Role of Supplementary Energy in meeting the design condition using a heat-pump water heater.

Background:

Heat-pump water heaters are a highly efficient technology for space heating, generating more units of heat output than the electricity required to operate them when correctly applied. Boiler replacement projects however present some challenges with the effective use of heat-pump water heaters due to the higher system operating temperatures required for non-condensing gas boilers. Operating heat-pump water heaters at these higher temperatures is less efficient than operating the water heater at a lower temperature. This is the case for all versions of heat-pump technology.

Generally, as the temperature differential between the source temperature (eg ambient air) and the heat-pump operating temperature (leaving water temperature) exceeds 60 deg C, the efficiency of the heat-pump will reduce to low levels. It is, however necessary to understand that the proportion of the time the unit operates at 'peak differential' is limited. The majority of the time, the units operate under mild operating conditions, with relatively few hours operating at the 'design condition'. This can been seen in Figure 1.

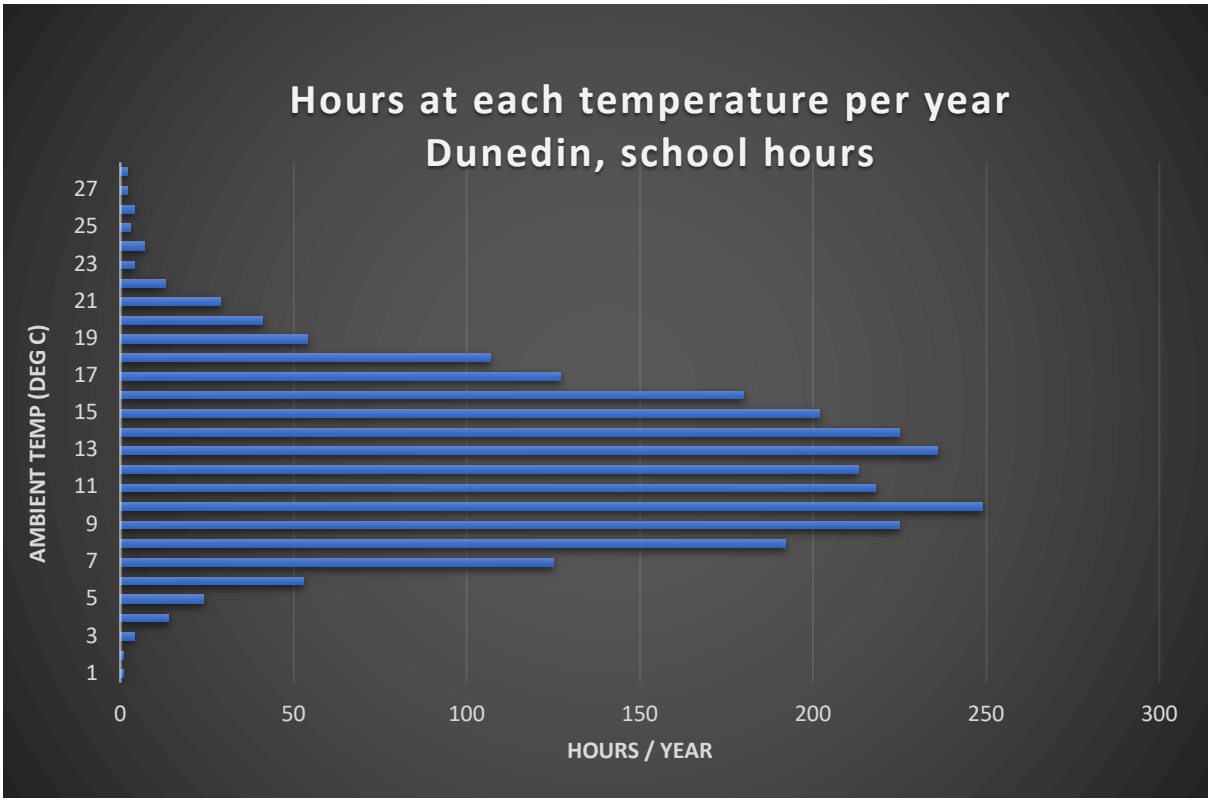

Figure 1: Hours at each temperature band in Dunedin during school hours.

Development of a model to illustrate effect of supplementary heating.

A model was developed to show how the use of appropriately integrated supplementary heating can allow the design condition to be achieved, whilst still maintaining the efficiency of a heat-pump water heating system.

For the development of this model, the following assumptions were made:

- School hours are 8 am to 4 pm

- The design condition of the heating system was 100 kW, at 80 deg C, at a 1 deg C ambient temperature.
- Required room temperature of 20 deg C
- Heating is required from a 15 deg C outdoor temperature.
- Heat-pump water heater producing a supply water temperature of 55 deg C, with a seasonal COP of 3.0
- Heat-pump water heater producing a supply water temperature of 70 deg C, with a seasonal COP of 1.6.
- Sufficient Thermal Store volume to meet the peak heating demand
- Model assumes steady state conditions.
- School holidays are not considered.
- There is a linear relationship between the surface temperature of the radiator, and the heat produced relative to the room temperature.
- Reference climate data is a Typical Metrological Year (TMY) from the Musselburgh Weather Station in Dunedin. TMY data provided by NIWA.

A more in-depth model would require the use of Thermal Simulation Software such as TRNSYS, and should be validated against physical data.

Based on the assumptions made in the model, the hourly heating load for a reference school in Dunedin in shown in Figure 2. There is a total of 58 MWh/year heating demand, based on the assumptions made in the model.

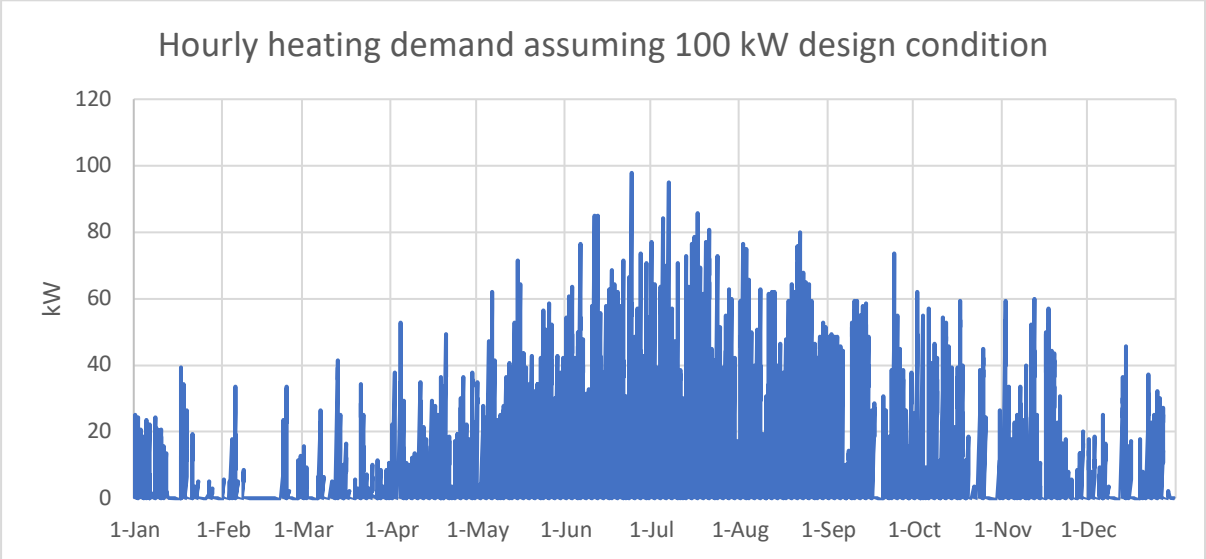

Figure 2. Total heating demand for reference school in Dunedin.

A heat-pump water heater maintaining a supply water temperature of 55 deg C can provide the full heating requirement the majority of the time. Figure 3 shows the total kWh/day that is required to be met with supplementary heating to meet the design condition as stated.

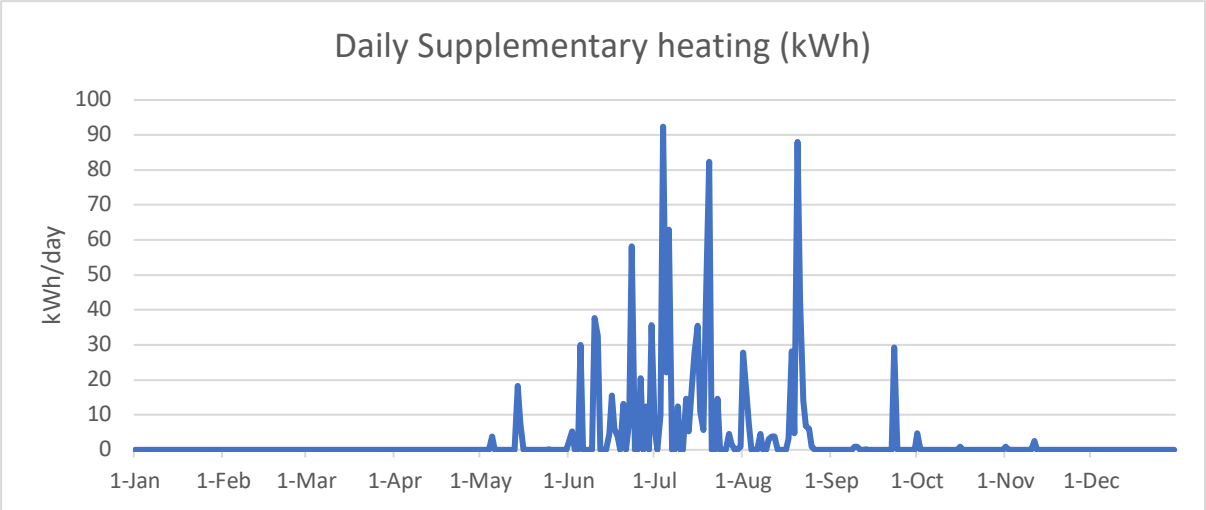

Figure 3. Daily supplementary heating required to meet design condition in Dunedin reference school.

The peak daily requirement for supplementary heating is 92 kWh, with only four days exceeding 60 kWh. The peak hourly supplementary heating demand is 40 kW. There is a total of 1088 kWh of supplementary heating a year required by this model. This represents 6% of the total electricity requirement from the heating system (assuming a seasonal COP of 3.0 from the heat-pump system when operating. In terms of gross heating requirements, supplementary heating accounted for 2% of the total heating demand.

Comparison with a higher temperature heat-pump water heater.

Increasing the supply water temperature of a heat-pump water heater reduces the COP of the unit. A comparison between a heat-pump water heater supplying 55 deg C hot water with a 70 deg C heat-pump water heater can be made based on this model.

	Annual kWh	Annual cost at 15c/kWh
Total Heating Demand	58474 kwh/yr	$8771
Supplementary Heating	1088 kW/yr	$163
Cost of operating 55 deg C HPWH	20580	$3087
Cost of operating 70 deg C HPWH	37226	$5584

Conclusion

Where appropriately applied, supplementary heating can allow a lower temperature heat-pump water heater to meet the design load of an existing installation without the degradation of the overall energy efficiency of the installation. Care is required to integrate Thermal Storage into heat-pump water heating systems as incorrect application will lead to the unit operating at higher than design water temperatures.

Adopting a variable flow primary system also allows significant reductions in the pump energy requirements for a system. This has not been taken into account in this report.

Report prepared by Adrian Kerr

Decarbonised Energy Solutions.