Heat Pump Domestic Hot Water Energy Consumption Prediction Report - Summary

22-038 Weymouth Rugby Football Club at Laurie Gibbons Memorial Park

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1. Summary

This energy consumption analysis was conducted for the proposed DHW system for the Weymouth RFC at Laurie Gibbons Memorial Park. The analysis considered the following scenarios:

- GAME days in warmer months
- GAME days in colder months
- PRACTICE/OTHER days in warmer months
- PRACTICE/OTHER days in colder months

These scenarios covered the differences in heat pump heating efficiency due to the weather, and the different usage patterns at Weymouth FRC. The energy analysis considered the heating energy required by shower usage, standing heat losses, and disinfection. The analysis also applied conservative assumptions and realistic usage patterns to minimise the uncertainties in the final results.

Overall, the annual DHW energy estimates produced the following results:

- Heating energy required: 24,793 kWh
- Electricity consumption: 10,353 kWh
- Heating efficiency: 2.39
- Running cost: 1,984 NZD
- Emissions: 1242 kgCO_2e

The comparison to a gas DHW heating system yields the following results:

- Estimated gas energy required: 29,169 kWh
- Estimated gas running cost: 2,526 NZD
- Estimated gas emissions: 5,688 kgCO_2e
- Electricity cost reduction: 21.4%
- Electricity emissions reduction: 78.1%

Thus, the conservative annual energy estimates indicate that the new heat pump DHW system achieves approximately 21.4% lower operating cost, and 78.1% lower carbon emissions. In addition, the cost of electricity is projected to fall over the lifecycle of the system, thereby further decreasing its’ operating cost. Most importantly, the new system will help Auckland Council to achieve the emissions goal.

2. Introduction

This report summarises the energy consumption predictions for the Performance Plus Heat Pump Domestic Hot Water (DHW) system for the Weymouth Rugby and Football Club (RFC) at the Laurie Gibbons Memorial Park. This summary report provides the estimated annual energy consumption and carbon emissions of the heat pump DHW system. The system is also compared to a gas DHW system.

The Weymouth RFC heat pump DHW system has two hot water cylinders (HWC) with a total storage capacity of 1600L. The HWCs are heated with 2 Performance Plus 7GD10E-1 heat pumps, one 6kW electric element, and two 3 kW electric elements. One 3 kW electric element is also added for backup, but it is not in use normally. The energy analysis was conducted based on the operations of this system.

2.1. Domestic Hot Water Production

The 2 heat pumps heat cold water from the incoming feedwater temperature (from 5 to 25°C) up to 60°C. The heat pump will also heat the tanks to account for residual losses in the system. To assist the heat pumps during high-demand game days, and if either of the two heat pumps fails, four electric elements are provided and described below:

- EL1 is a 6kW element located at the top of Tank A. This runs only on game day to heat water from 60 to 65°C to reduce water draw-off with peak loading. Outside of game day, it runs only for the disinfection cycle, which is for a maximum of two hours per week, or when a heat pump fails.

- EL2 is a 3kW element located at the bottom of Tank A. This runs when there is less than 600L of hot water available. In practice, based on modelling, this element would only come on for the disinfection cycle and a heat pump failure.

- EL3 is a 3kW element located at the top of Tank B. This runs when there is less than 1000L of hot water available. In practice, based on modelling, this element would come on during the game day. It will also turn on for the disinfection cycle or a heat pump failure.

- EL4 is a 3kW element located at the bottom of Tank B. This only runs when there is a failure of a heat pump and for the disinfection cycle.

The disinfection cycle only runs for 2 hours a week to maintain the DHW tank at 60 °C as required by Building Code G12. This is sufficient to kill all bacteria in the pressurised HWCs.

Refer to the Design Package for more details.

3. Analysis Methodology

The energy consumption analysis was conducted using a conservative approach and considered multiple scenarios. Generally, the energy consumption analysis was conducted considering the following factors:

1) The energy consumed to heat the DHW for showers.
2) The energy consumed due to heat losses.
3) The energy consumed due to disinfection.

To determine the energy consumed to heat the DHW for showers, four types of operations are considered:

1) GAME Day in warmer months
2) GAME Day in colder months
3) PRACTICE/OTHER Day in warmer months
4) PRACTICE/OTHER Day in colder months

This is to consider both the different ambient conditions and the difference in operations between Game Day and PRACTICE/OTHER days. Refer to the Design Package and assumptions below for more details.

3.1. Key Formulas

This section lists the key formulas used in this analysis.

3.1.1. Hot Water Consumption Formula

During the day when games are played, the system undergoes four distinct periods of operation. The amount of water available at time sample "n" is determined as follows:

$$V_{hot\ water,n} = V_{hot\ water,n-1} - \left(\dot{V}_{Showers} * (t_n - t_{n-1})\right) + \left(\dot{V}_{EL1} * (t_n - t_{n-1})\right) + \left(\dot{V}_{HP} * (t_n - t_{n-1})\right) + \left(\dot{V}_{EL3} * (t_n - t_{n-1})\right) + \left(\dot{V}_{EL2} * (t_n - t_{n-1})\right) + \left(\dot{V}_{EL4} * (t_n - t_{n-1})\right)$$

Where:

$V_{hot\ water,\ n}$ = Available Hot Water at time of sample "n" in Litres

$V_{hot\ water,\ n-1}$ = Available Hot Water at time of sample "n-1" in Litres

t_n= no. of minutes since the start of the period at sample "n"

t_{n-1}= no. of minutes since the start of the period at sample "n-1"

$V_{Showers}$= Rate of water draw off to showers in L/min

V_{EL1}= Rate of water recovery from Element EL1 in L/min

V_{EL2}= Rate of water recovery from Element EL2 in L/min

V_{EL3}= Rate of water recovery from Element EL3 in L/min

V_{EL4}= Rate of water recovery from Element EL4 in L/min

V_{HP}= Rate of water recovery from heat pumps HP1 and HP2 in L/min

For the summer scenarios, these are the following values:

- V_{EL2}= 0 for Game Day, 8.61 when conditions are met
- V_{EL4}=0 for both Game Day and outside of Game Day
- $V_{Showers}$ =60.32 when in use, 0 otherwise
- V_{EL1} = 17.22 for game day when available HW is less than 1600L, 0 otherwise
- V_{EL3} = 8.61 for game day when the conditions are met, 0 otherwise
- V_{HP} = 6.8 when operating, 0 otherwise
- During winter, V_{HP} = 5.21 L/min when operating, 0 otherwise

3.1.2. Overall Heating Efficiency Formula

$$Efficiency = \frac{Heat\ Generated\ (kWh)}{Energy\ Consumed(kWh)}$$

4. Analysis Assumptions and Inputs

The Analysis uses the following assumptions:

- The majority of the players finish their showers 20 minutes after games/practices (peak shower period). During this period, all showers are used, resulting in a peak DHW flow rate of 60.63 L/min draw-off from the tanks when Mains water is at 15°C. This is 66.78 L/min draw-off from the tanks when the Mains water is at 5°C.
- While the practices and games are going on, 15% of the peak DHW flow rates are used. This accounts for showers outside of the peak 20 minutes period.
- When there are no practices and games, no DHW is used.
- The number of GAME days in a year is 40 days.
- The number of PRACTICE/OTHER days in a year is 100 days.
- 50% of the operating days are in the warmer months, and 50% of them are in the colder months.
- The GAME day hours are 9 am to 5 pm. 4 peak shower periods were considered for each day. In practice, only 3 peak shower periods occur.
- The PRACTICE/OTHER day hours are from 4 pm to 8 pm. 1 peak shower period was considered for each day.
- On GAME days only, EL1 is always used to heat the water to 65 °C.
- Each tank losses heat at a rate of 0.106 kW. This was used to determine the standing heat losses.
- The tank heat losses were multiplied by 2.5 to account for hot water piping and connection heat losses.
- The electric elements raise the water temperature by 5 °C.
- The disinfection cycle(where EL1 to 4 all turn on for two hours) occurs once a week after the heat pumps will have completed a heating cycle. The elements will be on for 50% of the disinfection period.
- The mains water temperature is 15 °C in the warmer months, and 5 °C in the colder months.

The analysis has the following inputs:

- The energy prices and emission factors are taken from Auckland Council, the MBIE energy report and Ministry for the Environment report. They are as follows:
  - Commercial electricity price: 0.1916 NZD/kWh (Auckland Council)
  - Commercial gas price: 0.0866 NZD/kWh (MBIE December 2022)
  - Electricity emission factor: 0.12 kgCO_2e/kWh
  - Gas emission factor: 0.20 kgCO_2e/kWh
- The electrical element heating efficiency is estimated to be 95%.
- The gas heating efficiency is estimated to be 85 %.
- The average hourly temperature of the warmer months was determined using the TMY file from NIWA. The temperature data from December, January, February, and March were used.
- The average hourly temperature of the colder months was determined using the TMY file from NIWA. The temperature data from June, July, August and September were used.

5. Results

The results of the analysis are presented in this section. Firstly, the daily estimates are presented for clarity. After that, the annual estimates are presented. The annual estimates were determined using the daily estimates and the operating assumptions above.

Note: The running cost is conducted using 5 minutes intervals.

5.1. Daily Energy Consumption Estimates

Table 1 and Table 2 below show the daily energy consumption estimates and comparisons to a gas heating system.

Table 1: Daily Heating Energy Estimates

Scenario	Heating Required (kWh)	Electric Energy Required (kWh)	Electric Heating Overall Efficiency (W/W)	Estimated Gas Input (kWh)
GAME Day (warmer months)	238	105	2.27	280
GAME Day (colder months)	202	110	1.85	238
PRACTICE/OTHER (warmer months)	126	41	3.10	149
PRACTICE/OTHER Day (colder months)	126	48	2.64	149

Table 2: Daily Heating Comparisons to Gas Systems

Scenario	Electricity Cost (NZD)	Gas Cost (NZD)	Electricity Emissions ($kgCO_2e$)	Gas Emissions ($kgCO_2e$)	DHW Emissions Reduction (%)	DHW Running Cost Reduction (%)
GAME Day (warmer months)	20.12	24.27	12.60	54.66	76.9	17.1
GAME Day (colder months)	20.90	20.58	13.09	46.35	71.8	-1.5
PRACTICE/OTHER (warmer months)	7.81	12.89	4.89	29.02	83.1	39.3
PRACTICE/OTHER Day (colder months)	9.19	12.88	5.75	17.11	80.2	28.6

Thus, the result shows that the **new heat pump DHW system reduces daily emissions significantly**. It reduced emissions by 71% to 83%. Generally, it also reduces the operating cost except for GAME Days in the colder months. The annual estimates in the next section will provide a clearer picture of the analysis.

5.2. Annual Energy consumption Estimates

The annual energy estimates were produced based on the daily energy estimates and the assumptions. For clarity, the annual operation has the following assumptions:

- The number of GAME days in a year is 40 days.
- The number of PRACTICE/OTHER days in a year is 100 days.
- 50% of the operating days are in the warmer months, and 50% of them are in the colder months.

The annual DHW energy consumption estimate is as follows:

- **Heating energy required: 24,793 kWh**
- **Electricity consumption: 10,353 kWh**
- **Heating efficiency: 2.39**
- **Running cost: 1,984 NZD**
- **Emissions: 1242 kgCO_2e**

The comparison to a gas DHW heating system yields the following results:

- Estimated gas energy required: 29,169 kWh
- Estimated gas running cost: 2,526 NZD
- Estimated gas emissions: 5,688 kgCO_2e
- Electricity cost reduction: 21.4%
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Thus, the conservative annual energy estimates indicate that the new heat pump DHW system achieves approximately 21.4% lower operating cost, and 78.1% lower carbon emissions.

6. Conclusion

This energy consumption analysis was conducted for the proposed DHW system for the Weymouth RFC at Laurie Gibbons Memorial Park. The analysis considered the four daily operating scenarios and included the effects of the usage patterns and the ambient weather. Generally, the assumptions and inputs in the analysis were conservative, thus, the results have lower uncertainties.

Overall, the annual DHW energy estimates produced the following results:

- Heating energy required: 24,793 kWh
- Electricity consumption: 10,353 kWh
- Heating efficiency: 2.39
- Running cost: 1,984 NZD
- Emissions: 1,242 kgCO_2e

The comparison to a gas DHW heating system yields the following results:

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