of wastewater treatment options. This is particularly relevant with the New Zealand Government currently developing a Carbon Zero Bill which may have implications for wastewater treatment operations.

This paper discusses how an energy and carbon study can assist wastewater asset owners and their engineering advisors in identifying the impacts of upgrade and expansion actions on the energy consumption and carbon footprint of wastewater assets. The outcomes of such a study can also assist in maintaining or improving energy efficiency over time through the design of new assets and the modification or replacement of existing assets.

A recent study carried out by CH2M Beca for Tauranga City Council's (TCC) two wastewater treatment plants (Chapel Street and Te Maunga) is used as a case study for this discussion. The study, which was co-funded by the Energy Efficiency and Conservation Agency (EECA), identified the baseline energy use and carbon emissions of the existing facilities, developed a measurement process for undertaking annual reviews, and identified significant potential annual energy cost savings. The study's final output is a pathway for the incremental improvement in net energy consumption and carbon emissions reduction for the TCC wastewater treatment infrastructure over time.

KEYWORDS

Wastewater plants, energy use, energy conservation, carbon footprint, carbon emissions

PRESENTER PROFILE

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1 INTRODUCTION

In planning future development of municipal Wastewater Treatment Plants (WWTPs) Councils must consider a number of competing factors. The primary drivers are typically providing sufficient capacity for changing catchment populations and discharge habits and meeting increasing discharge quality requirements. Other factors to account for include land constraints (both area and quality), potential reverse sensitivity to odours and noise from plant operations, funding capacity and community affordability, protection of public health, and the sustainability goals or aspirations of the community. The development planning process for New Zealand municipal WWTPs is typically aligned with the council's long-term planning process, tying the timing and costs of upgrades and renewals into their organizational budgets.

Energy consumption is a key factor to consider as part of this planning process, as it impacts directly on operational affordability and environmental sustainability. With quality and capacity addressed elsewhere, reviewing the full system and future development plans with a focus solely on energy and emissions means that these drivers are not diluted by other issues. This provides an opportunity for an alternative mindset and the introduction of improvements which are not solely focused on increasing treatment capacity or quality, which can in turn result in the introduction of new ideas.

Internationally, many water and wastewater utilities have adopted goals of "energy neutral" or "nett energy positive" for their facilities in order to reduce operating costs and be more sustainable. In New Zealand, Watercare has announced an ambitious target to see its two major wastewater treatment plants become electricity neutral by 2025, and other Councils are likely to follow, particularly those who have recently declared climate emergencies.

A holistic review focused on the energy consumption and carbon emissions from wastewater treatment infrastructure allows consideration of existing and future developments affecting the system and allows decisions to be made that facilitate the ongoing improvement in energy consumption for the facilities over time. This enhances the ability of councils and their engineering advisors to identify and quantify the impacts of upgrade and expansion actions on the energy consumption and carbon footprint of their assets. This in can help make better use of existing assets or improve efficiency over time through the design of new assets and the modification or replacement of existing assets.

Quantifying the potential impacts of efficiency improvements on energy efficiency, carbon emissions, and capital and operational costs for the whole treatment system also allows councils to identify if the benefits proposed technologies or improvements will provide a net benefit to the treatment system, or if there are flow-on effects which will result in issues that counteract the benefits.

Considering the energy production and consumption of existing assets and future developments can also be a first step towards evaluating the carbon footprint of wastewater treatment options. This is particularly relevant with the New Zealand Government's Zero Carbon Act currently going through Parliament, which may have implications for wastewater treatment operations. The Act looks to legislate five-yearly carbon budgets for a rolling 15-year period, which will fundamentally change how the New Zealand Emissions Trading scheme operates and may significantly increase the cost of carbon.

2 FRAMEWORK

2.1 OVERVIEW

The first step in reviewing energy and carbon use is to determine the review framework. This sets out the way in which the measurement of energy efficiency and greenhouse gas emissions will be undertaken. The framework should identify:

- System boundaries – treatment system only, or treatment and conveyance?
- Performance metrics – what are the most suitable for the system under consideration?
- The baseline status, in terms of both current performance and programmed future upgrades.
- The goal of the assessment – is it to improve energy efficiency as far as possible? Get the best out of existing assets? Become carbon neutral?
- Any constraints on the system.

To assess both the baseline energy consumption and carbon emissions of the wastewater assets and the effect of any proposed improvements, a common comparison framework is required. As the key requirement of WWTPs is to treat wastewater, the framework adopted needs to relate energy consumption and emissions to the treatment performance of the WWTPs, rather than looking at just the total energy consumed, or emissions produced.

The framework should be simple, easily understood, and set out the data needed in the required units. The data should be sufficiently encompassing that it captures information that can be used to summarise the performance of the existing facilities and can be used to effectively benchmark these against other similar facilities in NZ or internationally. This will give a baseline of how the assets are performing comparatively, and a basis to assess potential improvements against.

In New Zealand, the Water NZ National Performance Review assesses a wide range of performance metrics, including energy use and greenhouse gas emissions for wastewater treatment and conveyance systems. Using the relevant Performance Review metrics in the energy and carbon assessment allows the outputs of the review to be compared with the Water NZ Performance review and used as a baseline for assessment of potential areas for improvement.

The Water Services Association of Australia (WSSA) has also carried out energy benchmarking for WWTPs in Australia using different metrics.

2.2 ENERGY EFFICIENCY ASSESSMENT

The main metric used in the National Performance review for energy consumption is energy intensity in megajoules (MJ) per cubic metre of wastewater conveyed (. This is a useful comparison basis used in the National Performance review to assess performance of the whole system, including conveyance and treatment.

For assessments focused on wastewater treatment plants, another useful parameter is the energy intensity in MJ per kilogram of BOD removed, as it relates energy consumption to WWTP performance, and accounts for the differences between the differing strength of wastewater in different catchments.

These two metrics can also be built on to provide other performance metrics as required, such as energy cost per unit volume treated or kg of COD/BOD received in the influent.

2.3 CARBON EMISSIONS ASSESSMENT

Greenhouse gas emissions, including carbon dioxide, methane and nitrous oxide, are typically presented in terms of the equivalent tonnes of carbon dioxide (CO_2e). The intensity of greenhouse gas emissions produced at WWTPs can be expressed in tonnes of CO_2e. per cubic metre treated or kg of BOD removed.

Wastewater treatment plant emissions can be broadly grouped into categories based on source:

- Emissions associated with the generation of electricity used.
- Emissions from burning fuel such as biogas or diesel for heat or transportation.
- Emissions produced by biological treatment processes.

In most wastewater treatment systems, the first two sources are the most significant, and so it is useful to do the two assessments in parallel.

Emissions from treatment processes can typically only be significantly addressed by wholesale changes in treatment processes and so are typically a secondary focus.

3 ASSESSMENT

3.1 BASELINE DEVELOPMENT

The baseline developed will become the reference point for assessing proposed changes against to determine and quantify the effects of any process improvements on energy or carbon intensity. The starting point is typically current operational performance.

If there have been recent significant process changes, or the region is undergoing significant year-on-year growth, it may be suitable to take the most recent 12 months of operational data, providing a 'snapshot' of current performance. However, if there have been any significant system outages, weather events or other issues in the system this snapshot may not be reflective of typical operation and introduces the risk of over- or under-estimation of the effects of any improvements. A more conservative approach is to take three to five years of operational performance to get annual average energy and carbon intensity values.

Once the current performance has been evaluated, population growth projections and any currently-planned process upgrades can be incorporated, and the baseline set. This can then be used as the starting point for the improvement's assessment.

3.2 IMPROVEMENTS ASSESSMENT

Once the performance baseline is established, improvements can be identified and quantified. This is done firstly at a strategic level (what should the plant be treating, are the treatment processes the most efficient to achieve the required outputs, and how this affects efficiency within the system?). Then secondly at a detailed level (are there more energy efficient processes or equipment that could create added value within the system?).

Consideration is given to changing flows and loads, changing the function of the existing assets, and changes in the processes or equipment used within the wastewater treatment facilities. If power usage information is available at a process unit level, high usage areas can also be identified and prioritized for improvement. A high-level assessment of treatment performance can also be used to identify inefficient processes, and if energy neutrality is an objective, areas where there is potential for on-site energy production should also be highlighted.

Typical energy efficiency improvement areas include aeration systems, large lift pumping stations, and digester gas production. For carbon emissions intensity diesel usage is typically the most significant improvement area.

Once improvement areas have been identified a long-list of potential improvements can be developed for initial assessment and quantification of their potential savings. At this point the ideas are assessed purely based on the magnitude of the potential improvement from power savings, increased power generation, and/or reduced carbon emissions. Options which have significant energy use, energy production or carbon emissions improvement can then be shortlisted for a fuller assessment, including associated costs, flow-on process effects, and an examination of how the potential improvements could be combined to best effect.

3.3 OUTCOMES

Typical outputs from the assessment are:

- Concept-level capital and operating cost estimates and net present value analysis for the short-listed improvements
- An assessment of the overall improvement in energy and carbon intensity for each
- Recommendations on which options are worth implementing in the short or medium term, and any areas where further development or trials would be of use to confirm viability of recommended options

These outputs can then form or be incorporated into improvement and development plans for the system under consideration

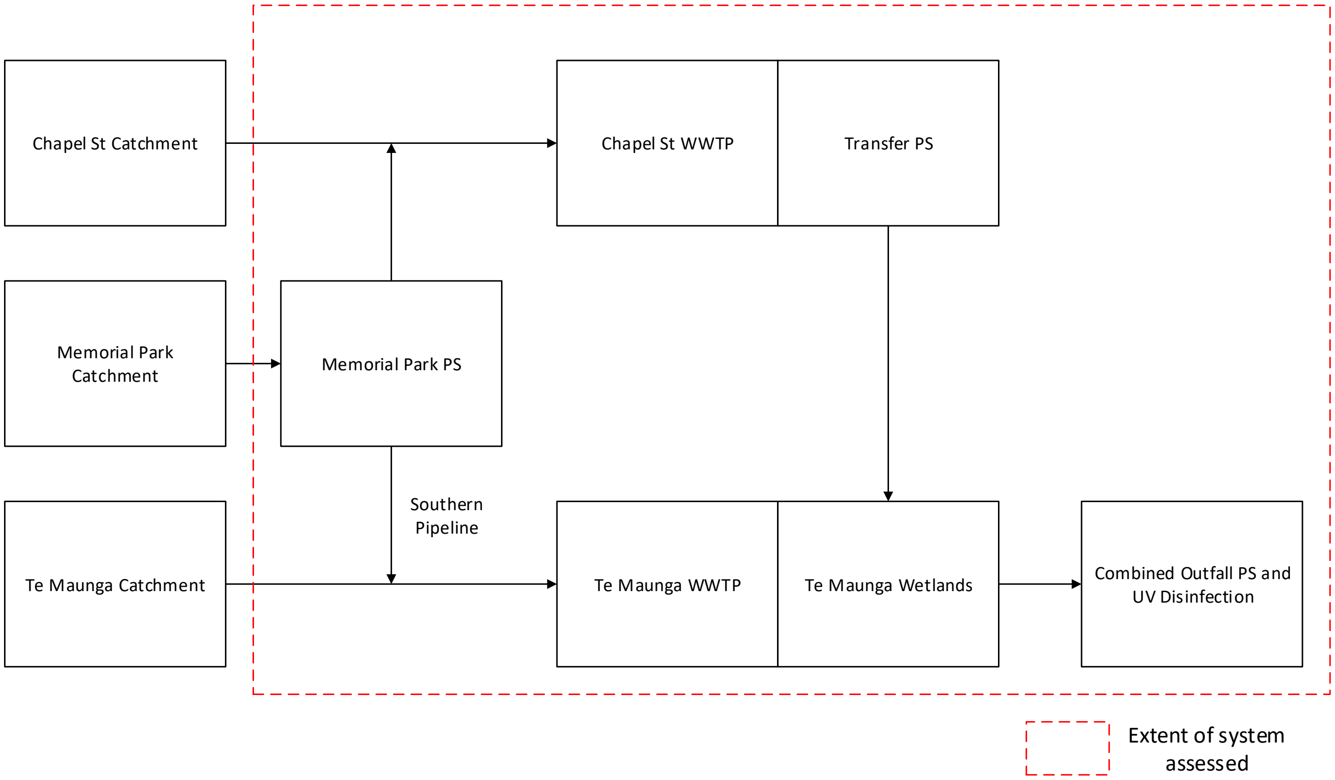
4 CASE STUDY – TAURANGA CITY COUNCIL

4.1 SYSTEM BOUNDARY AND FRAMEWORK

Tauranga’s wastewater is currently split between two wastewater treatment plants, a conventional primary sedimentation system with secondary treatment using an activated sludge/solids contact system at Chapel Street, and an extended aeration system followed by wetlands at Te Maunga. Treated wastewater from Chapel Street is pumped to the Te Maunga wetlands, and the combined flow is then disinfected and pumped to an ocean outfall. The boundary of the system considered for this assessment is shown in Figure 1.

There are a number of constraints on development at these two WWTP sites. Chapel Street in particular has very limited capacity for future expansion, due to space limitations and sensitivity concerns from neighboring developments. TCC’s current strategy is to ‘cap’ the treatment capacity of Chapel Street, and direct future increases in wastewater flows to Te Maunga via Memorial Park Pump Station (PS) and the Southern Pipeline. Te Maunga does not have the same issues with space and neighbourhood sensitivity, but due to the nature of the underlying soils all structures on site require significant ground improvements to protect against seismic failure, which adds considerable cost to any construction work.

Figure 1: Simplified schematic of TCC's wastewater system, showing which parts were included in the energy and carbon assessment



4.2 BASELINE ASSESSMENT

At the time of the review Memorial Park PS and the Southern Pipeline were in the process of being commissioned, and a new sludge dewatering system was in the process of being installed at Te Maunga, and so the operational energy use information did not include them. TCC also has a 35-year masterplan setting out future improvements required to maintain sufficient treatment capacity under projected future population growth.

The baseline assessment of the work underway and the masterplan projections showed the total energy intensity of the system increasing from 2.46 MJ/m^3 to 3.46 MJ/m^3 over the master plan period, and carbon emissions increasing from 3,510 tonne CO_2e to 6,670 tonne CO_2e per annum.

4.3 IMPROVEMENTS ASSESSMENT

4.3.1 SHORTLISTED OPTIONS

The initial assessment identified two key areas for reducing energy consumption and carbon emissions– energy production at Chapel Street WWTP, and energy efficiency at Te Maunga. From the long-list of options initially investigated two energy efficiency scenarios and two carbon emissions reduction options were identified as suitable for further investigation. These were:

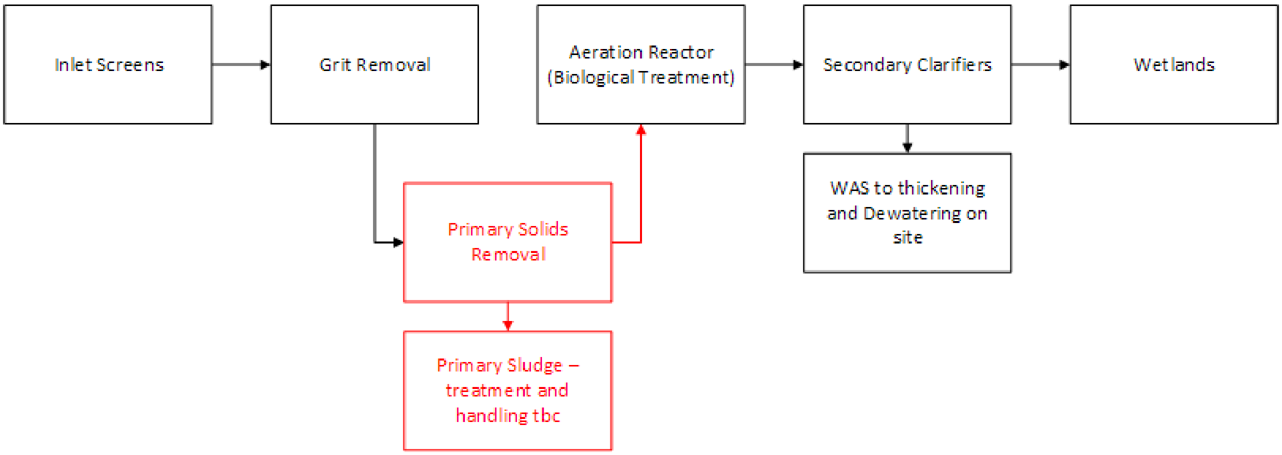
- Implementing primary solids removal at Te Maunga.
- Adding recuperative thickening to the Chapel Street digesters.
- Bringing forward or expanding the capacity of the solar sludge dryer planned for Te Maunga.
- Use of biogas or electricity to power sludge transportation instead of diesel.

More detailed investigations were then carried out on these options, as discussed below.

4.3.2 PRIMARY SOLIDS REMOVAL AT TE MAUNGA

Adding a primary solids removal step at Te Maunga, as shown in Figure 2, was assessed as a way of reducing the BOD load on the secondary treatment system, reducing aeration demand and associated blower power use. Initial investigations indicated that the power savings associated with primary sedimentation tanks were not significant enough to justify the required capital expenditure, but an alternative approach using fine filtration may be feasible. Further investigations showed that, if the filtration system performance was in line with the manufacturer's claims, these could be implemented for a similar cost to the current master plan strategy, with potential energy savings on the order of 1.8 million kWh/year.

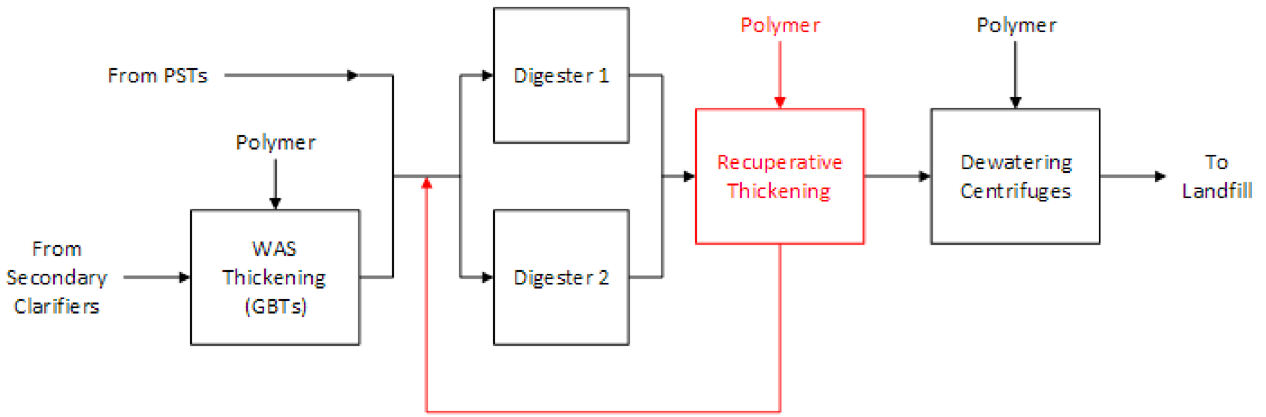
Figure 2: Te Maunga WWTP Flow Diagram showing where primary solids removal would be added (Black = existing system, Red = new process)



4.3.3 RECUPERATIVE THICKENING AT CHAPEL STREET

Increasing the Chapel Street digesters' Solids Retention Time (SRT) would improve digester gas production at Chapel Street by increasing the time for which the sludge is digested. It would also increase the volume of wastewater that can be treated at Chapel Street, as the current cap of 14,300 m^3/d is set based on the capacity of the digesters. Initial investigations indicated that the most effective method to increase SRT of the digesters is recuperative thickening (RT) (as shown in Figure 3). This decouples the SRT from the HRT by thickening and recycling a portion of the solids stream, increasing the SRT and improving biogas production. Further investigations showed that implementing RT at Chapel Street could also provide potential energy savings on the order of 1.8 million kWh/year, for an NPV of $1.8 M.

Figure 3: Chapel Street WWTP Solids Train Flow Diagram showing where recuperative thickening would be added (Black = existing system, Red = new process)



4.3.4 EMISSIONS IMPROVEMENTS

The largest source of carbon emissions at the Te Maunga and Chapel Street WWTPs is diesel use. The primary use of diesel associated with the two WWTPs, other than emergency generation, is the transport of dewatered sludge to the Hampton Downs landfill (an approximately 300km trip). Options considered to reduce emissions associated with this activity are:

- Reducing volumes of sludge transported (e.g. removing water in the sludge).
- Switching to lower carbon emission transport fuels (biogas) or implementing electric vehicles.

The best-case transportation emissions reductions were found to be in the scenario where recuperative thickening is implemented at Chapel Street, without any primary solids transported from Te Maunga. Replacing diesel use with either biogas or battery-electric powered vehicles reduces transport emissions to almost nil in all scenarios.

4.4 REVIEW OUTCOMES

4.4.1 ENERGY EFFICIENCY

There are essentially five potential implementation strategies combining primary solids removal at Te Maunga and recuperative thickening at Chapel Street, as summarized in Table 1.

Table 1: Implementation Options and Comparison-level accuracy NPVs

Option	Description	Te Maunga Works NPV	Chapel St Works NPV	Total NPV (WWTP sites only)	Energy Savings (kWh/y)
1	Status quo: no change to current masterplan	$42.5M	$8M	$50.5M	-
2	Implement primary filtration at Te Maunga, no RT at Chapel Street	NPV $40.1M (with dryer) - $52.2M (without dryer)	$8M	$48.1M - $60.2M	479,000 (2018) – 1,190,000 (2053)
3	No primary filtration at Te Maunga, implement RT at Chapel St	$42.5M	$8.8M	$51.3M	1,800,000
4	Implement primary filtration at TM, implement RT at CS,	$41M (without dryer) -	$8.8M	$49.8M - $52.1M	CS: 479,000 (2018) – 1,190,000

Option	Description	Te Maunga Works NPV	Chapel St Works NPV	Total NPV (WWTP sites only)	Energy Savings (kWh/y)
	digest TM primary sludge at CS (excluding 3rd digester)	$43.3M (with dryer)			(2053) TM: 1,809,000 (2018) - 1,818,000 (2053)
5	Implement primary filtration at TM, implement RT at CS, treat TM primary sludge on site	NPV $40.1M (with dryer) - $52.2M (without dryer)	$8.8M	$48.8M - $61.0M	CS: 479,000 (2018) – 1,190,000 (2053) TM: 1,800,000

Option 4 in Table 1 above has the best NPV and energy savings, but higher transport emissions from transporting primary sludge between Te Maunga and Chapel St. TCC can implement recuperative thickening as an initial step (Option 3), while conducting trials on primary filtration technologies to confirm if the assumed solids removal performance can be achieved.

4.4.2 EMISSIONS REDUCTIONS

While it does not provide the most significant emissions reductions, optimised implementation of a solar sludge drying facility at Te Maunga for all Tauranga's biosolids is, on balance, considered the better option to pursue in the short to medium term, as it provides a number of advantages, including:

- Already programmed and budgeted for in some form.
- Significantly reduces both transportation costs and emissions.
- Consolidates the sludges into one source (at Te Maunga) for transportation.
- Provides flexibility for future disposal routes or, more importantly, for biosolids re-use.

Eliminating diesel use by using electric of biogas-powered vehicles could then follow at a later date when these technologies are more widely available, and the implementation issues are resolved.

5 CONCLUSIONS

By considering WWTP system energy use as part of a holistic assessment of current and future flows, loads and treatment processes, it is possible to realise significant energy savings both in the short and long term.

Reductions in grid energy use also result in associated reductions in carbon emissions, but the primary sources of emissions at municipal WWTPs is likely to be transport fuel use, particularly diesel. While few councils transport sludge as far as TCC does, almost all will transport sludge off-site for disposal or beneficial use.

With respect to carbon emissions, implementing sludge drying reduces the amount of sludge transported and associated emissions. While more significant reductions in emissions will require a more fundamental shift away from the use of high-emissions fuels to more sustainable options, solar sludge drying provides other benefits in terms of disposal flexibility. This provides TCC with a strong starting point to respond to the upcoming changes in the New Zealand ETS, and any potential impacts this has on future WWTP operations.

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