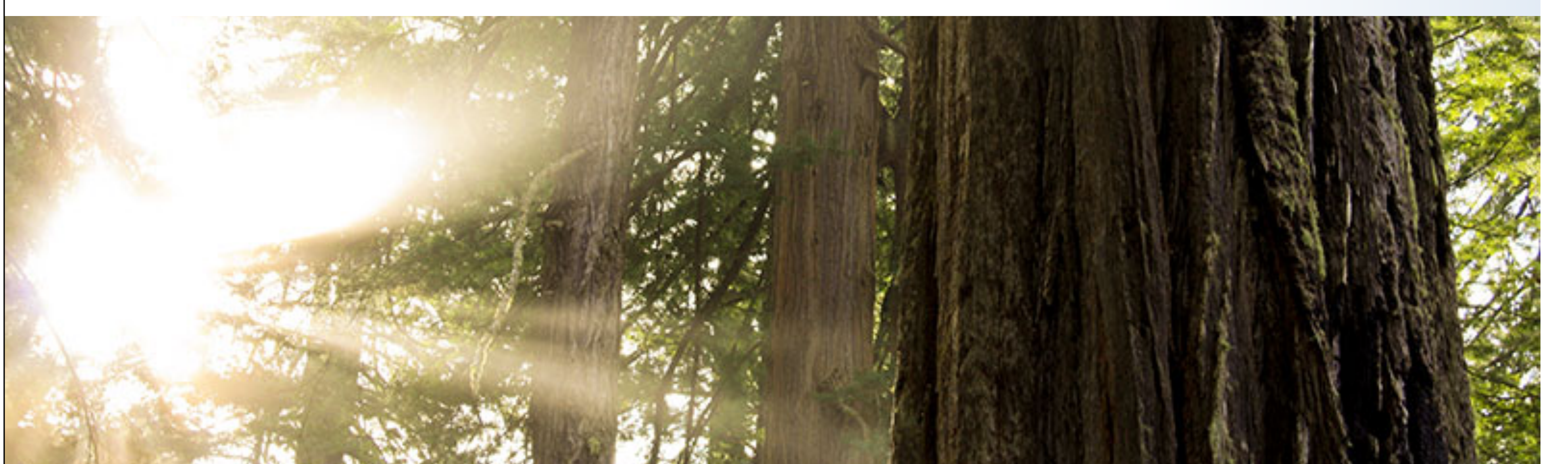
Domestic Hot Water Energy

Trends in electrical consumption by air source heat pump water heaters in multi-family housing

Greg Pfotenhauer & Sean Armstrong

9/12/2017



REDWOOD ENERGY

ABSTRACT

Heating water represents 13% of the total energy consumed in U.S. residences (EIA, 2015), 25% of total residential energy in CA (EIA, 2009), and in this study of Energy Star apartments designed for Zero Net Energy, the DHW use is closer to 32% of whole house energy. The heat pumps installed in early 2014 in this study are low-performance by 2016 standards—Energy Factor =2.4 compared to the EF=3.4 products now widely available at the time of this paper's publication—and today's air source heat pump DHW products would use about 25% of whole house energy, like average CA homes.

This paper studies 77 newly installed GE GeoSpring hybrid (heat pump with backup resistance element) water heaters in three different ZNE low-income multifamily housing communities in California—Lakeport, Dixon and King City. The field results presented are compared to Energy Pro 5.1 models (2008 Code), with variation from the model ranging from -41% to 50% between apartment types and the three complexes under study. *However, the combined average variation from the model for all studied tanks was just 2% above the Energy Pro v5.1 predicted energy use.*

Time-of-use electrical demand for the GeoSpring water heaters was studied in detail. In general, it was found that the GE water heaters operated in resistance-mode much more frequently than was necessary to meet all DHW loads (GE's Scott Shaffer field data analysis in April, 2016). This is a result of programming assumptions that did not bear out in reality—most intense demands did not last long enough to produce tepid water. Additionally, improper ventilation at one of the sites (King City) likely has a compounding effect on the true operating heat pump COP of these units. Suggested actions for minimizing energy usage in hybrid electric water heaters include:

- Program heat pump DHW tanks to reduce resistance heat, including allowing for the delivery of tepid water after high use events rather than triple daily energy use.
- Increase the storage temperature set point to 130F to allow for more heat storage, which in turn reduces or eliminates the need for make-up heat with resistance elements
- Increase the BTU output of the compressors, either by using CO2 refrigerant that maintains 100% BTU output down to -17F, or by increasing the size of the compressors to meet extreme demands without resistance heat
- Ensure that heat pumps are installed in properly ventilated spaces—unventilated closets at the King City site increased energy use 30-60% compared to same-size apartments with their Geospring DHW in vented garages
- Grid energy use by heat pump DHWs at the peak hours of late summer evenings is financially and environmentally expensive relative to using electricity during the daily solar maximum. By the tanks with timers the electric load can be shifted to midday.
- An important finding of this study was the high variation of usage patterns even among similarly-sized apartments with comparable demography. As such, there is no "one size fits all" approach to providing adequate thermal storage for residential installations. Ideally, water heaters with sophisticated controllers and the use of adaptive programming are the best ways to predict and minimize consumption.

Due to the high degree of variation across sites, an approximate amount of heat pump only equivalence was calculated (in other words, the amount of electrical energy required if the units were only operating without the use of the backup resistance element). Additionally, these values were corrected for true occupancy to smooth out variations among apartments of identical bedroom size but different occupancy. These corrections allow for a somewhat normalized comparison across complexes and a more accurate characterization of true electrical requirements for domestic hot water (DHW) consumption for heat pump water heaters. The resulting relationship was obtained:

$$y = 1.586 \ln(x) + 2.238$$

where: *y* = daily DHW energy usage (kWh)
x = number of occupants

Refer to the following analyses for more in-depth discussion. Detailed results can be found in the Appendices, and requests for specific data or additional questions should be directed to:

Greg Pfotenhauer: greg.pfotenhauer@gmail.com
Sean Armstrong: seanarmstrongpm@gmail.com

Thank you to our many mentors in Domestic Hot Water analysis—Nehemiah Stone, Peter Mayer, Martha Brook, Jim Lutz, Danny Parker, Gerald Van Decker, Troy Sherman, Gary Klein and Jonah Schein. Thank you especially to Canary Instruments/Nexi—Josiah Norton, Lonny Grafman, Gabe Krause, and many others--who built a highly accurate, robust, second-by-second datalogger for this research project.

BACKGROUND AND METHODOLOGY

Heating water represents a significant fraction of the total energy consumed within the residential energy sector and typically accounts for 15-25% of annual household energy consumption (this includes electric, gas, and other fuels; water heating accounts for approximately 4,650 kWh per household as a nationwide annual average).[1][2] Heat pump water heaters have become increasingly popular due to falling up-front costs, increased reliability, and the potential for long-term cost and energy savings. Heat pump water heaters therefore represent a viable way to reduce carbon footprints and achieve true zero net energy (ZNE) among residential buildings. Indeed, this has already been demonstrated in the projects contained herein as well as other multi-family developments. [3]

***Figure 1**: GeoSpring Hybrid Electric Water Heater (HEWH)*

This paper is a summary of a study performed on electrical usage of 50-gallon GE GeoSpring, Energy Factor 2.35/2.4 (2014 models), heat pump electric water heaters (Fig. 1) among 77 multi-family housing units in Dixon, King City and Lakeport, CA, which are a subset of 270 units being monitored. All apartments are fully electric, meet LEED Platinum standards, and are ENERGY STAR certified. Total daily, monthly, and annual domestic hot water (DHW) electrical usage in 1-, 2-, and 3-bedroom units is addressed, as well as daily time-of-use (TOU) trends. Demographic trends (occupancy, income) are also discussed.

DHW end-use for all apartments in this study is identical and represented by faucets, bathtubs/showers, and dishwashers. No clothes-washing machines or other devices that require hot water are present in any of the units studied. All units were monitored using energy meters from Canary Instruments (canaryinstruments.com), which include a breaker box data-logger and a "night light" plugged into the wall with a color-coded display to help tenants learn to budget their energy use (see Fig. 2). Current transducers (CTs) were used to monitor both current for whole-house electrical consumption as well as individual 240V split-phase DHW lines. In addition to current, date, day, time, voltage, and phase angle were recorded. All data was recorded in 1-second intervals and the internal clock was synchronized approximately every 3 minutes.

***Figure 2:** Canary Instruments color display*

Following the period of monitoring, the raw data collected by the meters was extracted, converted to comma separated value (CSV) file, cleaned, and processed using a combination of C++, python, and FORTRAN 95. Data visualization and analysis was completed in Microsoft Excel.

***Table 1**: Relevant metadata for all apartments monitored in this study. Note that for the purposes of analysis all 2-bedroom Lakeport residences were treated as 1-bedroom due to their occupancy. Note that some units were installed later than others; the datasets have been trimmed to represent a full seasonal year where necessary. The number of water heaters correctly programmed to hybrid mode are shown in parentheses.*

	Demographic Type	Install Date	Removal Date	Number of 1-Bedroom	Number of 2-Bedroom	Number of 3-Bedroom
Dixon	General/ Family	1/13/15	1/16/16	5 (5)	14 (12)	12 (11)
King City	General/ Family	12/24/14	1/14/16	12 (7)	-	9
Lakeport	Senior	8/4/14	1/16/15	18 (18)	7 (7)	-

It should be noted that this paper largely focuses on the benefits of heat pump technology. Some of the water heaters (for unknown reasons) were set to operate without utilizing the heat pump (see Table 1), which significantly increased the overall energy use in these apartments. While this serves as a somewhat valuable comparison, it does decrease the sample size of the primary analysis, which was aimed at characterizing energy usage for heat pump water heaters with resistive element backup.

DAILY, MONTHLY, AND ANNUAL ENERGY CONSUMPTION: HYBRID MODE

Primary analysis for these sites was performed on a per-bedroom basis, since the vast majority of modeling software uses bedroom size as a proxy for occupancy (generally 1.5 occupants per bedroom). This is expected to hold mostly true for population-wide averages, but is subject to a significant degree of variation which is highly dependent upon factors such as age, occupation, etc. All tables/figures/results in this section include only those apartments where DHW appliances were properly set to "hybrid mode."

Daily, monthly, and annual DHW energy consumption was found to make up a significant portion of total electrical energy, accounting for 20-50% of annual household electricity consumption. This is a considerably larger fraction than is typical, and can be partly explained by slightly lower whole-house energy consumption compared to statewide averages (17.3 kWh/day at the locations studied compared to 18.02 kWh/day statewide for both single- and multi-family dwellings).[1] Some influencing factors include:

1) Energy efficiency measures present in the complexes studied
2) Fundamental efficiencies associated with multifamily housing (i.e., decreased heating and cooling energy due to shared walls)

Overall, most apartments' whole-house usage falls at or below models, but with DHW energy consumption exceeding predictions. Daily totals throughout the year are shown graphically in Figs. 3-5, average daily usage is summarized in Fig. 6. Apartment-specific tabular results can be found in Appendices A.1-A.3.

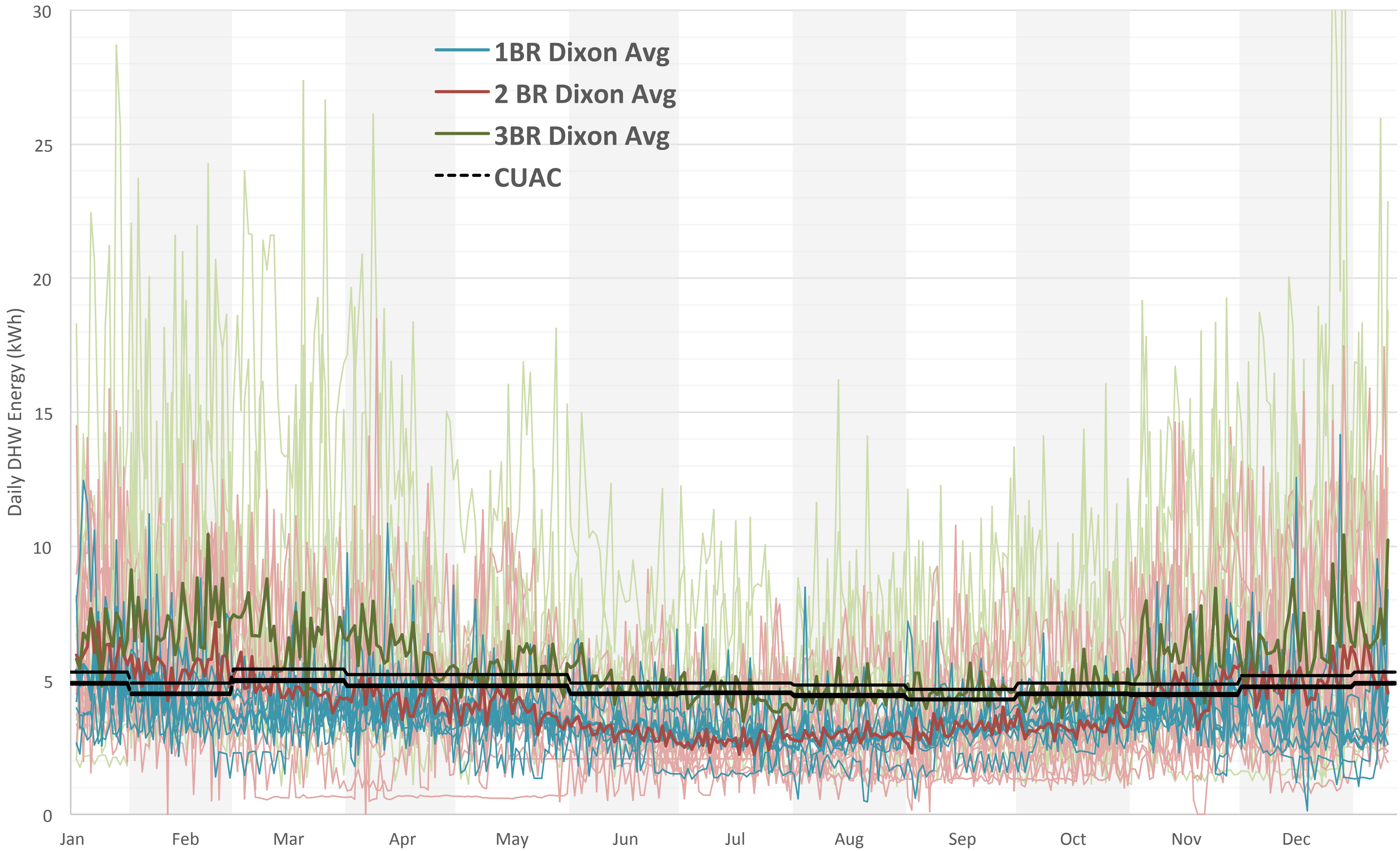


Figure 3: *Graphical representation of daily DHW electrical consumption at* ***Dixon*** *for all 1-, 2-, and 3-bedroom apartments with properly installed water heaters operating in hybrid mode, from 1/16/2015 to 1/10/2016. Anticipated usage for 1-, 2-, and 3-bedroom apartments, as determined by the EnergyPro and the California Utility Allowance Calculator (CUAC), is also shown. Note that it is possible to derive standby usage during periods during periods of vacancy and there is no hot water demand (all electricity used is a result of conductive heat loss from the tank). This is evident for one tenant from approximately early March to late May, accounting for, on average, 0.63 kWh/day.*

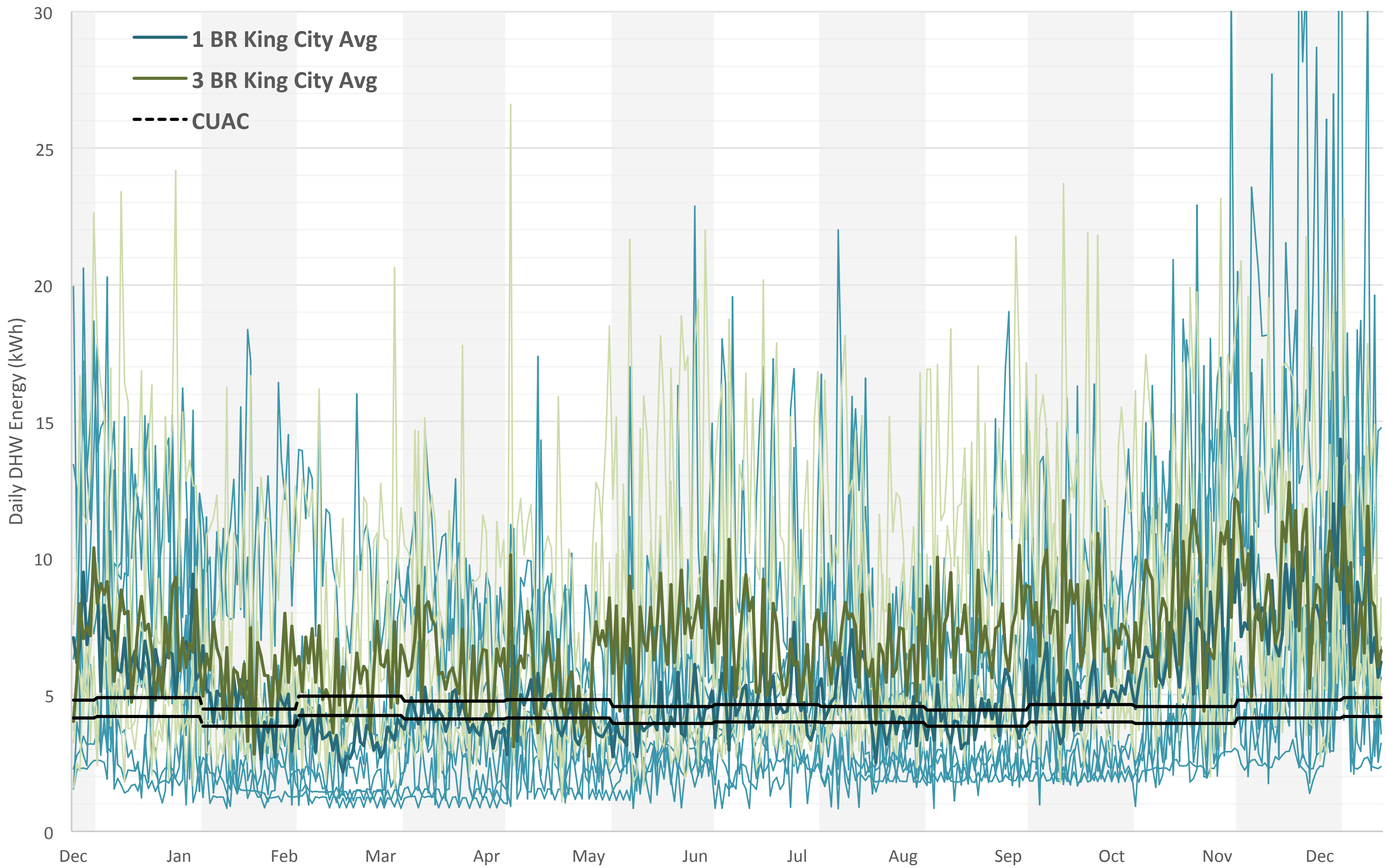


Figure 4: *Graphical representation of daily DHW electrical consumption at* ***King City*** *for all 1- and 3-bedroom apartments with properly installed water heaters operating in hybrid mode, from 12/25/2014 to 1/12/2016. Anticipated usage for 1- and 3-bedroom apartments, as determined by EnergyPro/CUAC models, is also shown. Note the greater number of high-usage days not only among 3-bedroom apartments, but also in 1-bedroom apartments, compared to Dixon and Lakeport.*

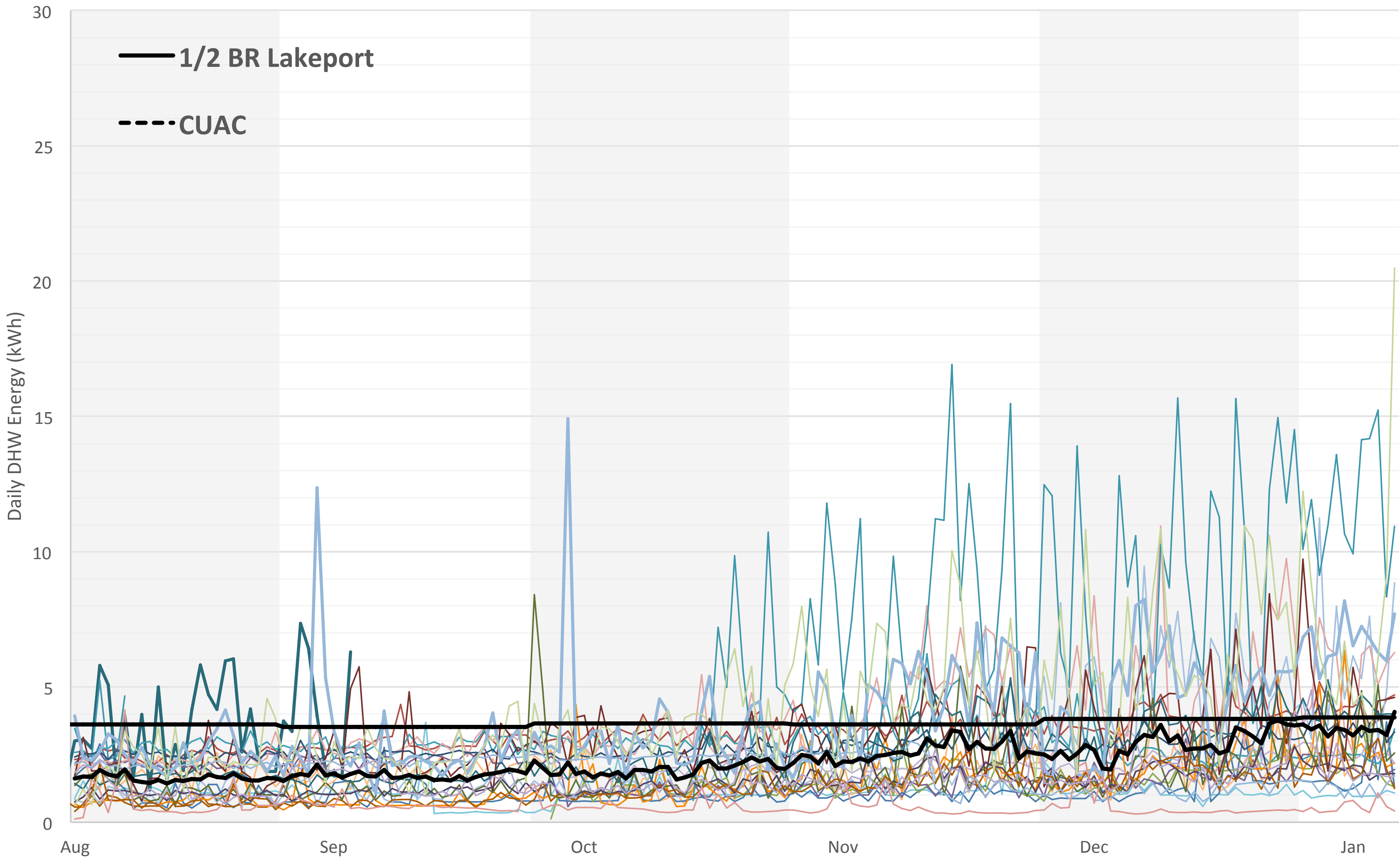


Figure 5: *Graphical representation of daily DHW electrical consumption at* ***Lakeport*** *for all 1- and 2-bedroom apartments with properly installed water heaters operating in hybrid mode, from 8/7/2014 to 1/12/2015. Due to occupancy, all units are treated as if they are single-bedroom dwellings for the purposes of comparing to models. Note that, while Lakeport data does not represent a full year, the dataset does cover roughly half of both the summer and winter months. For this reason, no factors were applied to the data for the sake of comparing it to other complexes; it is assumed that the half-year shown here is representative of a full year.*

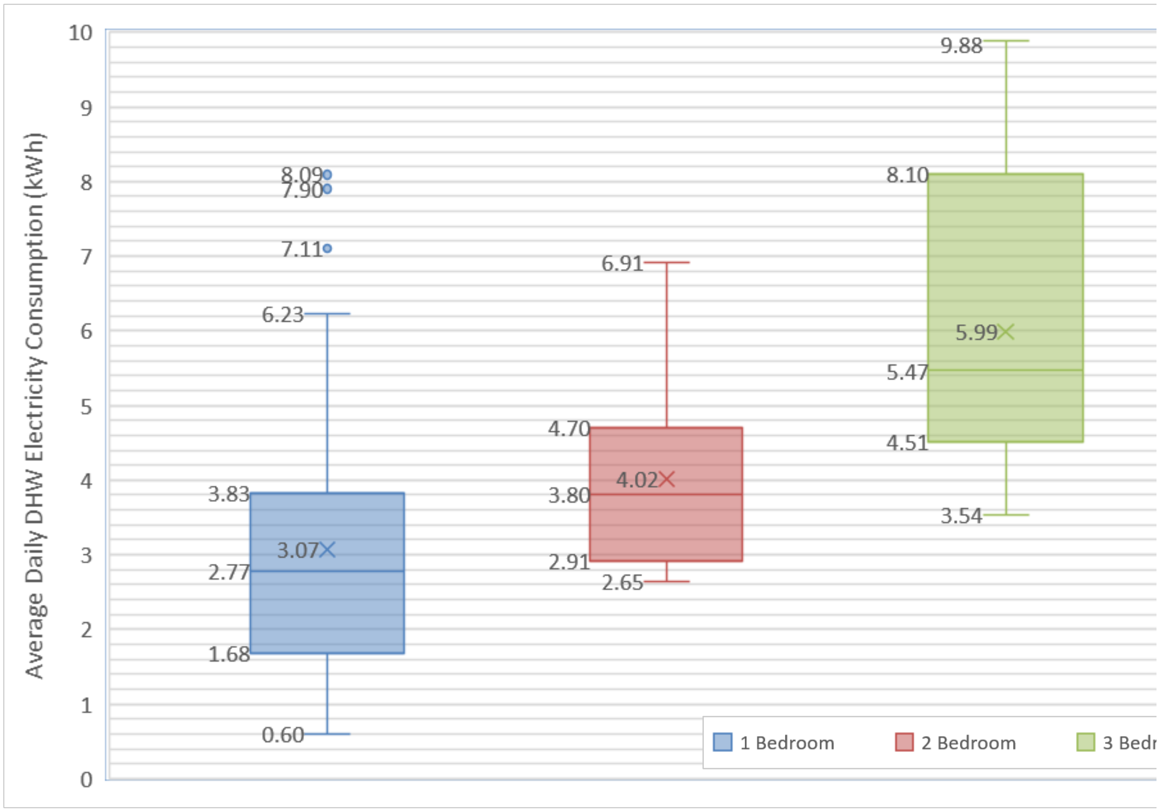


***Figure 6**: Distribution of average daily DHW energy for all complexes. Tabular summary statistics are presented on p*

It is important to note that 50-gallon tanks were installed at all apartments regardless of occupar apartment size. Similarly, hot water set points for all apartments was 125°F, so thermal storage c was identical despite significant differences in hot water demand. Thus, certain units would frequ go into recovery mode when the tank water reached its low-temperature threshold. This explain both the large degree of variation and resulting skew of averages towards heavy users as shown i 6. Many of these "heavy users" indeed turned out to be higher-occupancy households. An occup corrected algorithm is presented on page 12.

COMPARISON TO ENERGYPRO 5.1/CUAC

Expected energy usage was modeled using EnergyPro 5.1 and utility bills were calculated us California Utility Allowance Calculator (CUAC). Previous studies have shown, on average, that ap ACM software are relatively reliable when modeling whole-house usage in coastal climate zone less so in inland regions that have large AC loads or other vapor-compression cycle driven ap such as heat pump water heaters. This holds true, generally, for DHW at these locations and d from models can be attributed to:

1. Variance of actual occupancy compared to expected occupancy.
2. Thermal storage undersizing, primarily in 3-bedroom and larger apartments.
3. Improper installation, resulting in cooler ambient temperatures and decreased COP.
4. User behavior, which heavily drives DHW loads. This compounds issues 1-3.

Significant variation exists among residents of all apartments, particularly at King City (see Table 2), but in general low-income households (families and mixed demography) with properly installed water heaters (i.e., Dixon), apartment-wide averages match current models with a fair degree of accuracy.

Table 2: *Statistical summary and comparison to EnergyPro/CUAC models*

Yearly							
	Bedrooms	**Average (kWh)**	**Standard deviation (kWh)**	**Skew**	**Percent of Whole-House Consumption**	**CUAC/ EnergyPro (kWh)**	**Percent Difference from CUAC/EnergyPro**
King City	1	5.100	2.106	0.264	49%	4.07	25%
	3	7.063	2.580	0.672	40%	4.71	50%
Dixon	1	3.617	0.277	0.603	23%	4.63	-22%
	2	4.128	1.230	1.203	28%	4.69	-12%
	3	5.581	1.626	0.683	33%	5.06	10%
Lakeport	1	2.191	1.410	2.003	20%	3.74	-41%
Summer (May-October)							
	Bedrooms	**Average (kWh)**	**Standard deviation (kWh)**	**Skew**	**Percent of Whole-House Consumption**	**CUAC/ EnergyPro (kWh)**	**Percent Difference from CUAC/EnergyPro**
King City	1	4.466	1.992	0.284	48%	4.07	10%
	3	6.345	2.890	0.838	43%	4.71	35%
Dixon	1	3.334	0.288	0.330	23%	4.63	-28%
	2	3.363	1.045	1.294	26%	4.69	-28%
	3	5.143	1.561	1.081	30%	5.06	2%
Lakeport	1	1.864	0.943	0.866	20%	3.74	-50%
Winter (November-April)							
	Bedrooms	**Average (kWh)**	**Standard deviation (kWh)**	**Skew**	**Percent of Whole-House Consumption**	**CUAC/ EnergyPro (kWh)**	**Percent Difference from CUAC/EnergyPro**
King City	1	5.998	2.459	0.357	49%	4.07	47%
	3	6.624	3.062	1.709	38%	4.71	41%
Dixon	1	4.065	0.322	0.466	24%	4.63	-12%
	2	5.052	1.623	0.774	31%	4.69	8%
	3	6.682	2.364	0.348	36%	5.06	32%
Lakeport	1	2.875	1.854	1.534	20%	3.74	-23%

SEASONAL EFFECTS

An interesting, if unexpected, outcome of this study is the effect of season on electrical demand and performance of heat pump water heaters. Decreases in water heating energy during the summer months of 10-12% have been confirmed previously as a result of increased ambient supply water temperature.[2][4] This is evident to varying degrees at all sites; a higher number of high-usage days during winter months indicates that the resistance heater was operating more frequently. However, it is likely that there are other contributors to seasonal variation in this study.

A site inspection was performed following analysis of King City due to the presence of large spikes and an absence of a decrease in summer DHW energy. King City is demographically and climatically similar to

Dixon, but demand was higher throughout the year, especially in the summer (40% and 47% higher for 1- and 3-bedroom apartments, respectively). The inspection of King City found that the DHW tanks were installed in unventilated closets with sealed doors, as opposed to garage at Dixon and a large patio closet at Lakeport. In the winter this would result in cooler heat pump source air as a result of heat pump exhaust air being trapped in the installed space. Per GE's specifications [5] the energy factor (EF) of GeoSpring hybrid water heaters varies between 3.1 (at 100°F) and 1.9 (at 47°F). Below 47°F, the heat pump will fail to function at all; the resistive element will function alone resulting in an EF of approximately 0.9. This underscores the importance of installing heat pump water heaters in properly conditioned space that are adequately ventilated.

DAILY DHW TIME OF USE (TOU)

Time-of-use data is expressed in summed one minute increments, and was separated by both weekend and weekday (see Figs. 8 & 9). Expected peaks in the morning and evening are present, though not as pronounced as when operating in resistance-only mode. Some of the TOU is diluted by the considerably lower quantities of energy used by the heat pump, compared to resistance heaters or those that more frequently operate in recovery mode (3 bedroom). In fact, loads for those in hybrid mode ***on average*** are quite constant even during the night, with slight increases in the early morning and mid-afternoon largely due to the resistance element. That said, there is a high degree of consistency within specific apartments particularly on week days, though also to a degree on weekends. In general, consumption throughout the week is very constant, with notable decreases on Saturdays. (see Fig. 7).

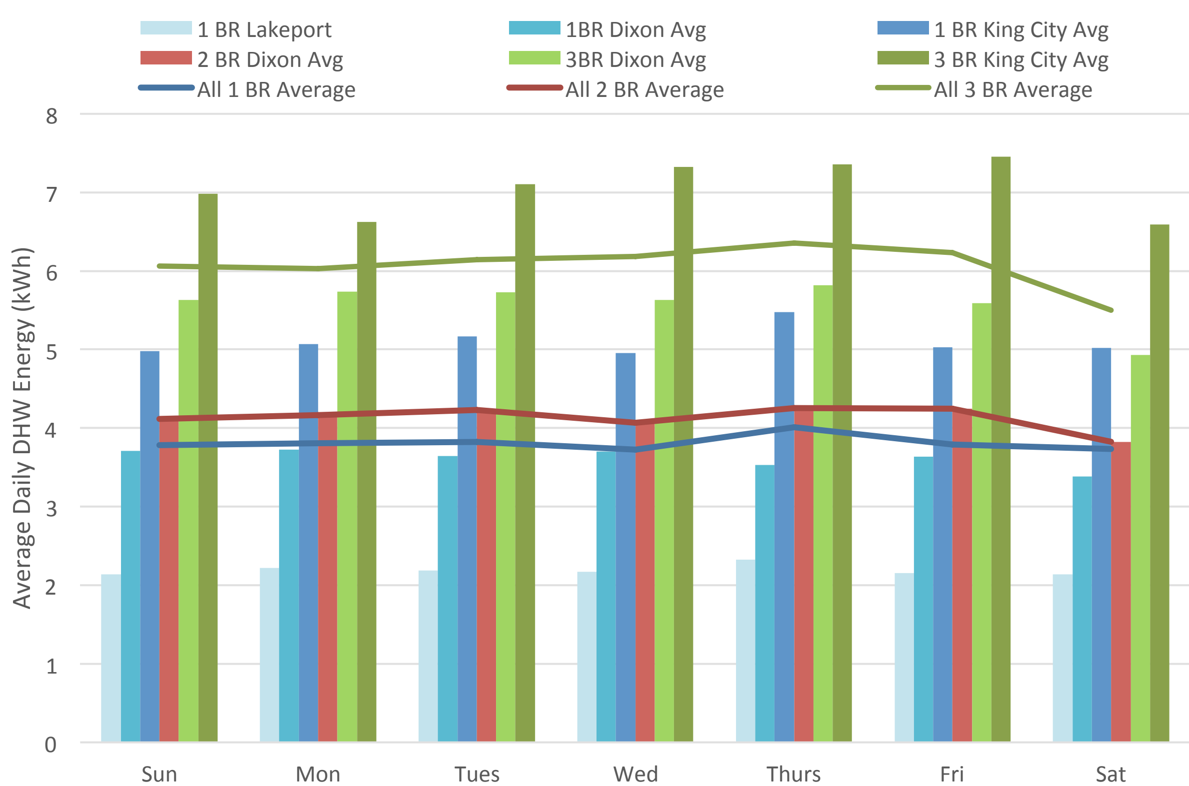


Figure 7: *Average daily DHW energy on week and weekend days*

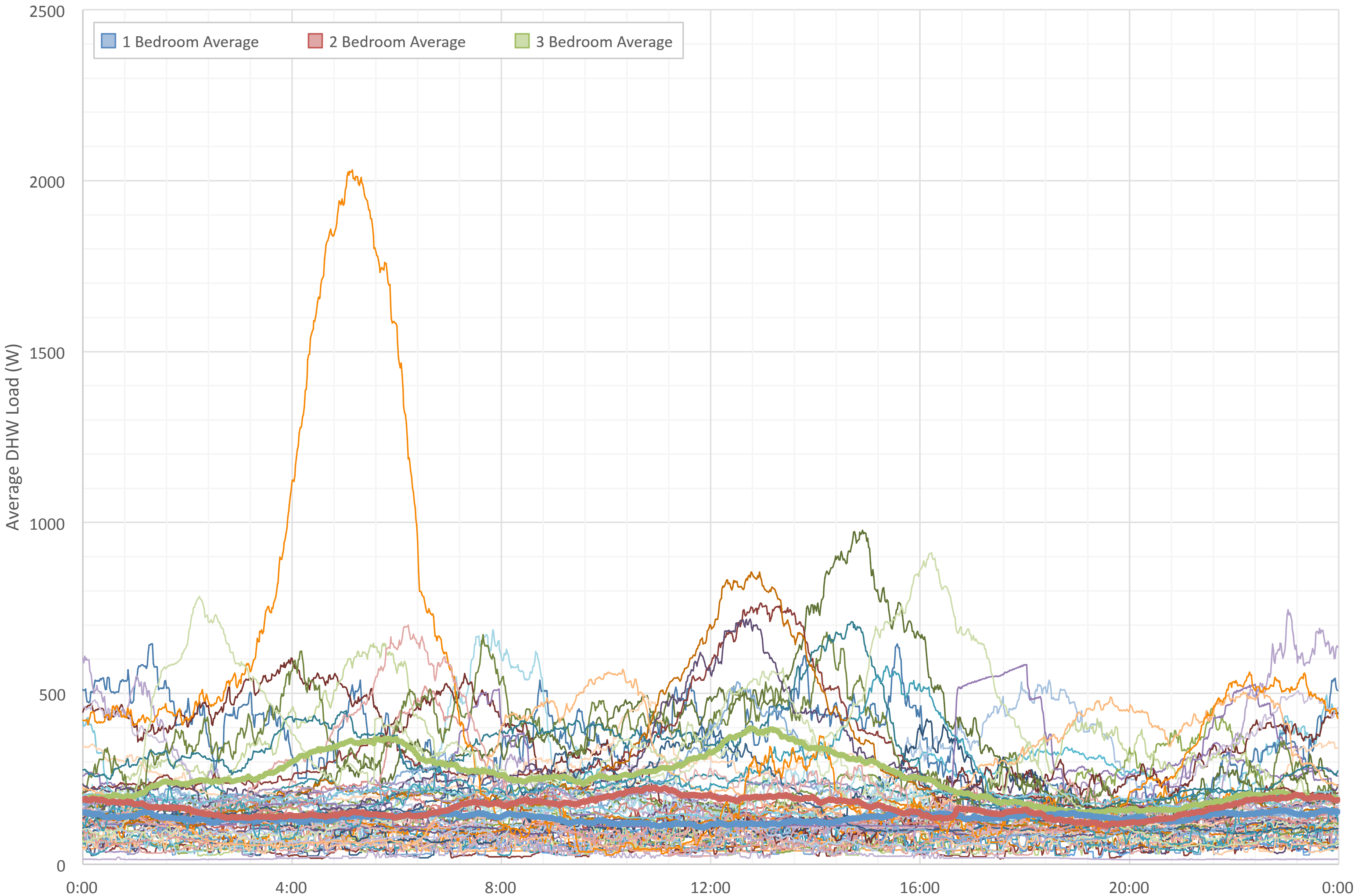


Figure 8: *Average* ***weekday*** *DHW loads for the period of study for all apartments (Lakeport, Dixon, and King City). Note that certain individuals (those whose DHW heaters operate in recovery mode frequently), influence the overall averages significantly. This is most noticeable for 3-bedroom apartments.*

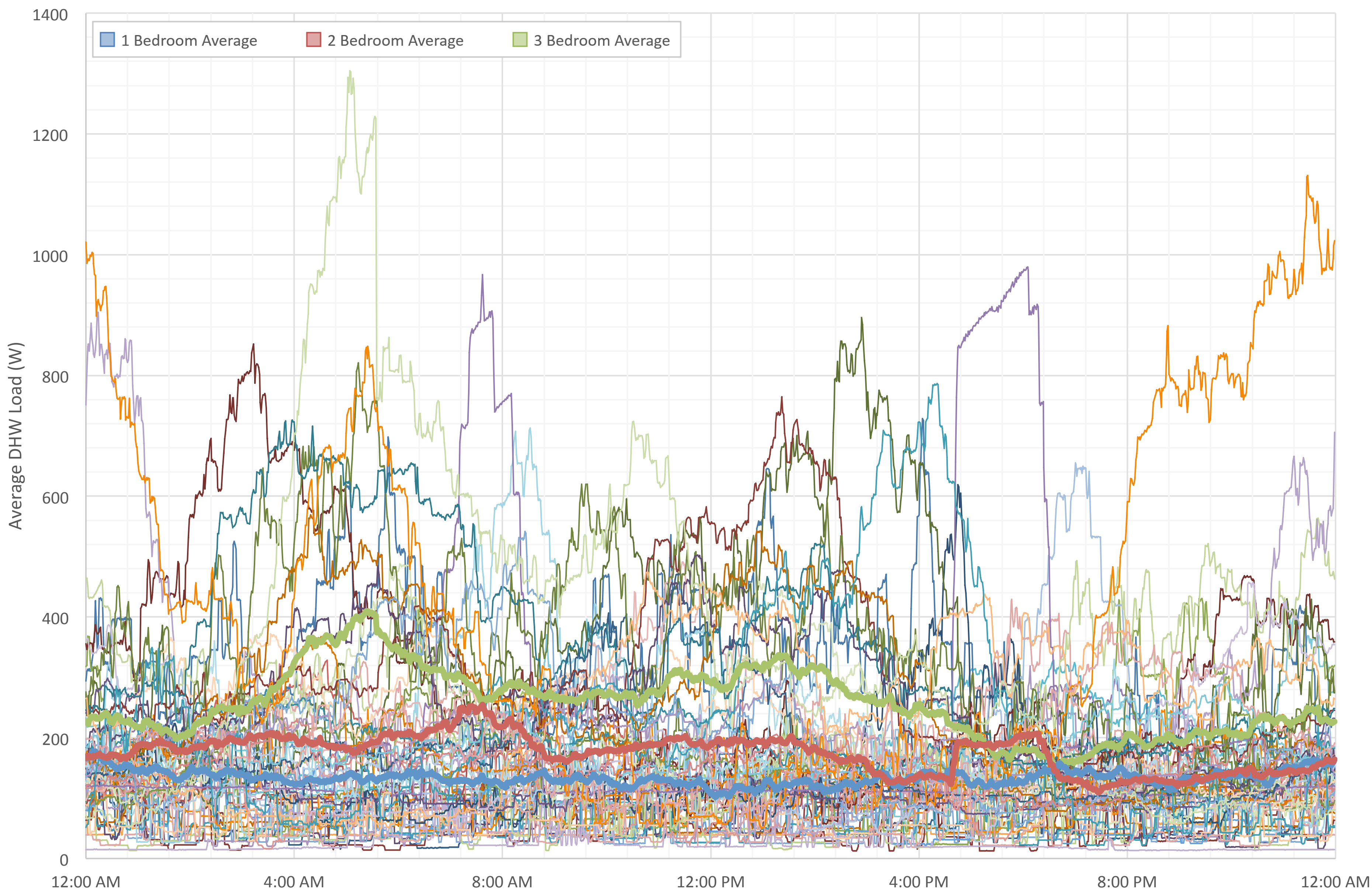


Figure 9: *Average* ***weekend*** *load during the period of study for all apartments (Lakeport, Dixon, King City). Note that individual patterns are less consistent, but the average load throughout the day is roughly the same. Peaks for certain users, especially heavy users, are smaller, indicating (expectedly) that schedules are more variable on the weekends*

The variation across apartments at both Dixon and King City can be explained in mostly by differences in work schedules. The complexes likely serve many farmworkers (perhaps the cause of the prevalence of many early risers), but also serves those who have regular full-time and (perhaps multiple) part-time jobs. Some apartments have children, which also greatly influences DHW usage schedules. Lakeport is even less consistent, with almost no daily patterns visible complex-wide, though individual patterns are still present. This is probably attributed to the (generally) flexible lives of retirees.

Increased variability among larger apartments can be further explained simply by increased occupancy. There is both a greater spread in the *actual* occupancy of larger apartments, as well as an increase in the chance that individual schedules may coincide and hot water demand spikes greater on any given day and prompting the water heaters to enter recovery mode

REVISED DHW MODEL

As has been demonstrated, numerous factors play into the variation present in all three apartment complexes. Firstly, the assumption of 1.5 occupants per bedroom, while a useful tool for estimating usage among large populations, is often a poor proxy for actual occupancy. True occupancy data was therefore obtained to provide a more useful model of population-based DHW energy consumption. Secondly, back-calculations converting resistance heater electricity into heat pump electricity allow an apples-to-apples comparison of all units. In this way, the previously excluded units set to resistance-only mode can also be included for characterization of usage and comparisons to EnergyPro/CUAC models.

OCCUPANCY-CORRECTED CONSUMPTION

A simple per-occupant comparison yields much "tighter" data, with fewer outliers and a clearer trend (see Fig. 10). There is a relatively steep difference between 1- and 2-occupant; usage tapers off after 3 occupants. This is due to both economies of scale in many hot-water end uses as well as the possibility that children use less hot water than their parents. The decrease in usage from 3- to 4-occupant households can be attributed to random variation due to small sample sizes for higher-occupancy residences.

As noted, some economies of scale exist in larger households (usage of hot water for dish washing, hot water "leaks", and standby losses, for instance), but the vast majority of hot water demand (60-80%, depending on occupancy) will come from showers and baths.[6] Similar schedules among cohabitating individuals result in a non-linear increase in the amount of DHW electricity used as resistance heaters are required to keep up with demand. This again emphasizes the importance of adequately sizing the thermal storage of a heat pump or hybrid electric water heater to adequately match demand.

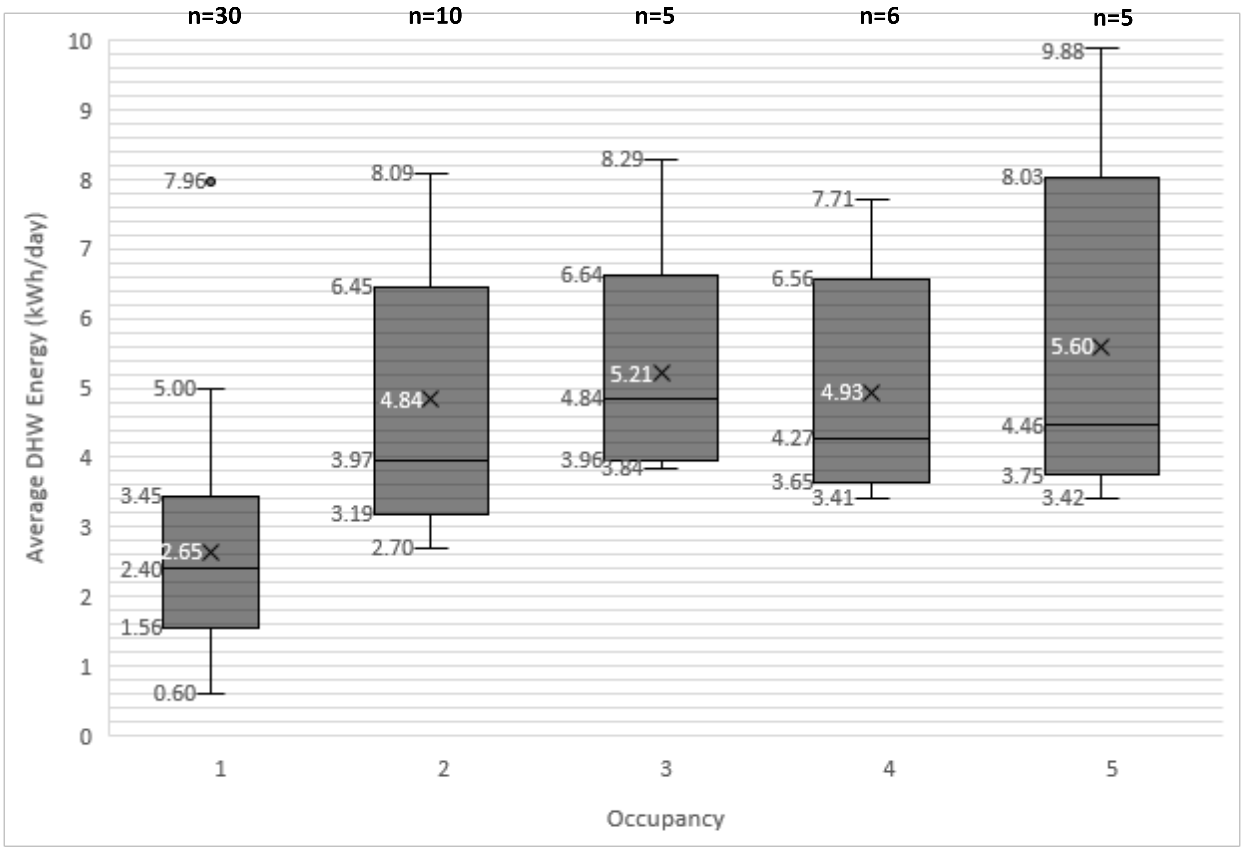


Figure 10: *Average DHW electrical consumption on for all households (on hybrid mode) based on true occupancy (1-5 people). Note that children and adults were given equal weight in this comparison.*

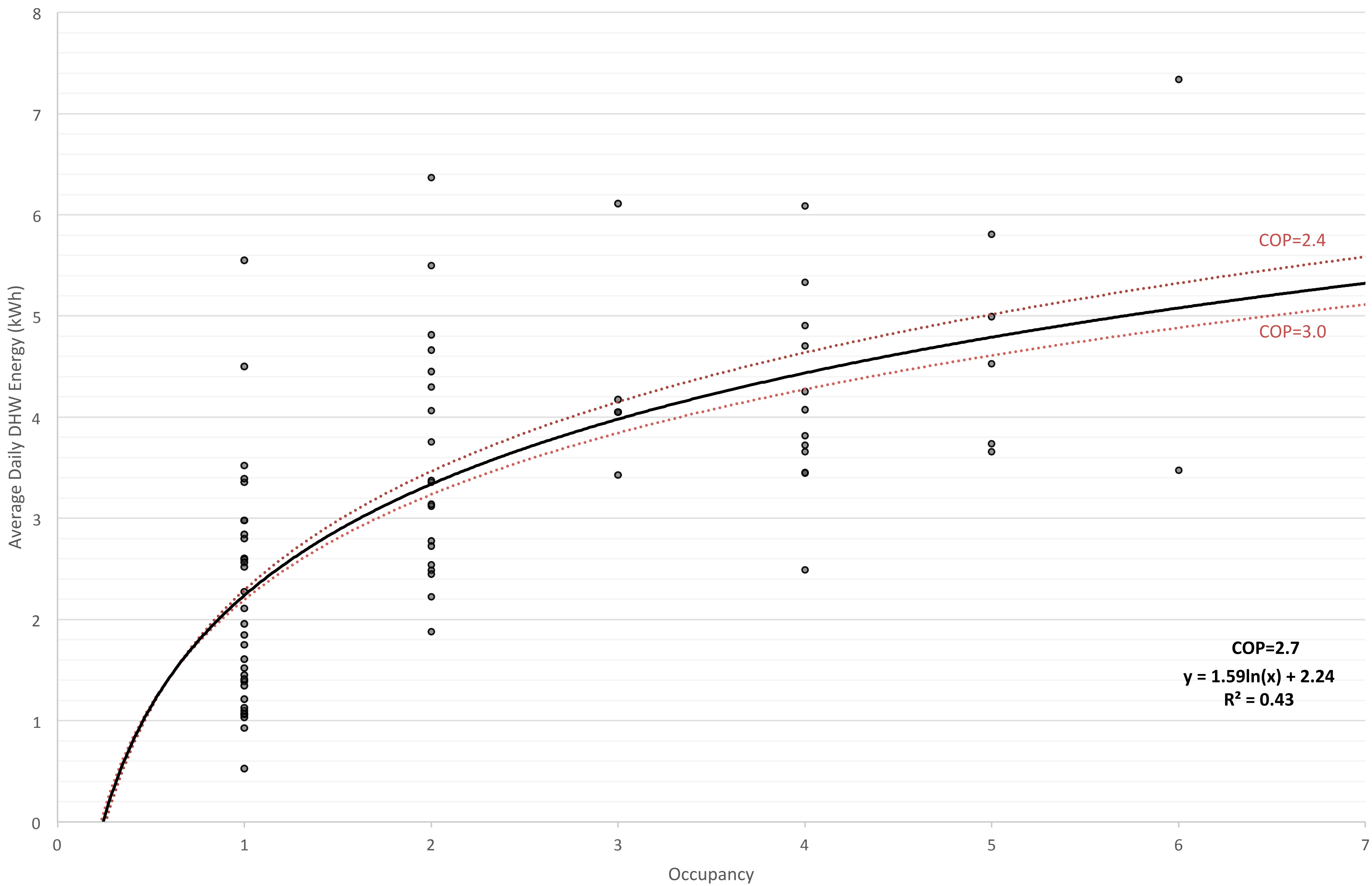
HEAT PUMP ONLY MODEL

Hot **water** consumption with relation to occupancy is generally best characterized with a logarithmic or power function,[6] but water use does not parallel electrical energy usage of a hybrid (bimodal) water heater. This necessitates the conversion of resistance-only events to a heat pump electrical equivalent using an assumed COP for the heat pump unit to obtain a better characterization of DHW energy usage behavior. Unfortunately, ambient water and air temperatures were not collected in this study, so this back-calculation is somewhat approximate. Calculations were therefore performed under a range of COP values (2.4-3.0) as cited by a robust study of the GeoSpring units to account for this potential error.[2] This conversion also includes apartments previously omitted from the study due to improper initialization in "resistance-only" mode.

An occupant-dependent function is proposed using the aforementioned method of normalization. A logarithmic function (Equation 1, also presented in Fig. 11) provides the best fit which is reinforced by previous studies of DHW use:[6][7][8][9]

$$y = 1.586\ln(x) + 2.238$$

where: y = daily DHW energy usage (kWh)
x = number of occupants (Equation 1)



Average Daily DHW Energy (kWh)
Occupancy
0
1
2
3
4
5
6
7
8
COP=2.4
COP=3.0
COP=2.7
y = 1.59ln(x) + 2.24
R² = 0.43

While there are still heavy users for all occupancies, it is clear that the data shows a much clearer trend and a reasonable fit using normalized data. This relationship is appropriate for estimating DHW electrical usage for heat pump water heaters of similar EF ratings (At the DOE standard of 68°F, 50-gallon GeoSpring models have an EF of 2.5). Note that similar calculations could be done to approximate sizing for heat pump water heaters of other energy factors.

Using the prescribed 1.5 occupants/bedroom factor and interpolating, a new comparison of DHW electricity usage can be made to the EnergyPro/CUAC modeling (see Table 3). Trends are more consistent, relative differences are significantly lower (overall), and most averages fall below the EnergyPro/CUAC model. There is still significant variation among 1-bedroom residences, which can be most likely be attributed to overestimation of losses by the EnergyPro model. Overall this normalized approach is an improvement in characterizing of the data.

Table 3: *Comparison of CUAC/EnergyPro model to normalized daily averages and a logarithmic best fit of those averages (y=1.586ln[x]+2.238). A factor of 1.5 occupants per bedroom was used, and interpolation was used for normalized averages where necessary.*

Daily Occupancy- and Electricity-Normalized Averages (Jan-Dec)						
	Bedrooms	**CUAC/ EnergyPro (kWh)**	**Normalized Average (kWh)**	**Normalized Log Function Model (kWh)**	**Normalized Averages Percent Difference from CUAC/ EnergyPro**	**Log Function Percent Difference from CUAC/ EnergyPro**
King City	**1**	4.07	3.66	2.88	-10%	-29%
	2	4.27	4.62	3.98	8%	-7%
	3	4.71	4.68	4.62	-1%	-2%
Dixon	**1**	4.63	3.40	2.88	-27%	-38%
	2	4.69	3.73	3.98	-20%	-15%
	3	5.06	4.10	4.62	-19%	-9%
Lakeport	**1**	3.74	2.62	2.88	-30%	-23%
All	**1**	-	3.28	2.88	-14%	-
	2	-	4.38	3.98	10%	-
	3	-	4.36	4.62	-6%	-

EFFECT OF INCOME ON DHW ENERGY

Numerous studies have shown the correlation between income (both as a function of individual incomes and of GDP at the state level), but there are income-dependent factors that can work both ways (energy efficiency of appliances, or quantity and energy intensity of miscellaneous electric loads, for instance). This study offers a unique control with identical appliances, a mixed demography, and similar housing characteristics between sites. Income data was collected and compared to normalized energy consumption on a per-occupant basis (see Fig. 12).

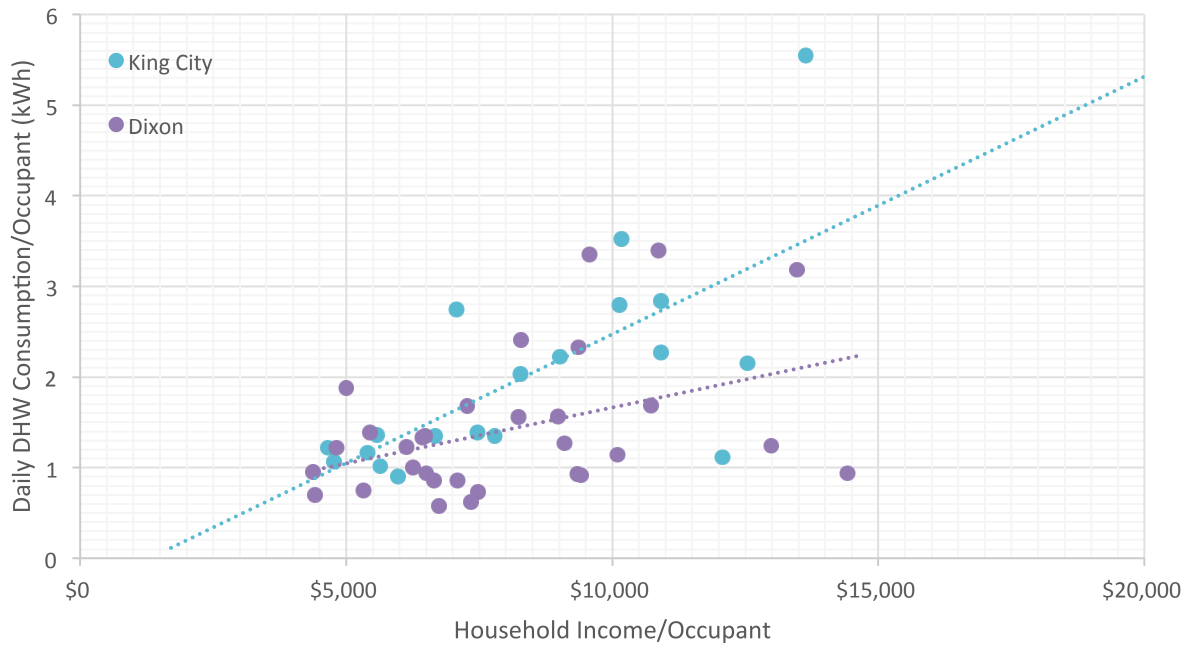


Figure 12: *Per-occupant DHW energy usage as a function of per-occupant annual income separated by location. DHW energy is normalized using the back-calculation described in the preceding section.*

There is clearly a positive correlation between household income and DHW energy usage. A significant amount of scatter exists and because it is unknown how many working adults reside in each household it is unclear exactly what the relationship is in quantitative terms. With that in mind, actual trends may not be as significant in this relatively narrow income bracket.

Operational Improvements

As has been noted repeatedly, thermal storage provided by the heat pump often appears to be inadequate for larger households. A preliminary review by General Electric[10] suggests that much of the electricity used by the high-power resistance element may actually be unnecessary; the tanks do not actually appear to reach a tepid or unusable temperature when the tanks switch to the resistance element.[10] Further studies involving time-dependent temperature data need to be conducted to confirm this, but it does seem that the Geosprings' full heating potential is not being utilized.

The higher-than-expected utilization of the backup resistance element highlights the importance of appropriately sizing and programming water heaters that have multiple modes of operation (i.e., HEWHs). Clearly, heat pump water heaters benefit from having a resistance backup during times of extremely heavy hot water draw, heat pump failure, or under circumstances where the ambient temperature falls outside of the operating range of the refrigerant (35°F to 115°F for the GeoSpring HEWH). Still, significant increases in thermal storage can be made without vastly oversizing the primary heat pump system:

1) **Increased temperature:** For existing units, where re-programming is limited, raising the temperature to increase thermal storage could help offset peak usage times, especially in large households or in places where hot water usage of occupants coincides. Higher temperatures will also slightly increase standby losses, but in many cases would be more than offset by the gains made during high-usage periods. GeoSpring units can safely operate at tank temperatures of up to 160°F, which would result in approximately 60% increase in the amount of available hot water.[10] It should be noted that for the GeoSpring HEWHs studied here, an increase in the set temperature would result a decrease the operating COP of the heat pump as the tank water temperature increased.
2) **Increased tank size:** For particularly large new installations, an increased (e.g., 80-gallon) tank might make more sense than increased temperature, as standby losses could be reduced with lower temperatures.
3) **Decreased cut-off temperature:** As noted, many of the units may have switched to resistance mode earlier than necessary. Typically, once hot water availability drops below 50%, the HEWH switches to resistance mode and does not shut off until the tank capacity has again reached 100%. Decreasing the set point at which the HEWH switches modes would result in less frequent utilization of the resistance element.
4) **Intuitive Programming:** Much electricity goes into heating the space around the water heater as a result of convective standby losses. This can be reduced using intuitive programming:
    a. **Time-dependent temperature increases**: As has been shown, there are many users with significant usage peaks in the early morning. Programming the units to raise the temperature during certain key times would decrease the likelihood that the resistance heater would need to operate.
    b. **Time-dependent temperature decreases:** Similarly, decreasing the temperature during periods of low usage would reduce reliance on the heat pump to offset standby losses.
    c. **Real-time feedback with adaptive programming:** Every household uses hot water differently, and it is impossible to tailor each water heater to the individuals' needs without the use of adaptive programming. Letting the HEWH "learn" when users need hot water can optimize performance over the long-term and provide maximum utility for users.

It should be mentioned that all HEWHs studied in this paper operated with either the heat pump ***or*** the resistance element, but not both. This has been changed in later models, also somewhat reducing electrical demand of the resistance element by approximately 400W.

CONCLUSIONS

The following conclusions can be made from this study:

- A significant amount of variation across different apartments as well as within individual complexes is present (%RSD of 29-64% depending on apartment size). This emphasizes the importance of large sample sizes when undertaking similar studies.
- For both multi-family and senior housing, average daily TOU patterns are reasonably flat, particularly among properly-sized installations. This is in part due to the efficiency of the hybrid water heaters but also due to highly variable personal schedules among different residents.
- Occupancy- and energy-normalized averages compare much more closely to current models than per-bedroom averages, though in many instances 1-bedroom usage appears to be overestimated by the EnergyPro/CUAC model. Normalized daily averages are 3.28, 4.38, and 4.36 kWh for 1-, 2-, and 3-bedroom apartments, respectively. The agreement of these

normalized values to existing models confirms the accuracy of the models as long as the 1.5 occupants/bedroom standard holds true for large populations.

- Seasonality plays a role in DHW energy usage. In general, energy decreases in the summer as a function of:
    - Primarily, warmer supply water temperature
    - To a lesser extent, warmer ambient air supply temperature
- A logarithmic curve fit to the normalized data, shows overall good agreement with the EnergyPro/CUAC model. The following logarithmic function was used to best describe per-occupant DHW energy usage:

$$y = 1.586\ln(x) + 2.238$$

where: *y* = daily DHW energy usage (kWh)
x = number of occupants

- Improper ventilation results in depressed supply air temperatures and decreased heat pump COPs. This results in hybrid water heaters entering recovery mode more readily and significantly increases overall consumption.
- Per-occupant income appears to be weakly positively correlated with DHW energy usage, but results are inconclusive due to significant unknowns.
- Current thermal storage (50 gallons at 125°F) for both 2- and 3-bedroom hybrid water heaters was insufficient. To avoid operating frequently in recovery mode and increase thermal storage, the following is recommended:
    - For new installations, larger (80 gallon) water heaters should be used.
    - In locations where 50-gallon hybrid water heaters are already installed, the water storage temperature should be increased to 130°F or higher
    - Future updates of the GeoSpring HEWH (and others) should include adaptive programming that intelligently reacts to user behavior.

References

[1] U.S. Energy Information Administration. (2009). "Residential energy consumption survey." <http://www.eia.gov/consumption/residential/>

[2] Ecotope, Northwest Energy Efficiency Alliance. (March 2, 2015). *Heat pump water heater model validation study.* <http://www.ecotope.com/wp/ecotope-publications-database/>

[3] Armstrong, S., Winkler, M., and Pfotenhauer, G. (September 15, 2013). *Is the modeling produced by the California Utility Allowance Calculator Accurate? A study of seven apartment complexes.*

[4] Gerin, O., Bleys, B., and De Cuyper, K. (2014). "Seasonal variation of hot and cold water consumption in apartment buildings." *CIBW062 Symposium 2014*. <www.cstc.be/homepage/download.cfm?dtype=research&doc=A2_1523.pdf&lang=en>

[5] General Electric. (2009). *GeoSpring efficiency as a function of ambient air temperature.*

[6] DeOreo, B., Mayer, P., Armstrong, S., and Adabie, L., (2015). *REU2015 and select REU1999 algorithms for occupancy vs. consumption.*

[7] Aquacraft. (2011). *Albuquerque single-family water use efficiency and retrofit study.*

[8] Zhang. (2013). *Multifamily central domestic hot water distribution systems.*

[9] DeOreo W., Mayer, P., Dzeigielewski, B., and Kiefer, J. (2016). *Residential end uses of water, version 2.* The Water Foundation.

[10] Shaffer, S. (April 4th, 2016). "Redwood analysis & recommendation." *ACEEE Hot Water Forum, Portland, OR in February, 2016.*

APPENDICES

The following appendices include selected results from the study. For additional results or analyses please contact the authors. It should be noted that apartment numbers have been changed to protect the identity of those in the study.

APPENDIX A: DAILY SUMMARIES AND METADATA

The following tables contain a variety of useful data as daily averages (on an annual basis). Note that "heat pump" energy is never zero even for those units that were incorrectly programmed. Logged power is either due to parasitic loads or noise which was impossible to disaggregate from the low-power heat pump load. It is also possible that some of these units could have been operating properly for a short period. Those units that were incorrectly programmed are marked with a * in the "Notes" column.

TABLE A.1: KING CITY

Apartment Index	Bedrooms	Number of Occupants	Household Income	Average Daily Electrical Consumption (kWh)				
				Whole House	HEWH	Heat Pump	Resistance Element	Notes
K1	1	1	$ 10,913	8.92	3.27	2.50	0.77	
K2	1	1	$ 16,548	13.65	7.11	2.52	4.59	
K3	1	1	$ 14,144	13.63	8.09	4.13	3.97	
K4	1	2	$ 22,403	20.36	11.08	0.15	10.92	*
K5	1	2	$ 11,158	19.37	6.55	0.55	5.99	*
K6	1	1	$ 10,133	7.03	3.30	2.43	0.87	
K7	1	1	$ 10,914	13.99	5.11	0.61	4.49	*
K8	1	1	$ 24,137	5.70	2.70	1.97	0.73	
K9	1	2	$ 25,088	16.48	6.23	3.20	3.03	
K10	1	1	$ 10,177	11.00	5.00	2.59	2.41	
K11	1	2	$ 18,041	18.17	10.19	1.05	9.14	*
K12	1	1	$ 13,639	23.12	15.03	0.05	14.97	*
K13	3	5	$ 29,903					Corrupt Data
K14	3	4	$ 19,080	17.48	10.85	0.40	10.45	*
K15	3	6	$ 27,925	32.40	19.66	0.10	19.63	*
K16	3	3	$ 22,547	15.74	9.73	0.76	8.98	*
K17	3	3	$ 20,020	13.44	4.98	3.49	1.50	
K18	3	4	$ 26,977	21.43	9.88	3.43	6.45	
K19	3	5	$ 29,855	19.41	11.32	0.55	10.78	*
K20	3	3	$ 23,386	13.53	4.84	3.67	1.17	
K21	3	3		38.79	8.55	4.72	3.83	Manager unit

Table A.2: Dixon

Apartment Index	Bedrooms	Number of Occupants	Household income	Average Daily Electrical Consumption (kWh)				
				Whole House	HEWH	Heat Pump	Resistance Element	Notes
D1	1	1	$ 9,576	9.18	3.43	3.31	0.11	
D2	1	2	$ 14,556	13.05	3.44	3.33	0.12	
D3	1	1	$ 10,870	10.10	3.37	3.37	0.00	
D4	1	2	$ 18,204	21.05	3.90	1.75	2.16	
D5	1	2	$ 17,954	23.96	3.96	2.71	1.25	
D6	2	2	$ 10,008	17.54	3.81	3.67	0.15	
D7	2	2	$ 10,886	14.33	2.81	2.76	0.05	
D8	2	2	$ 16,577	23.11	4.82	4.81	0.01	
D9	2	2	$ 16,474	8.16	3.23	3.08	0.15	
D10	2	1	$ 25,967	12.62	2.67	2.36	0.31	
D11	2	6	$ 40,432	17.06	3.70	3.29	0.42	
D12	2	3	$ 30,289	26.80	3.97	3.05	0.91	
D13	2	2	$ 19,434	14.29	4.39	3.76	0.64	
D14	2	2	$ 17,479	18.99	3.97	3.56	0.41	
D15	2	2	$ 18,736	14.03	5.31	4.12	1.20	
D16	2	2	$ 12,252	10.63	3.82	1.51	2.32	*
D17	2	3	$ 26,633	20.12	7.25	1.63	5.61	
D18	2	4	$ 29,396	13.98	6.11	0.30	5.81	
D19	2	2	$ 28,842	7.16	2.79	1.33	1.46	*
D20	3	4	$ 37,370	20.15	4.04	3.55	0.49	
D21	3	3	$ 24,091	20.94	7.16	5.44	1.72	
D22	3	3	$ 30,842	39.08	8.28	2.99	5.29	
D23	3	4	$ 32,544	17.71	6.06	3.83	2.23	
D24	3	2	$ 26,942	20.40	8.08	5.38	2.70	
D25	3	5	$ 31,247	18.79	5.94	4.23	1.71	
D26	3	4	$ 26,595	12.36	4.65	2.78	1.86	
D27	3	1	$ 21,450	10.37	3.53	3.27	0.27	
D28	3	4	$ 37,397	19.49	7.36	1.35	6.01	*
D29	3	4	$ 37,650	9.12	4.55	3.09	1.46	
D30	3	4	$ 28,348	18.20	4.38	2.90	1.47	
D31	3	4	$ 25,747	21.93	5.99	4.84	1.14	Manager
D32	3							

TABLE A.3: LAKEPORT

Apartment Index	Bedrooms	Number of Occupants	Household income	Average Daily Electrical Consumption (kWh)				
				Whole House	HEWH	Heat Pump	Resistance Element	Notes
L1	1	1	$ 10,812	11.93	1.12	0.99	0.14	
L2	1	1	$ 10,926	14.43	1.78	1.19	0.58	
L3	1	1	$ 10,924	4.93	1.07	0.83	0.24	
L4	1	1	$ 22,967	11.36	3.22	2.80	0.42	
L5	1	1	$ 10,897	9.47	2.05	1.15	0.89	
L6	1	1	$ 10,380	9.69	1.48	0.85	0.63	
L7	1	1	$ 19,180	14.87	1.46	1.42	0.04	
L8	1	1	$ 13,440	7.18	1.73	0.75	0.98	
L9	1	1	$ 17,039	10.17	3.00	2.46	0.54	
L10	1	1	$ 11,729	7.43	1.38	0.92	0.46	
L11	1	1	$ 11,738	12.98	2.25	1.09	1.16	
L12	1	1	$ 10,922	13.17	3.61	2.61	1.00	
L13	1	1	$ 14,444	12.87	2.08	1.72	0.36	
L14	1	1	$ 10,673	20.82	7.14	2.67	4.47	
L15	1	1	$ 10,913	14.09	2.68	2.42	0.26	
L16	1	1	$ 19,274	10.79	2.95	1.58	1.37	
L17	1	1	$ 9,566	14.63	1.68	1.22	0.46	
L18	1	1	$ 10,673	8.38	1.42	1.09	0.33	
L19	2	1	$ 16,931	16.12	2.42	1.63	0.79	
L20	2	1	$ 10,918	15.37	3.61	1.96	1.65	
L21	2	1	$ 10,673	9.91	1.24	0.94	0.31	
L22	2	1	$ 10,181	9.84	1.97	1.76	0.21	
L23	2	1	$ 18,548	11.14	0.59	0.49	0.10	
L24	2	1	$ -	15.86	3.91	1.62	2.29	
L25	2	1	$ 12,724	12.05	1.52	1.22	0.30	

Appendix B: Weekday TOU Averages

The following tables include weekday averages (in Wh) on an hourly basis. One apartment at Dixon has been removed due to time jumps in the raw data.

Table B.1: King City

Hour	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13	K14	K15
0:00	136.3	444.9	161.6	320.1	348.9	139.9	341.2	70.2	213.1	493.0	263.8	572.6	20.5	282.7	1218.1
1:00	127.5	400.6	153.7	222.6	374.9	167.3	187.6	76.5	289.9	410.4	189.9	575.5	19.7	426.6	802.8
2:00	136.1	456.2	189.4	406.6	278.7	168.1	200.1	88.6	266.9	233.5	192.9	469.7	20.3	432.6	302.2
3:00	121.8	546.7	184.0	937.5	373.4	179.1	245.4	114.6	361.8	185.8	153.9	588.4	20.4	604.9	143.3
4:00	99.5	544.2	236.3	763.9	326.4	192.2	174.0	92.8	464.5	148.1	160.7	977.0	20.8	1471.1	93.8
5:00	85.7	459.0	274.4	520.5	304.3	113.6	175.6	227.8	614.0	152.7	383.4	952.0	27.8	1086.5	123.8
6:00	70.6	461.6	320.9	220.3	253.7	117.9	143.8	467.1	423.8	216.2	439.9	828.7	20.0	244.2	466.4
7:00	78.1	493.7	328.3	80.7	208.4	82.7	186.6	336.1	197.2	219.3	393.5	776.2	25.3	84.8	574.7
8:00	104.0	347.1	362.5	75.8	180.6	91.7	133.8	163.5	153.7	253.8	528.2	656.6	22.5	103.7	572.4
9:00	112.2	319.4	356.1	139.6	167.1	93.9	129.6	81.2	131.1	219.6	858.1	496.9	20.9	98.5	537.4
10:00	107.4	272.2	455.8	180.7	144.2	86.4	141.1	50.1	75.0	179.6	1038.1	413.0	22.9	71.8	643.3
11:00	96.5	128.0	451.9	147.8	136.3	105.1	149.7	43.5	105.3	145.8	1072.1	542.5	23.0	109.5	884.5
12:00	121.5	122.9	486.5	177.3	151.2	117.1	118.0	64.3	179.2	97.6	770.0	429.6	21.0	270.6	1257.9
13:00	96.6	86.7	578.8	177.2	153.1	79.6	125.7	56.9	184.0	104.5	450.3	398.9	20.3	623.7	1240.9
14:00	160.4	91.8	885.3	165.5	175.4	139.1	104.6	60.2	191.6	107.2	326.2	336.5	20.1	472.4	1194.9
15:00	271.9	118.8	752.6	143.7	221.8	131.1	152.2	71.3	186.3	106.2	355.6	381.1	22.5	1217.8	978.9
16:00	362.4	207.0	479.9	175.8	217.0	215.7	409.8	74.8	124.6	92.7	417.3	368.0	27.2	1062.0	853.9
17:00	253.5	250.1	308.8	468.6	271.4	183.5	481.6	105.6	237.5	107.1	362.4	496.2	20.5	414.1	914.6
18:00	217.3	253.6	212.7	839.2	373.0	198.8	307.0	161.5	337.0	107.0	333.7	720.6	20.3	207.8	1297.5
19:00	138.4	228.8	162.8	1294.1	443.2	184.2	289.0	119.0	382.2	121.8	367.8	989.3	21.5	264.0	1308.6
20:00	95.8	245.8	137.1	1438.8	413.3	127.6	214.1	96.6	312.2	138.8	322.8	1037.6	21.9	291.9	995.7
21:00	107.2	301.4	224.3	1302.9	328.6	143.5	239.7	87.7	305.7	198.7	375.6	927.7	22.2	208.0	898.6
22:00	105.2	383.3	210.9	799.0	364.7	159.6	234.4	69.6	272.1	515.2	406.0	825.4	20.6	163.5	1205.8
23:00	108.4	397.7	254.6	457.1	424.0	122.8	329.9	93.8	201.4	642.5	292.0	666.3	21.2	316.1	1450.5

TABLE B.1: KING CITY (CONTINUED)

Hour	K16	K17	K18	K19	K20	K21
0:00	510.0	141.2	432.2	614.1	148.6	96.9
1:00	586.2	178.0	433.4	533.9	125.2	490.0
2:00	662.9	146.8	488.5	553.9	162.6	694.7
3:00	564.4	111.8	737.8	1065.4	257.4	492.7
4:00	499.4	127.6	1600.6	1811.9	346.2	293.7
5:00	623.9	155.7	1858.3	1627.2	519.8	329.4
6:00	629.4	225.3	934.4	612.9	628.1	345.3
7:00	437.1	228.3	309.5	194.9	406.0	310.3
8:00	465.7	217.9	107.5	133.3	151.2	252.8
9:00	431.6	244.2	79.7	138.0	91.9	252.4
10:00	260.7	244.1	44.4	93.7	83.7	342.6
11:00	244.2	233.9	60.1	106.3	91.3	347.4
12:00	149.8	251.1	189.7	314.8	130.5	490.4
13:00	187.5	316.3	298.9	397.8	229.9	489.8
14:00	185.7	386.1	229.5	160.5	247.6	411.0
15:00	382.9	533.7	153.1	362.6	202.2	725.2
16:00	644.1	417.8	125.2	267.5	156.6	789.3
17:00	174.1	198.2	114.8	245.3	96.2	516.7
18:00	227.6	132.9	151.2	299.7	106.9	249.0
19:00	187.4	97.7	134.6	278.2	129.7	131.7
20:00	298.5	80.3	242.2	290.9	139.5	73.8
21:00	412.7	72.0	419.7	439.4	150.5	54.0
22:00	408.7	98.3	524.1	362.8	160.2	67.0
23:00	409.2	104.5	494.6	365.1	180.7	68.4

TABLE B.2: DIXON

Hour	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15
0:00	146.8	103.2	117.0	240.9	166.5	136.4	164.7	181.6	125.3	110.8	119.3	90.8	444.9	201.7	321.5
1:00	161.0	102.6	130.8	191.7	165.2	142.9	164.7	171.5	138.7	112.0	117.0	89.1	350.3	183.0	265.5
2:00	163.0	112.8	146.2	189.3	137.7	157.6	108.6	209.7	144.6	100.3	127.8	85.5	160.8	183.2	204.5
3:00	152.3	130.1	158.3	182.4	126.0	166.7	101.4	209.6	130.5	95.0	121.0	82.1	69.7	183.9	204.4
4:00	152.9	131.4	151.7	173.3	111.9	178.1	100.4	238.4	136.5	98.1	108.9	100.2	65.7	172.3	190.2
5:00	137.8	145.6	151.4	171.3	104.9	185.7	106.5	219.9	119.0	127.4	110.3	147.2	69.9	164.5	192.9
6:00	142.3	155.8	207.9	123.2	102.2	210.8	97.3	210.7	108.6	148.6	107.5	158.3	81.1	140.6	213.6
7:00	171.6	166.2	206.2	99.4	106.3	193.6	106.7	196.7	92.8	94.4	128.3	181.7	114.8	163.0	233.6
8:00	157.5	187.1	176.8	83.9	113.1	222.4	91.6	195.2	109.3	102.8	158.9	213.5	149.6	146.0	285.0
9:00	150.9	218.4	142.8	85.5	104.1	210.2	105.3	202.2	132.9	114.6	192.6	219.9	221.4	161.5	301.6
10:00	126.6	209.3	134.8	89.5	100.9	187.0	133.9	228.3	134.2	184.3	259.0	229.8	265.6	173.8	431.4
11:00	149.1	170.6	129.1	88.6	101.4	176.7	177.3	244.8	126.4	206.9	274.6	283.9	175.1	176.3	333.3
12:00	151.8	167.5	145.2	83.2	101.6	170.3	155.9	245.4	134.8	137.6	253.3	351.7	113.9	171.8	284.9
13:00	160.1	167.7	117.5	88.3	95.4	203.4	127.2	238.2	156.0	75.9	218.6	376.7	110.7	250.1	289.5
14:00	129.0	133.6	127.8	77.8	118.1	243.7	123.8	228.8	164.5	60.2	143.6	273.3	116.6	229.6	322.8
15:00	131.8	126.3	118.5	116.1	238.6	216.8	98.2	217.5	178.2	48.3	108.3	183.3	135.3	213.7	249.8
16:00	129.3	97.6	131.3	139.8	290.8	146.4	98.6	199.0	153.0	46.1	109.9	126.6	112.5	163.3	185.6
17:00	122.2	99.0	131.6	182.2	288.8	116.9	82.2	166.8	144.4	62.2	97.0	91.8	102.4	148.3	118.8
18:00	126.3	93.5	132.8	240.7	327.0	106.6	83.2	169.0	119.1	122.9	97.1	78.0	140.2	147.1	99.7
19:00	125.2	106.9	132.0	265.9	298.6	113.9	89.1	151.6	106.2	135.2	92.0	80.3	148.3	147.6	115.7
20:00	128.3	107.9	145.9	277.5	241.4	97.3	93.9	178.8	96.8	114.3	99.0	81.0	197.6	150.5	114.8
21:00	133.4	113.1	131.9	325.6	190.9	105.8	98.8	207.1	91.6	95.5	116.0	87.0	304.0	156.1	120.8
22:00	140.1	114.8	121.6	278.1	178.5	94.8	120.1	203.9	97.8	127.5	99.1	107.1	409.4	156.9	193.0
23:00	135.1	107.5	120.9	267.7	181.4	107.3	122.6	189.5	106.8	126.1	134.1	108.6	478.0	173.7	336.3

TABLE B.2: DIXON (CONTINUED)

Hour	D16	D18	D19	D20	D21	D22	D23	D24	D25	D26	D27	D28	D29	D30	D31
0:00	350.6	247.0	133.1	132.7	226.0	268.8	220.1	272.4	138.4	161.4	136.0	415.1	177.6	207.6	193.7
1:00	249.0	315.1	116.5	146.6	239.6	313.5	221.7	312.1	125.8	196.2	135.5	198.2	186.5	192.6	132.0
2:00	177.2	324.9	117.5	137.9	239.1	354.1	200.6	301.1	137.7	189.3	158.6	141.0	186.0	188.7	72.1
3:00	156.5	320.9	166.0	153.3	240.9	437.6	204.5	348.5	184.8	191.3	166.3	107.0	209.0	191.5	54.8
4:00	135.1	316.6	186.6	146.5	282.6	463.6	181.2	421.2	226.0	187.3	199.1	134.9	217.5	195.8	63.7
5:00	143.1	204.8	170.7	158.4	348.9	317.9	179.3	386.4	207.1	216.4	227.5	223.8	231.8	214.2	65.4
6:00	134.3	152.8	133.8	174.2	292.3	453.3	243.3	289.4	198.5	282.7	186.3	217.2	210.2	218.7	95.9
7:00	129.1	146.3	431.7	200.9	263.5	524.0	248.9	342.8	195.3	271.2	182.7	227.0	202.4	206.6	230.4
8:00	132.9	138.4	309.7	226.3	262.3	428.3	269.3	397.8	179.1	207.2	196.0	321.3	238.8	173.0	444.8
9:00	226.2	111.8	148.6	294.5	274.2	404.4	244.8	402.4	234.9	202.6	168.8	273.1	200.1	164.2	493.8
10:00	253.8	133.7	110.6	264.3	321.1	413.6	299.5	372.8	343.6	204.9	162.5	237.5	205.8	141.1	498.1
11:00	188.8	69.0	111.3	359.0	474.2	385.6	525.0	370.5	578.0	305.5	156.8	308.7	194.8	142.1	249.9
12:00	136.0	85.4	112.3	339.9	688.9	451.1	666.9	369.8	804.3	471.1	139.4	434.4	210.3	147.6	205.5
13:00	117.6	118.0	113.0	229.3	709.1	477.7	510.7	501.2	705.2	375.3	143.5	575.9	232.1	148.9	163.0
14:00	90.8	162.0	113.5	128.7	474.3	575.0	394.7	665.0	433.0	193.1	129.9	509.9	225.3	162.2	146.4
15:00	85.9	201.4	112.7	99.2	333.9	336.5	287.3	421.7	273.7	117.3	128.5	372.1	156.6	190.9	145.5
16:00	122.9	252.3	260.0	100.3	200.4	230.0	227.8	211.9	167.6	81.8	120.5	297.3	157.1	208.4	190.0
17:00	120.6	314.1	555.2	105.8	199.7	246.1	179.9	196.1	116.3	80.7	109.9	280.4	160.8	200.4	295.4
18:00	132.9	369.2	352.2	104.3	184.0	198.9	124.5	178.8	103.0	78.2	102.6	294.2	162.5	202.3	370.0
19:00	87.3	426.7	131.1	110.1	168.3	191.7	124.2	168.9	93.2	81.1	102.2	302.1	150.7	183.9	457.5
20:00	114.5	435.0	206.4	100.5	164.2	155.4	128.5	189.8	138.6	101.3	125.0	316.8	160.5	179.8	408.7
21:00	143.9	340.2	368.8	101.0	167.3	164.6	131.9	217.8	180.6	96.6	128.6	417.7	185.1	167.1	442.1
22:00	245.3	261.4	464.2	96.7	203.1	248.0	154.7	223.6	178.5	136.1	135.7	541.2	172.6	181.6	480.8
23:00	303.0	271.0	274.1	101.9	208.7	239.8	188.1	276.4	154.7	169.3	132.2	589.4	167.5	197.7	287.5

TABLE B.3: LAKEPORT

Hour	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	L14	L15
0:00	51.1	87.3	52.7	127.4	63.2	45.3	66.6	55.4	121.0	93.5	48.6	262.9	103.4	517.0	117.5
1:00	54.6	100.6	45.2	130.8	102.7	83.6	62.4	73.6	135.8	92.5	85.2	145.8	84.4	521.4	111.9
2:00	63.1	78.9	54.3	138.0	72.0	54.7	69.2	75.8	142.6	37.5	90.7	156.0	100.2	403.8	113.7
3:00	57.2	45.7	51.0	132.4	64.4	65.9	59.6	109.7	152.9	57.1	45.2	134.5	82.7	427.5	111.3
4:00	57.4	44.4	29.8	114.9	53.5	68.3	62.4	68.1	151.2	70.8	80.0	114.8	104.0	307.0	101.4
5:00	46.2	70.2	41.5	124.9	124.3	83.1	68.0	86.1	113.2	67.4	70.5	108.9	79.2	424.3	97.8
6:00	43.3	38.1	59.1	137.3	129.9	67.8	61.3	39.0	119.5	59.1	59.4	125.3	94.1	299.9	106.6
7:00	38.7	74.1	25.9	131.0	103.7	85.4	62.6	81.2	106.1	70.7	62.5	148.5	94.5	213.2	129.3
8:00	39.2	78.0	27.6	114.6	94.6	52.6	64.1	72.2	113.1	60.5	59.0	155.5	104.8	400.8	142.5
9:00	39.0	57.6	48.7	138.5	88.4	55.3	56.1	64.2	124.5	41.7	69.5	232.5	91.4	383.3	109.7
10:00	39.3	83.7	58.9	190.4	69.4	44.3	62.2	72.1	96.5	46.6	82.0	189.3	74.4	343.6	116.9
11:00	39.2	90.9	44.0	167.7	75.9	44.1	53.6	67.9	87.0	77.8	120.1	123.4	102.0	438.2	114.2
12:00	39.2	70.6	51.1	153.5	74.5	41.8	54.0	70.6	126.1	73.7	104.1	136.0	93.9	358.6	122.1
13:00	39.4	107.9	48.1	164.3	113.2	80.1	59.8	64.8	117.6	60.8	133.7	117.5	78.3	474.7	113.3
14:00	42.4	121.6	47.8	131.0	60.9	65.7	63.0	66.8	102.0	40.7	123.9	114.6	67.2	440.9	114.0
15:00	41.8	76.4	57.0	146.4	103.5	67.9	70.6	90.1	114.5	52.6	209.4	136.8	89.7	484.7	106.3
16:00	41.0	68.9	30.1	149.3	204.7	41.9	75.1	89.4	152.5	53.0	179.7	132.9	107.1	283.2	120.5
17:00	44.0	101.6	38.1	140.0	191.0	58.5	74.5	91.4	169.4	40.9	149.4	129.2	69.9	154.4	109.0
18:00	46.3	94.2	50.7	141.2	157.5	44.1	63.0	113.7	161.4	52.3	171.4	97.5	82.6	201.2	108.4
19:00	62.8	59.3	42.1	152.1	56.4	98.5	65.5	67.9	126.6	67.6	203.9	118.5	87.2	173.3	120.9
20:00	62.3	55.8	50.1	133.3	54.5	116.7	57.1	63.0	140.4	81.3	183.1	122.4	104.9	178.1	126.6
21:00	58.3	95.9	52.7	153.7	50.6	126.3	60.4	62.3	120.2	78.9	137.8	153.1	84.0	231.0	134.0
22:00	52.4	104.1	53.6	142.8	57.8	127.8	61.0	72.8	118.8	112.9	118.4	296.0	84.0	322.4	105.7
23:00	52.7	113.0	55.2	121.7	68.8	47.0	60.1	83.5	123.7	94.4	81.6	410.6	90.6	393.1	122.7

TABLE B.3: LAKEPORT (CONTINUED)

Hour	L19	L20	L21	L22	L23	L24	L25
0:00	141.0	144.9	67.1	82.1	14.7	72.7	67.0
1:00	142.0	206.7	39.7	91.6	14.1	61.9	79.5
2:00	99.6	141.7	56.6	74.9	14.3	45.5	58.1
3:00	79.6	113.5	45.4	73.0	16.0	57.0	59.2
4:00	98.5	89.5	49.2	77.5	19.7	86.2	65.2
5:00	108.3	65.7	60.1	85.0	24.3	118.2	83.5
6:00	91.6	72.6	60.6	77.5	33.9	273.9	63.3
7:00	80.7	88.4	58.0	92.4	58.7	584.1	50.7
8:00	88.5	118.6	66.1	85.0	51.0	541.2	76.8
9:00	87.6	77.2	48.2	82.8	39.3	277.5	71.6
10:00	90.1	77.7	60.1	79.2	25.4	188.9	54.4
11:00	117.8	51.0	34.1	81.2	28.6	141.8	71.6
12:00	106.0	71.7	38.4	89.4	27.6	173.7	75.1
13:00	106.4	73.0	57.7	87.8	45.7	151.2	56.0
14:00	83.8	96.8	66.1	100.9	34.0	140.5	63.1
15:00	109.4	267.2	60.9	78.9	25.2	137.6	76.7
16:00	99.6	353.6	51.9	77.3	21.3	151.6	70.0
17:00	87.8	437.4	39.8	79.4	19.4	109.2	69.0
18:00	98.1	496.4	49.5	74.3	18.3	87.7	76.6
19:00	125.6	362.5	58.1	70.0	15.2	86.9	83.9
20:00	175.0	206.5	55.7	80.1	13.8	117.4	76.3
21:00	176.3	126.4	97.8	72.1	14.4	208.1	50.1
22:00	117.1	102.9	95.8	68.2	14.2	179.9	56.6
23:00	98.9	135.8	64.6	90.4	14.4	110.3	47.2

APPENDIX C: WEEKEND TOU AVERAGES

The following tables include weekend averages (in Wh) on an hourly basis. One apartment at Dixon has been removed due to time jumps in the raw data.

TABLE C.1: KING CITY

Hour	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13	K14	K15
0:00	142.8	350.7	179.8	284.4	385.2	117.4	234.4	123.6	381.6	825.2	197.3	662.6	19.9	428.9	1763.0
1:00	186.6	446.0	222.5	235.6	389.0	107.6	265.4	143.4	305.9	448.8	255.4	429.1	20.1	507.8	1086.2
2:00	149.9	665.6	115.4	453.8	352.2	137.6	200.8	160.4	246.6	205.5	205.0	483.3	19.6	460.9	338.6
3:00	125.6	731.6	172.8	754.4	225.1	236.1	137.0	42.5	282.0	209.8	176.8	801.9	19.7	325.1	142.3
4:00	82.4	596.7	238.1	608.6	416.1	184.2	184.3	68.0	289.5	141.1	180.1	824.8	20.4	628.2	33.3
5:00	83.6	434.0	227.9	371.9	246.8	176.6	145.3	103.4	313.3	224.8	485.1	994.3	51.3	504.2	109.3
6:00	71.9	294.3	345.3	198.8	254.6	221.1	191.7	195.1	351.8	183.0	533.9	834.3	27.6	288.7	425.0
7:00	89.2	231.7	285.8	168.1	240.4	157.8	93.6	193.1	217.8	170.7	327.0	643.9	42.6	132.0	760.3
8:00	79.7	233.8	327.1	121.3	204.2	73.9	190.8	130.1	78.1	197.1	362.0	641.6	21.6	164.7	759.9
9:00	135.6	263.8	376.2	65.9	108.1	114.6	166.8	122.5	100.5	230.3	621.8	470.3	22.2	205.5	659.5
10:00	106.6	182.2	517.5	205.8	144.0	102.9	120.6	69.5	69.1	238.6	971.5	441.9	21.2	108.9	653.5
11:00	100.8	126.5	492.3	123.5	142.6	104.2	106.9	47.9	82.5	173.2	825.2	651.4	20.7	119.0	762.6
12:00	113.5	152.3	456.4	193.2	151.3	78.4	122.7	51.5	117.0	90.9	546.6	425.7	20.6	141.8	1154.2
13:00	100.4	184.3	652.2	173.9	203.3	101.8	115.8	47.9	166.4	59.7	374.7	358.5	20.5	450.3	1192.7
14:00	115.7	90.6	743.5	191.3	127.9	174.7	127.4	91.3	183.2	70.8	376.9	336.6	20.4	484.5	1271.2
15:00	268.6	137.8	689.2	253.7	134.5	153.8	190.2	73.9	155.9	89.4	556.7	331.1	20.3	535.4	999.1
16:00	435.8	137.7	450.6	331.3	201.9	211.5	390.1	102.7	174.2	116.6	347.6	465.8	31.3	1063.7	636.2
17:00	288.6	213.0	182.8	674.8	206.7	318.9	437.5	50.6	122.7	105.1	396.1	692.7	28.1	1626.2	764.0
18:00	180.5	190.6	242.0	1131.7	315.0	355.1	447.1	128.2	277.5	91.8	492.5	620.5	35.9	1196.5	910.4
19:00	187.5	152.9	176.9	1131.8	439.7	190.5	272.9	127.3	410.1	100.4	524.6	953.5	20.9	833.6	879.6
20:00	111.7	151.2	100.6	1031.3	297.9	145.4	299.0	107.5	379.1	156.9	750.8	869.6	20.7	384.1	1173.0
21:00	65.1	348.6	180.1	868.1	391.0	155.7	149.3	127.0	456.1	250.7	647.6	961.3	26.5	310.9	1115.8
22:00	127.8	425.4	267.3	674.3	307.3	85.6	186.3	90.7	416.8	344.3	306.9	753.1	20.6	300.8	1427.9
23:00	144.5	392.4	361.7	413.7	307.3	95.6	187.8	179.5	476.8	587.0	269.8	685.2	20.2	277.3	1538.5

TABLE C.1: KING CITY (CONTINUED)

Hour	K16	K17	K18	K19	K20	K21
0:00	693.0	190.3	841.7	862.0	172.5	66.3
1:00	554.0	281.5	502.5	630.0	188.6	98.7
2:00	759.9	159.0	411.3	718.0	190.7	211.8
3:00	461.3	87.3	288.0	636.7	142.9	450.0
4:00	376.5	66.0	604.2	518.8	213.4	970.9
5:00	392.9	96.4	731.3	838.7	266.9	1034.1
6:00	373.2	125.3	481.9	544.5	220.3	735.5
7:00	540.6	203.1	340.6	313.7	195.0	564.6
8:00	518.3	246.2	267.6	279.5	186.7	476.0
9:00	437.2	249.6	115.7	200.4	129.7	482.2
10:00	214.6	225.9	102.9	111.1	100.3	635.2
11:00	200.7	184.7	79.2	158.2	120.0	527.4
12:00	165.1	311.4	97.5	193.9	97.4	318.1
13:00	147.9	436.4	141.5	243.6	145.0	289.2
14:00	203.6	466.7	142.0	201.1	170.2	273.3
15:00	307.4	649.4	160.0	158.6	183.4	304.7
16:00	233.7	661.5	149.5	133.0	135.4	259.0
17:00	235.0	314.3	176.5	253.6	157.9	250.5
18:00	318.1	137.2	215.3	405.9	246.7	199.7
19:00	449.6	57.2	383.9	726.2	336.6	119.8
20:00	598.6	73.4	730.6	898.8	326.9	78.6
21:00	676.7	72.6	791.0	798.4	310.9	78.7
22:00	618.2	63.2	885.4	922.7	251.5	108.1
23:00	656.6	96.0	1003.3	801.9	191.5	84.2

TABLE C.2: DIXON

Hour	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15
0:00	166.0	104.1	120.6	197.2	157.4	97.0	267.1	182.6	157.1	151.6	125.0	118.0	323.7	168.7	165.3
1:00	210.1	143.2	119.9	212.6	170.8	118.7	215.0	194.9	188.2	114.0	176.6	134.1	290.0	183.6	311.5
2:00	209.6	238.4	147.1	169.9	154.2	177.6	164.0	241.3	218.4	117.1	200.4	149.5	177.1	250.6	280.3
3:00	185.5	265.3	139.0	124.3	134.0	231.3	128.1	259.8	253.5	169.2	237.7	228.1	90.0	149.8	352.3
4:00	185.2	285.5	156.3	136.2	118.4	210.4	97.1	241.8	332.3	144.5	178.4	269.1	72.5	141.9	274.6
5:00	172.3	188.1	172.4	158.9	116.5	211.4	104.1	216.2	207.2	147.0	202.9	404.5	74.8	124.5	242.9
6:00	138.2	139.8	206.2	116.0	103.8	252.3	92.6	188.8	188.8	145.7	236.9	412.6	76.1	137.7	346.3
7:00	162.8	165.5	195.5	105.7	99.0	235.4	84.9	190.5	143.2	177.1	250.6	261.8	78.7	148.1	274.7
8:00	143.7	208.4	224.2	98.6	95.3	204.1	94.7	193.7	148.2	120.2	243.2	207.1	133.0	182.8	256.6
9:00	118.4	237.3	136.2	89.0	93.7	194.4	117.8	193.1	110.0	110.0	301.6	131.1	162.1	150.4	294.2
10:00	114.1	191.8	142.3	77.7	92.8	186.7	148.1	210.3	106.7	114.8	359.1	186.1	177.5	140.3	280.0
11:00	114.9	178.7	136.2	83.2	95.0	160.1	137.5	238.9	125.2	88.0	426.3	175.8	195.3	163.2	307.4
12:00	121.8	163.9	133.9	83.3	102.1	148.3	167.5	213.8	138.2	94.2	332.1	306.1	174.8	145.9	290.2
13:00	139.6	161.3	114.1	114.1	101.0	147.5	111.3	179.3	141.4	81.8	257.6	412.4	173.3	250.6	235.2
14:00	157.6	122.4	113.5	82.2	127.5	160.7	124.0	167.3	147.3	59.2	147.9	334.5	157.7	222.6	211.4
15:00	138.2	127.0	99.6	101.2	201.6	147.4	114.9	151.5	134.4	61.0	93.3	165.2	160.9	163.1	173.7
16:00	135.3	130.9	109.9	135.0	267.4	141.3	88.1	177.9	116.9	62.6	89.4	153.5	129.9	140.4	233.7
17:00	135.0	108.1	142.7	167.3	274.2	112.0	73.8	172.4	129.2	71.3	112.9	81.0	160.0	138.2	132.7
18:00	117.4	116.0	138.9	264.3	293.5	121.1	86.9	147.4	131.5	160.4	111.3	105.2	197.4	139.9	114.2
19:00	128.1	107.6	154.3	266.9	258.4	93.1	97.6	184.3	124.6	144.7	102.9	66.7	120.8	143.8	130.7
20:00	113.4	111.2	150.5	206.4	248.5	113.9	86.9	185.9	101.8	92.1	125.0	96.6	221.4	142.6	145.1
21:00	121.1	111.3	123.2	218.9	190.2	111.2	98.9	158.7	112.9	67.8	91.2	84.7	294.0	150.7	108.4
22:00	110.7	103.6	120.4	185.2	180.8	107.3	111.0	153.4	98.2	100.6	98.9	87.2	395.4	160.8	98.8
23:00	113.2	104.1	115.7	156.9	160.9	87.7	172.1	176.1	110.8	132.5	133.1	103.8	365.6	159.0	98.6

Table C.2: Dixon (Continued)

Hour	D16	D18	D19	D20	D21	D22	D23	D24	D25	D26	D27	D28	D29	D30	D31
0:00	255.6	325.8	119.9	144.6	245.9	340.8	210.7	266.0	148.2	138.9	130.2	413.6	172.9	172.9	209.3
1:00	212.5	332.8	118.5	137.8	251.4	305.4	230.3	282.7	184.4	99.4	138.2	338.0	199.6	159.8	131.2
2:00	271.3	266.9	118.2	190.0	251.9	343.0	222.7	475.6	251.3	188.6	177.0	350.4	214.3	189.6	85.6
3:00	287.6	249.0	116.3	154.3	291.2	490.9	284.9	644.6	381.7	244.2	200.1	240.2	217.6	167.4	72.0
4:00	189.3	231.2	127.7	170.9	292.8	605.0	383.8	656.1	498.7	251.8	183.7	190.5	218.2	174.5	58.6
5:00	169.3	243.5	176.0	168.5	307.9	664.3	421.6	612.0	477.9	369.7	177.6	205.5	179.2	173.8	61.5
6:00	111.7	144.4	235.7	181.9	387.7	341.1	330.6	603.3	421.6	374.0	162.8	216.6	206.1	184.4	71.0
7:00	151.6	167.9	769.0	173.5	291.2	381.9	205.6	483.6	292.2	406.5	170.4	273.7	234.2	206.5	76.5
8:00	128.4	115.5	396.0	207.6	275.1	373.5	263.0	383.7	243.3	458.1	166.9	204.8	238.8	219.5	185.7
9:00	174.7	136.8	110.2	330.5	283.6	529.7	249.6	351.0	214.1	256.9	141.5	246.4	240.9	169.6	268.4
10:00	241.2	149.3	111.5	323.8	350.3	391.0	284.5	284.9	218.2	239.1	138.7	310.3	218.2	141.8	391.0
11:00	172.7	115.6	111.5	390.8	532.0	433.6	447.8	353.7	286.1	212.1	141.7	253.8	221.8	132.5	419.1
12:00	100.0	128.0	113.0	327.2	558.5	444.9	382.2	353.8	461.6	226.5	174.1	236.3	239.8	138.2	406.2
13:00	135.9	81.4	112.5	236.0	689.6	373.5	374.8	456.3	470.7	256.6	153.0	334.1	270.4	140.7	377.8
14:00	94.0	138.0	113.1	129.8	549.7	462.1	416.6	420.7	454.5	101.5	147.3	460.9	204.7	139.3	234.8
15:00	90.2	177.9	111.1	115.9	281.6	347.2	301.3	308.4	369.5	83.5	127.5	444.0	173.4	152.7	247.1
16:00	94.5	400.1	346.4	103.0	195.6	302.5	250.0	259.5	228.4	86.1	128.5	409.5	181.7	163.7	363.7
17:00	86.6	593.4	919.2	101.1	183.7	200.0	165.3	180.0	148.5	79.3	103.8	381.7	138.9	180.0	361.6
18:00	103.9	762.7	533.2	102.3	164.9	171.1	147.9	161.1	88.8	81.1	90.6	315.7	141.9	210.7	350.1
19:00	113.1	648.6	124.0	100.0	166.1	214.4	136.3	172.8	92.7	99.6	89.9	293.2	140.5	239.0	352.9
20:00	123.5	719.6	105.9	107.5	179.7	145.2	121.1	181.4	90.3	93.8	132.5	262.8	137.3	239.8	303.5
21:00	188.5	542.4	182.0	99.2	182.8	141.6	140.2	205.0	125.0	96.3	166.8	282.0	146.7	265.0	258.0
22:00	233.2	433.6	150.9	105.9	191.8	199.9	135.8	210.2	149.6	122.8	172.9	333.9	149.0	228.9	333.3
23:00	352.2	356.9	118.8	140.8	226.8	244.8	168.8	236.2	179.9	133.4	134.5	473.9	187.6	176.0	296.2

TABLE C.3: LAKEPORT

Hour	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	L14	L15
0:00	51.0	128.1	62.4	131.3	97.9	50.0	73.5	116.0	133.2	34.7	126.0	162.2	73.3	362.6	111.6
1:00	49.5	76.7	33.2	147.3	77.0	65.4	74.3	66.4	132.5	26.9	95.7	127.4	93.3	278.1	104.3
2:00	49.4	92.3	39.4	171.6	99.1	62.8	56.8	98.4	114.3	57.5	55.3	118.0	83.2	366.6	109.7
3:00	40.3	52.4	62.5	120.5	126.4	33.7	57.9	79.0	187.2	45.8	36.4	108.2	91.6	241.7	99.2
4:00	46.3	37.7	56.3	103.5	55.5	41.4	55.7	28.3	101.1	43.3	62.8	153.1	105.3	440.3	105.9
5:00	39.0	62.4	18.7	150.0	136.7	30.1	64.5	75.9	95.0	64.4	72.1	105.0	91.5	496.7	108.1
6:00	38.9	32.5	30.7	127.8	74.0	51.8	55.5	89.2	85.8	45.2	78.4	139.9	117.0	429.9	123.6
7:00	38.6	83.1	76.2	107.6	54.9	76.8	75.7	76.4	108.5	61.1	54.0	113.9	80.6	204.3	127.6
8:00	39.3	148.7	56.3	120.0	61.1	56.5	66.7	64.6	137.9	74.9	54.0	209.3	75.3	157.1	150.6
9:00	39.3	89.0	58.7	171.1	69.7	80.6	70.3	73.3	125.9	75.1	82.7	180.4	73.1	322.1	100.4
10:00	39.3	62.3	118.9	162.7	68.6	74.8	53.7	46.6	153.4	73.7	146.3	116.0	94.4	312.6	108.8
11:00	39.2	51.1	59.1	189.4	109.1	66.4	48.2	101.5	99.3	55.8	58.4	167.6	96.2	401.9	153.7
12:00	39.3	64.6	71.3	139.7	55.4	29.5	63.6	52.9	166.2	55.2	89.6	119.5	89.1	275.0	119.6
13:00	39.2	73.6	49.1	180.3	117.6	46.8	57.1	71.8	105.5	32.1	87.8	127.0	71.2	400.3	104.8
14:00	39.7	102.9	32.6	125.3	63.7	83.2	51.9	37.9	106.6	30.3	144.4	92.8	91.0	351.9	97.9
15:00	43.5	112.2	47.6	125.3	61.5	32.9	80.9	109.5	103.2	64.6	153.1	112.1	59.7	343.1	106.8
16:00	41.9	76.1	49.4	127.3	170.0	25.3	47.8	65.4	119.5	53.5	156.0	124.3	81.6	413.8	119.7
17:00	42.2	49.6	23.2	170.2	249.0	109.8	65.7	68.8	107.1	61.8	87.5	86.7	97.9	239.1	107.8
18:00	44.9	73.2	46.9	135.8	179.6	66.2	52.4	50.0	145.7	60.2	245.3	119.8	73.9	131.5	119.6
19:00	41.1	58.1	53.3	131.6	99.9	42.6	84.0	117.3	135.7	64.1	196.2	114.8	89.0	125.0	97.5
20:00	52.9	38.6	41.0	127.5	41.1	95.4	50.8	74.6	131.7	75.8	105.5	153.1	105.2	201.8	131.4
21:00	59.3	51.0	36.2	134.6	40.3	59.1	58.5	67.6	150.9	98.4	56.8	180.9	90.9	103.0	146.6
22:00	71.8	108.5	70.4	136.2	24.8	46.2	52.9	62.5	95.8	55.0	121.6	214.1	90.0	197.2	109.8
23:00	43.8	102.9	42.2	132.5	62.0	122.9	64.0	85.5	142.2	68.3	100.7	342.2	77.6	296.2	122.7

TABLE C.3: LAKEPORT (CONTINUED)

Hour	L16	L17	L18	L19	L20	L21	L22	L23	L24	L25
0:00	207.5	81.0	67.9	136.5	164.8	31.1	85.0	14.9	182.3	69.8
1:00	140.4	97.2	73.9	138.2	186.5	48.8	90.5	14.6	49.6	72.1
2:00	164.6	113.5	58.1	64.2	137.9	102.5	88.6	16.6	110.6	58.9
3:00	42.7	72.2	48.1	119.7	129.8	52.1	85.6	16.2	49.1	81.0
4:00	69.2	114.0	57.2	73.5	66.7	36.7	86.2	17.8	97.1	78.8
5:00	125.2	60.9	64.2	117.0	92.5	40.4	72.5	34.7	110.1	73.3
6:00	263.5	43.8	45.0	63.3	72.3	53.3	117.5	61.1	271.8	71.9
7:00	174.3	110.9	88.9	57.2	59.9	70.1	77.7	36.9	452.6	43.2
8:00	63.0	79.4	73.8	118.0	146.3	45.8	69.4	35.3	609.6	76.1
9:00	63.7	141.8	79.2	77.2	132.9	41.2	76.7	43.0	359.0	54.4
10:00	74.3	56.6	48.4	141.2	117.2	33.5	84.0	23.3	306.1	91.8
11:00	70.8	102.0	41.1	83.4	137.3	55.2	87.2	24.5	388.4	72.9
12:00	96.3	86.5	42.4	121.5	127.5	49.0	90.9	22.6	218.7	49.2
13:00	155.2	94.0	81.5	102.1	77.0	61.1	73.3	26.4	160.2	66.5
14:00	76.6	81.1	55.5	130.5	112.5	34.2	87.4	32.6	143.2	40.9
15:00	70.1	57.9	76.8	115.6	180.3	37.2	96.5	26.7	106.7	51.6
16:00	33.4	29.3	80.6	103.6	200.5	102.3	85.1	19.7	103.8	77.8
17:00	57.5	77.2	81.9	56.3	237.9	33.2	66.0	20.0	121.2	71.9
18:00	109.6	51.4	33.8	95.7	484.1	47.6	68.4	18.7	132.8	72.7
19:00	188.1	64.4	31.2	116.2	503.7	36.6	73.2	16.3	202.5	82.1
20:00	302.9	61.9	50.2	176.2	140.0	46.2	76.7	13.7	205.0	102.2
21:00	351.6	49.6	52.3	182.4	80.3	35.1	86.5	14.2	193.6	52.1
22:00	175.4	62.1	46.9	190.5	127.4	30.7	76.0	14.5	112.2	52.4
23:00	235.5	63.3	38.7	112.0	157.7	60.9	66.4	14.7	82.7	38.0