Impact Evaluation of 2011-2012 Prescriptive VSDs

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Massachusetts Energy Efficiency Advisory Council
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1. Acknowledgement

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2. Executive Summary

2.1 Introduction

This report presents the results of the Impact Evaluation of Prescriptive Variable Speed Drives (VSD) conducted by DNV KEMA and DMI between 2011 and 2012. The objective of this impact evaluation is to begin to quantify how well prescriptive VSD installations are performing and to estimate the energy and demand savings resulting from a sample of (26) VSDs installed in Massachusetts between 2011 and 2012 using both pre- and post-installation metering. Data collected as part of this evaluation is intended to be used to help inform the savings factors used in future updated TRMs.

2.2 Background

The Massachusetts PAs offer a wide range of prescriptive rebates on energy efficient measures including VSDs. Prescriptive VSDs typically account for 1% to 15% of each PAs' Large Commercial and Industrial (C&I) portfolio of measures. This is based on tracking data files from NSTAR, NGRID and WMECo from installations occurring between 2005 and 2009. In the past, impact evaluations have not specifically covered prescriptive VSDs due to the relatively small amount of energy savings compared to the PAs entire portfolios. In 2010, a new Technical Reference Manual (TRM) was developed, which included common gross savings algorithms for prescriptive VSDs, to support the PAs move to common measure offerings statewide. Included in the new TRM are savings factors for the following nine prescriptive VSD measure types:

- Building Exhaust Fan (BEF)
- Cooling Tower Fan (CT)
- Chilled Water Pump (CWP)
- Boiler Feed Water pump (FWP)
- Hot Water Circulating Pump (HWCP)
- Make-up Air Fan (MAF)

- Return Fan (RF)
- Supply Fan (SF)
- WS Heat Pump Circulating Loop (WSHP)

2.3 Sampling Strategy

The evaluation of Prescriptive VSDs required that sample projects would be selected as applications are received in order to collect interval data before the measures are installed. Since this program has not been evaluated previously on its own, and the population of projects cannot be determined in advance, a conventional stratified sample design was not pursued. An alternative approach, based on historical patterns of installations, was necessary.

DNV KEMA first looked at past VSD installations across the PAs' programs to determine their historical population characteristics. Adjustments were made to remove all VSDs that were not measure types included in the TRM. Also, due to the small number of VSDs installed by CLC, UNITIL and WMECO, a decision was made to only sample NGRID and NSTAR projects.

Given the fact that the distribution of future project applications was not known, and the lack of information on the variability of the estimated savings, it was very difficult to anticipate the precision and accuracy of the results of this evaluation. The goal of the evaluation was to estimate a statewide savings realization rate with ±20% relative precision at an 80% confidence level. A challenge for this design was that it was important to represent a range of projects across PA, measure types, and complexity (in terms of numbers of drives). Since a project site can include one or more measure types, and a measure type can include one or more VSD installation, the number of site visits and meters required to achieve these goals could vary depending on the types of project applications received during the selection process. Based on the historical data, and an assumed estimated error ratio of 1.0, a target sample size of 44 drives was selected.

A traditional sample design would have stratified the population and would have allocated the 44 sample points to PAs and measure categories in a manner that would result in the best precision overall. However, in this case, the characteristics of the population of measure categories were only a very rough indicator of what may be installed in the coming year(s). In addition, the requirement that the sample be selected in real time, based on applications received by the PAs, makes it necessary to build more flexibility into the design. The application of the standard statistical formulas to determine the number of sample points in each stratum and determine the case weight for each point entails more structure than this project could realistically support. Therefore, a simple proportional allocation by measure category and PA was recommended. This recommended sample allocation is presented in Table 1.

While this sample allocation was recommended, it was also recognized that it may not be achievable given the schedule of upcoming VSD installations and the conditions encountered at each site. Ideally, each drive in each application would be considered against the numbers completed in the cell it

represents. If the required number has not been reached, the drive would be metered; if the number has been reached, it would be rejected as a sample point. Table 1also shows the final sample allocation of actual metered drives. There were several reasons for why the targeted number of sample points was not achieved. The primary reason was that in most cases, the VSDs had already been installed by the time the evaluation team was notified of it being a pre-approved installation. At this point, it was usually too late to obtain any pre-installation metering.

Table 1: Recommended and Final Sample Allocations

	Total		NGRID		NSTAR	
Measure Category	**Recommended Sample**	**Qty Monitored**	**Recommended Sample**	**Qty Monitored**	**Recommended Sample**	**Qty Monitored**
FWP	1	0	1	0	0	0
BEF	3	1	2	0	1	1
CWP	4	5	1	2	3	3
CTF	4	1	2	0	2	1
HWP	4	4	2	1	2	3
MAF	2	1	1	1	1	0
RFA	5	1	2	1	3	0
SFA	19	12	11	9	8	3
WHP	2	1	1	1	1	0
Total	**44**	**26**	**23**	**15**	**21**	**11**

2.4 Results

2.4.1 Major Findings and Observable Trends

Figure 1 presents a scatter plot of evaluation results for annual kWh savings using all 26 sample points. The dashed line represents a realization rate of one. The slope of the solid line in this graph is an indication of the overall realization rate, and can be seen to be close to one. These sample data are scattered pretty widely around the trend line, which supports the estimate made during the design process that the error ratio would be relatively high.

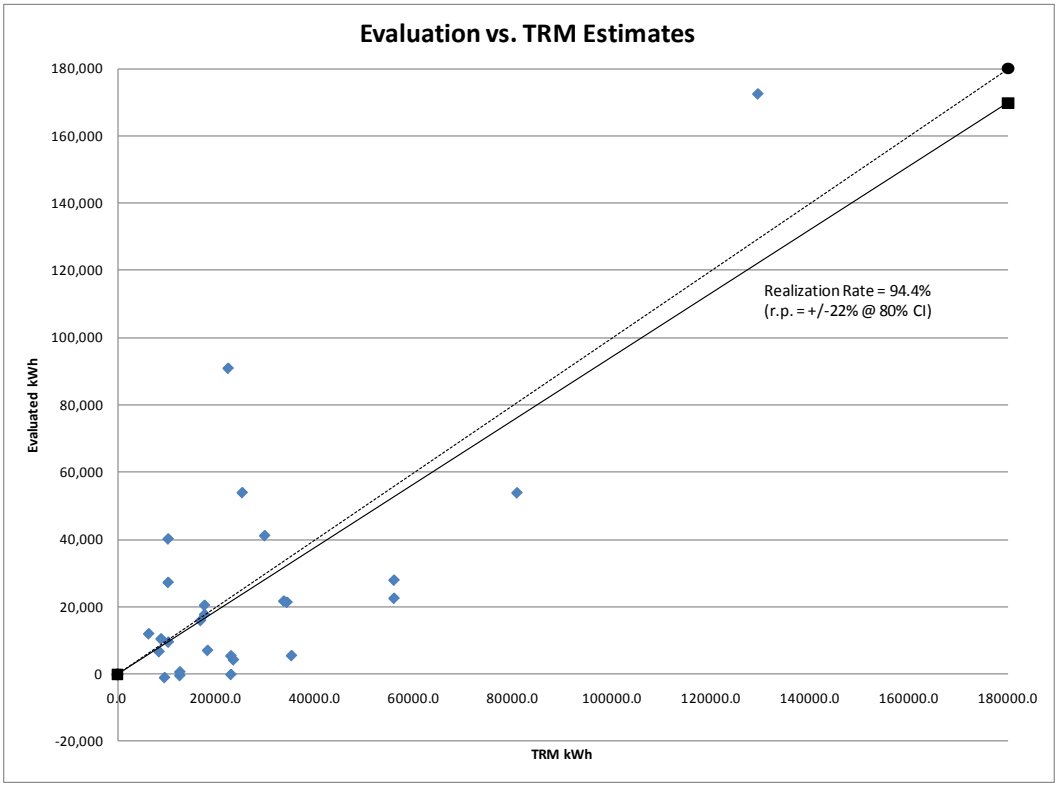


Figure 1: Scatter Plot of Evaluation Results for Annual Energy (kWh) Savings

Baseline Findings

The Massachusetts TRM for the baseline efficiency case assumes that all motor types being evaluated are either constant speed or two-speed motors with control being provided using valves or dampers. Using these methods of control on a constant speed motor can have a significant impact on input kW. For example, a forward-curved fan throttled with inlet guide vanes may operate at approximately 50% of full load power when throttled to just 75% of maximum airflow. Prior to collecting metering data it was expected that this would result in baseline profiles with significant variation; however, the collected baseline data did not support this. As shown in the site-by-site metering summary pages included in the Appendix, the majority of the pre-retrofit motors were observed to operate at a relatively constant input kW (<20% variation). The most significant exception was a cooling tower fan equipped with a two-speed motor.

For many of these installations, the post-retrofit VSD was observed to operate at fixed speed without automatic controls. The consistent operation could result in the baseline demand profile having the constant shape.

2.4.2 Presentation of Results

The motor-level evaluation results were averaged to develop overall statewide realization rates. The statewide realization rate is the ratio of the total sample measured savings to the total sample TRM savings. Table 2 summarizes the statewide results of this study.

Table 2: Summary of the Prescriptive VSD Results

MA Prescriptive VSD	Annual kWh	Summer kW	Winter kW
Realization Rate	94%	224%	38%
Confidence Interval	80%	80%	80%
Relative Precision (+/-)	23%	37%	55%

A summary of the key findings include the following:

- While the overall realization ratio is close to 100%, there is a significant variation at the motor level, and many motors are either close to 0% or much higher than 100%.
- Failure to install controls or configure manual VSD speeds is the most common reason for a poor realization ratio.
- Automatic controls are required by the prescriptive VSD applications but are infrequently installed.
- VSD installations were observed to replace existing and failed VSDs and received incentives.
- A small number of motor types are miscategorized. For example, a swimming pool circulation pump was categorized as a hot water circulating pump.
- Manually set fixed VSD speeds are common. This results in constant post-retrofit power demand and very high summer demand reduction realization ratios.
- In some cases comparable energy savings could have been achieved through proper balancing and without a VSD installation. This approach would be less costly and achieve faster payback periods.
- The TRM assumes that hot water pumps will operate during summer months and chilled water pumps operate during winter months. In most cases, these seasonal motor types were shut down and did not operate during the off seasons.
- Summer kW reductions were significantly higher than predicted by the TRM due to the post-retrofit motor operating with manual controls at constant input kW.

2.4.3 VSD Burden Analysis

Variable speed drives consume energy and each installation has an associated “drive burden” penalty. A common practice in energy modeling is to assume that the VSD burden is equal to 3% of the full load motor kW. There were several motors that were metered in this study where kW data was collected when the motor was running at 60 Hz both with and without a VSD. These periods were isolated and analyzed

in an attempt to quantify the drive burden for the particular motor. Table 3 below shows a summary of these cases.

Table 3: Motor Level VSD Burden

Site ID	TRM Motor Type	HP	Demand (kW) w/o VFD	Demand (kW) w/ VFD	VSD Burden
4	HWP	15	9.4	8.9	-5.9%
5	HWP	10	4.2	4.8	15.4%
7	SF	15	4.1	4.3	2.7%
7	SF	15	5.0	5.3	5.6%
9	WSHP	40	35.2	34.8	-1.2%
10	SF	25	14.1	14.2	0.3%
12	CWP	7.5	6.4	6.4	0.3%
12	CWP	25	16.6	17.5	5.4%
13	CWP	75	48.1	51.0	6.1%
				Average	**3.2%**

There is a fair amount of variation from motor to motor, although the average of the sample is very nearly the expected 3%. In the extreme cases the motor input kW varied from -5% to +15%. While these particular cases were based on long term metering that would be expected to improve the accuracy, there may be other factors impacting the input kW. For instance, these particular motors are hot water pumps and the hot water temperature may be on a reset schedule, which would affect water density and pumping power. Similarly, air temperature may affect this analysis for supply fans.

It is not recommended that the results of the VSD burden analysis are applied for any purpose. There is too much dependency on the selected periods. Even slight variations in power demand within the selected periods have a dramatic impact on the analysis. Input kW often varies by +/- 2% from day to day in both the pre- and post-retrofit case, and this can be the difference between a -1% VSD burden and a 3% VSD burden.

For the data presented above, the analysts practiced a consistent unbiased approach, but it is expected that if this exercise were repeated by other analysts that the results could vary significantly.

2.4.4 Conclusions and Recommendations

Evaluation Protocol

- In many instances it was found that VSD installations had been completed when initial contact was made. Unless a VSD bypass option was installed and the customer was willing to operate with it and recreate the pre-retrofit conditions, the project could not be evaluated. It was unclear in these cases if the installation had been completed prior to the incentive.

- Seasonal operation of equipment is a significant delay to the evaluation. Many of the VSD categories involve seasonal equipment such as cooling tower fans or hot water pumps that are shut down for several months per year. Data collected during shoulder seasons is often insufficient for analysis and cannot be performed during off seasons.

- There were several instances in which the VSD retrofits had been categorized incorrectly, which came up either during the initial phone call contact or at the metering setup site visit. These cases were not included in the evaluation sample since the metering data would not be representative of the desired motor type.

VSD Operational Characteristics

- Many VSDs are installed but never utilized. The motors were observed to operate at 60 Hz after the installation. Post-inspections should be performed to ensure that automatic controls are installed as required by the prescriptive applications.

- VSD installation dates were found to vary significantly from installation of control sequences. In the majority of installations, the VSD was installed several weeks or months before any type of control sequence was implemented. During this period VSDs would typically operate at 60 Hz. The standard protocol for this evaluation was to await confirmation of the controls installation rather than encourage the installation by calling for updates. In some cases DMI installed kW meters for the pre-retrofit condition, but VSDs were never installed. It is recommended that a six-month follow-up is performed before the full incentive is paid so that proper operation can be confirmed.

- Once the control sequences were implemented, it was common for VSDs to operate at fixed speeds rather than modulate to maintain set points. This type of operation results in a constant motor input kW and causes the summer demand peak realization ratio to be very high. It is unknown if these sites experience operational issues during extreme conditions as a result.

- Multiple instances were observed in which the VSD retrofit was replacing an existing drive. In all of these cases, the facility operator reported that the existing drives were failing and had operational issues. It appeared that these failing VSDs were approximately 15 years old or more. The prescriptive VSD application states that incentives are not available to VSDs replacing existing drives. Evaluated savings for two of these installations were found to be small or even zero based on metering data.

- In at least one case (Site ID 9, see below for more details), energy savings resulted primarily due to proper balancing rather than VSD control of the motor. Prior to the VSD retrofit, a chilled water pump was providing an excess of water to end users and the motor was observed to operate at over 100% load. The VSD installation was used to essentially balance the chilled water flow.

This resulted in significant energy savings, the majority of which could have been achieved simply through balancing and without installation of a VSD. It is recommended that a pre-inspection be done to identify cases in which a VSD might not be the most economical solution.

A quantitative breakdown of critical VSD application requirements that were observed in the evaluation is shown below in Table 4:

Table 4: Installations Satisfying Critical Application Requirements

Automatic Controls	2000+ Annual Hours	Replaced Existing VSD	Used for Balancing	Demonstrate Load Diversity	Miscategorized
9	26	3	1	5	1

TRM Adjustments

Energy Impacts

- Even though the energy realization rate of 94% was good for a program like this, the individual metered VSD energy realization rates varied from -2% to 407%. The -2% case was the only one that was negative, but 15 drives, or 58% of all metered drives had a realization rate less than 100%. The remaining 10 drives or 38% of all metered drives had a realization rate greater than 100%, and in most cases, they were significantly greater. It is recommended that this realization rate be applied to the TRM energy savings estimates as an immediate step.

- The MA PAs and EEAC should also look to improve upon the motor level savings assumptions following the completion of the current Northeast Energy Efficiency Partnerships (NEEP) VSD Load Shape study. [1] This study includes post-installation metering on hundreds of drives, which would help to refine the TRM savings assumptions for certain motor, and possibly building types.

Demand Impacts

- The TRM claims summer kW reductions for hot water pumps and winter kW reductions for chilled water pumps. In most cases, hot water pumps were observed to be shut down for the summer months and chilled water pumps shut down for winter months. It is not expected that this would apply to all of these motor types, but based on the sample observed in this evaluation, it appears that the TRM should be adjusted downwards. Currently, it appears that the TRM assumes 100% of these motors will operate during their off-seasons. It is recommended that the TRM be reviewed, and appropriate adjustments be made to ensure that demand savings are

[1] An ongoing NEEP VSD Load Shape study is currently being conducted, which may provide more data to support the TRM energy and demand savings estimates. This study includes post-only metering on up to 400 drives across 12 program administrators.

realistic for certain measure types. Consider near-zero summer kW reduction for hot water pumps and near-zero winter kW reduction for chilled water pumps.

- Summer On-Peak kW reductions in the TRM are generally very close to zero for motor types not related to heating. This seems to be a reasonable assumption for motors with automatic controls as it would be expected that an appropriately-sized motor would operate near full load on a design day; however, the evaluation observed significantly more motors with manual controls than expected, with the motors operating below full-load input kW. Since the TRM predicts near-zero summer kW reductions, this results in very high realization ratios.

- It is not recommended that the realization rates for demand savings from this study are applied to the TRM due to the poor precisions. However, we think that the observations noted above, plus the results of the aforementioned NEEP study, can be used together to improve upon the savings estimates in the TRM.

2.5 Evaluation Methodology

This section provides a brief description of the site recruitment and data collection methodologies. Overviews of the analysis methods are also provided.

2.5.1 Standard Protocol

Massachusetts PAs notify KEMA and DMI as potential VSD retrofit projects come in. With permission, DMI contacts the person at the site in charge of the potential project. Through this discussion the project status is determined, including the likelihood of a VSD installation and the expected installation date.

For projects with an expected VSD installation date of more than one week away, DMI travels to the site to observe the equipment, speak with facility personnel about operation, and set up kW monitoring equipment. Projects that are less than a week from installation are not used in the sample, since they would not result in sufficient pre-installation data. Licensed electricians are either provided by the site or a third party electrical contractor to assist with the physical metering installation. Three phase kW meters allowing for power factor correction are used in all instances.

In some cases the VSD installation has already been completed at the site, but a VSD bypass was included and the site is willing to operate in bypass mode to simulate the pre-retrofit conditions for the sake of the evaluation. There are four such cases included in the evaluation sample.

Ideally, one month of both pre-retrofit and post-retrofit data is collected. The site contact is asked to inform DMI when the installation is completed so the metering equipment can be uninstalled in a timely matter. DMI did not contact the sites for six months after the installation date in the interest of avoiding project influence. It is expected that repeated phone calls from the evaluator regarding the installation

status would impact the installation status, which is not the intent of the evaluation. For example, repeated inquiries from the evaluator about the status of controls programming may result in a job being completed that would otherwise be left unfinished. If the site contact does not inform DMI of the installation, the metering equipment is uninstalled after the six month period and the data collected is considered representative of the post-retrofit case.

2.5.2 Metering Equipment

Onset Wattnode kWh transducers (208/240V and 480V) were used to collect kWh data based on voltage and amperage readings. The Wattnode is rated for +/-0.45% accuracy but could vary to 1.5% to 4% dependent on the current transducer used and line variation. The evaluation used a variety of current transducer sizes that were selected to reasonably match the rated full load amperage of the motor being monitored.

Hobo Micro Station Data Loggers and pulse counters were used to record the kWh readings provided by the Wattnode kWh transducers. Logging intervals were selected to be as frequent as possible while allowing for adequate acquisition periods and were generally no longer than 5-minutes.

2.5.3 Analysis Methodology

Inputs

A screenshot of a sample input screen is shown below in Figure 2:

Select Trend Style --->>	Daily	Select Building Type --->>	University/College
		Select type for Mech 1 --->>	Chilled Water Pump
		Enter Motor HP --->>	30

Figure 2: Screenshot of Sample Input Screen

Metered data is first entered into the spreadsheet analysis template. All of the metered data that may be analyzed is entered in a continuous column. Data representative of non-typical operation would not be included. The raw data is then graphed with respect to time to give an overview of the metering effort. This graph is also used in conjunction with known installation and operation information to specify the dates used for pre and post installation analysis. Weather data, concurrent with the monitoring period, and specific to the site location, is also added to the spreadsheet for use in the analysis. The weather data includes hourly temperature observations from National Oceanic and Atmospheric Administration (NOAA) weather stations.

In addition to the metered and weather data, the analysis also relies on a specified occupancy schedule, list of holidays, and peak demand periods to make calculations. A known occupancy schedule can be entered to perform a more detailed analysis, though most of the time it is not used. The holiday list

includes the federal holidays for the years spanned by the metered data, but can be changed to be site specific. The summer and winter on-peak and seasonal demand periods are defined in the spreadsheet.

Finally, the user selects the building type, motor type controlled by the VSD, and enters the motor horsepower. The building type is selected from a list of possibilities stipulated in the Massachusetts Technical Reference Manual (TRM)[2]. The motor type is also selected from a list that comes from the TRM. These selections are used to look up an Annual Energy Savings Factor (kWh/HP), Summer Demand Savings Factor (kW/HP), and Winter Demand Savings Factor (kW/HP) that is expected for the VSD application as a basis for calculating the evaluation realization ratio.

Analysis Model

The analysis uses an 8,760 model that represents each hour in a typical year. The model is based on the year 2011, which is when much of the metering occurred. For each hour of the year, a weekday value from 1 to 7 is assigned (where Monday is 1). The bin is then assigned flags to indicate if the hour is during occupied hours, holidays, or on-peak and seasonal peaks. Each bin is also assigned an outside air temperature based on TMY3 typical weather data.

For each bin in the 8,760 model, a pre-VSD install and post-VSD install power demand is calculated. These values are calculated based on the metered data, which expanded to the 8,760 model using a trend type chosen by the user, which are discussed in more detail below. From the calculated power demands, a power savings is also calculated for each bin.

Some motor types have seasonal schedules and the motors do not operate during specific seasons. For example, hot water pumps may not operate during summer months when there is no call for space heating, and cooling water pumps may not operate during winter months when there is no call for space cooling. In these cases, the facility operator was interviewed to determine when the motors are shut down. The typical response was that the motors would be shut down based on ambient conditions, with November and April being the approximate cutoff points. For modeling purposes, it is assumed that chilled water pumps operate from April 1 to November 30, and hot water pumps operate from November 1 to April 30.

Savings numbers are summed to generate annual energy savings. Power savings are averaged for bins flagged as occurring during summer or winter on-peak and seasonal peak periods to calculate the summer and winter demand savings. Both the energy and power savings are divided by the motor horsepower to generate values that can be compared to the TRM Annual Energy Savings Factor, Summer Demand Savings Factor, and Winter Demand Savings Factor.

[2] Massachusetts Technical Reference Manual for Estimating Savings from Energy Efficiency Measures, 2011 Program Year – Plan Version, October 2010, pages 222 – 225.

The calculated savings factors are divided by the expected TRM values to generate a Realization Rate (RR). A calculated realization ratio of greater than one indicates that more savings were achieved, according to the evaluation, than originally predicted. Likewise, an RR value less than one indicates that fewer savings were achieved than were originally predicted.

Trend Options

Pre and post VSD install power demand values are calculated based on a user selected trend. There are five options available for use in the analysis. A separate trend is created for both the pre and post VSD installation periods:

- Daily — Creates an hourly average of metered data for each day of the week
- Weekday/Weekend — Creates an hourly average of metered data for weekdays and weekends
- Temperature — Creates a regression of metered data based on power dependence to outdoor temperature
- Temperature and Occupancy—Creates a regression of metered data based on power dependence to outdoor temperature and building occupancy
- Temperature, Occupancy, and Day—Creates a regression of metered data based on power dependence to outdoor temperature, building occupancy, and day of the week

The spreadsheet analysis creates a trend for each one of these options for both the pre and post VSD installations. When a different trend option is selected, the spreadsheet repopulates the 8,760 bin model with values for each case and recalculates the savings numbers. The most accurate representation of the system is selected as the model to use in the analysis.

A. Site and VSD Summaries

This appendix provides a brief project description and discussion of the results of each of the VSDs monitored in this evaluation. Table 5 presents the motor level results obtained from this impact evaluation. The following site summaries are provided to highlight the savings results shown in this table. Appendix B includes overviews of the metering, analyses and trends used for each installation; please refer to Appendix B for details.

Table 5: Motor Level Results

Site ID	PA*	HP	TRM Motor Type	Building Type	TRM kWh	TRM kW_S	TRM kW_W	Eval kWh	Eval kW_S	Eval kW_W	RR kWh	RR kW_S	RR kW_W
1	NG	10	RF	Elementary/High School	8,790	1.0	1.1	10,581	3.4	2.5	120%	332%	218%
1	NG	30	SF	Elementary/High School	25,200	1.9	3.4	53,971	18.4	10.3	214%	960%	303%
2	NG	20	SF	Elementary/High School	16,800	1.3	2.3	16,006	6.0	0.0	95%	470%	-2%
3	NS	5	BEF	University/College	18,205	0.5	1.9	7,150	0.8	0.8	39%	149%	44%
3	NS	10	SF	University/College	10,230	0.6	1.1	27,323	3.1	3.1	267%	488%	279%
3	NS	10	SF	University/College	10,230	0.6	1.1	40,241	3.3	3.2	393%	509%	287%
4	NS	15	HWCP	University/College	35,160	6.9	6.9	5,605	0.0	0.6	16%	0%	9%
5	NS	10	HWCP	University/College	23,440	4.6	4.6	4,339	0.0	1.4	19%	0%	30%
6	NS	7.5	HWCP	University/College	17,580	3.4	3.4	17,796	0.0	4.1	101%	0%	120%
7	NG	15	SF	Elementary/High School	12,600	1.0	1.7	-311	-0.4	0.0	-2%	-42%	0%
7	NG	15	SF	Elementary/High School	12,600	1.0	1.7	761	-0.2	0.0	6%	-19%	0%
8	NS	30	CWP	University/College	22,350	1.7	13.7	90,883	15.4	0.0	407%	915%	0%
9	NG	40	WSHP	Office	129,400	2.2	16.7	172,310	20.9	20.7	133%	934%	124%
10	NG	25	MAF	Warehouse	80,725	6.5	6.5	53,918	6.1	6.2	67%	94%	95%
11	NG	20	SF	Retail	22,920	1.3	2.3	0	0.0	0.0	0%	0%	0%
11	NG	20	SF	Retail	22,920	1.3	2.3	0	0.0	0.0	0%	0%	0%
12	NS	10	CT	Offices	9,500	-0.2	-0.1	-922	-0.7	0.0	-10%	321%	0%
12	NS	7.5	CWP	Offices	10,275	0.4	3.4	9,624	4.2	0.0	94%	1000%	0%
12	NS	25	CWP	Offices	34,250	1.4	11.4	21,420	8.6	0.0	63%	615%	0%
13	NG	75	CWP	University/College	55,875	4.2	34.3	22,617	13.6	0.0	40%	324%	0%
13	NG	75	CWP	University/College	55,875	4.2	34.3	28,002	5.5	0.0	50%	130%	0%
14	NG	40	SF	Elementary/High School	33,600	2.6	4.5	21,794	4.6	1.7	65%	179%	38%
15	NG	10	SF	Elementary/High School	8,400	0.6	1.1	6,764	0.9	1.3	81%	134%	111%
15	NG	7.5	SF	Elementary/High School	6,300	0.5	0.8	12,080	1.2	0.9	192%	256%	104%
16	NS	20	SF	Health	29,740	1.3	2.3	41,200	4.7	4.7	139%	370%	207%
17	NG	7.5	HWCP	University/College	17,580	3.4	3.4	20,543	2.1	2.3	117%	62%	67%
				Totals	**730,545**	**54.2**	**166.2**	**689,225**	**124.1**	**66.3**	**94%**	**229%**	**40%**

*NG – NGRID, NS – NSTAR

A.1 Site ID: 1 & 2

Elementary/High School

Project Description

DMI metered four variable speed drive installations at two public schools within a township. DMI contacted the site prior to the installation of any variable speed drives, and coordinated site visits to get metered data before and after the drives were installed.

On 5/3/12 the evaluator installed two meters at one of the elementary schools. One meter was installed on a 30-hp air handling unit supply fan. The second meter was installed on a 10-hp return fan for the same air handling unit. At this time, the motors were observed to have no VSDs installed, and were indicated by the staff to operate at a constant speed.

DMI staff also installed two meters at the second elementary school. One meter was installed on a 20-hp air handling unit supply fan, and one meter was installed on a 7.5 hp return fan for the same unit.

In August, the site contacted DMI to inform us that the meters had been removed during the installation of the drives. DMI returned to the site on 9/12/12 to reinstall each of the meters. At this time it was observed that drives were installed on each of the motors. DMI returned on 11/27/12 to remove all of the meters.

Discussion of Results

For three of the VSDs, the installation reduced the average input kW from one relatively constant input kW to a significantly reduced input kW. The post-retrofit input kW was observed to be relatively constant but with a small amount of variation in some cases. Based on the pattern observed, this is likely due to the VSD speeds being optimized for the end users' comfort.

In the fourth case, there was a low power factor error that prevented collection of usable data. The post-retrofit input kW was significantly higher than the pre-retrofit as a result. This motor is not included in the sample.

In all cases the schedules remained mostly unchanged after the VSD was installed, with the motors operating five days per week and approximately 30% of the time including during summer months..

All of the VSD operate at a relatively constant speed when the fan is in use and is not dependent on heating or cooling loads or ambient temperature. The 'Weekday/Weekend' trend was selected in the analysis tool. This results in a constant demand reduction.

These applications save from 95% to 215% of the energy savings claimed by the TRM. The site set VSD speeds manually and in two cases achieved power demand values that were lower than predicted by the TRM (120% and 214% realization ratios). The power demand achieved in the third case was very similar to the TRM, yielding a 95% realization ratio.

The summer and winter demand savings realization ratios were generally significantly higher, but ranged from -2% to 960%. The constant demand reduction results in higher demand reductions during the peak periods than predicted by the TRM. In the case of the 2% winter demand reduction realization ratio, this is due to the fan not operating during that period (5-7pm non-holiday weekdays).

A.2 Site ID: 3, 4, 5 & 6

University/College

Project Description

DMI metered a total of five VSD installations as part of several VSD projects done on this college campus. The metered installations were spread across four different buildings.

DMI installed one meter on the supply fan for an air handling unit. A second meter was installed on the exhaust fan for the same unit. The VSDs had already been installed by the time DMI visited the site. Both meters were installed on 5/16/11, and the VSDs were run in bypass for approximately 10 days. On 5/26/11 both VSDs were placed in "auto" control by the customer. DMI observed that both drives appeared to be set to run at 50 Hz. DMI removed the meters on 12/16/11.

DMI installed three meters at additional locations on the campus. Each meter was installed on a hot water pump in a different building beginning on 2/18/11.

The first meter was installed on a 7.5-hp hot water pump. The VSD had already been installed by the time DMI visited the site, so the drives were run in bypass mode from 2/18/11 until 3/4/11 (two weeks). After this time, the drives were put in "auto" mode and metered until 5/3/11. DMI returned to the site on 12/6/11 to reinstall the meter. Based on the information provided to DMI, the pump had been removed from the rotation of pumps pending the completion of maintenance, so on 2/24/12 DMI switched the meter to the adjacent pump of the same size. This meter remained in place until 5/16/12.

The second meter was installed on a 10-hp hot water pump. The VSD had not been installed when DMI first visited the site on 2/18.. The VSD was installed while the meter was in place, between approximately 3/30/11 to 4/1/11. The meter remained in place until 5/3/11.

The third meter was installed on a 15-hp hot water pump on 2/18/11. The VSD had not been installed when DMI visited the site. The meter was removed during the VSD installation, which occurred on approximately 3/24/11. DMI reinstalled the meter on 12/16/12, and it remained in place until 5/16/12. DMI observed the unit appeared to be maintaining a fixed setpoint of 60 Hz.

Discussion of Results – AHU Supply and Exhaust Fans

The supply fan was observed to operate at a relatively constant input kW in the both the pre-retrofit and post-retrofit cases, as the VSD operated at a constant frequency. Beginning in August, the VSD was tied into an operating schedule that reduced the operating hours from 100% to approximately 70%. It was

reported that this schedule would not have been implanted without the VSD installation, so the analysis includes savings based on the post-scheduling point.

The exhaust fan was observed to encounter operational issues beginning in August, and the drive screen indicated an operating fault. This is the same point that the supply fan began to operate on a schedule. Since the exhaust fan was not observed to operate correctly under the schedule, the analysis is based on the period before the schedule was put in place.

These applications save from 267% and 39% of the energy savings claimed by the TRM for the supply fan and exhaust fan, respectively. The supply fan includes the scheduling savings while the exhaust fan does not. The summer and winter realization ratios are significantly higher, 509% and 149% for the summer period and 279% and 44% for the winter period. The constant demand reduction results in a higher demand reduction during the summer peak period than predicted by the TRM. The winter realization ratios are proportionally lower because the TRM assumes greater demand reductions during those periods than the summer periods.

Discussion of Results – Hot Water Pumps

For all three of the hot water pumps observed at this site, the VSDs were installed but controls were never implemented and the VSD speed was never reduced from 60 Hz. However, there is an apparent reduction in operating hours that resulted from the installation of the VSDs. This reduction appears to be due to the pumps cycling, not an operational schedule. There is not a strong relationship with ambient temperature and the 'Daily' trend style was used in the analysis for each case.

The energy savings realization ratios were 18%, 19%, and 101% for the hot water pumps at this site. There was no demand reduction observed for the installations with ratios of 18% and 19%, but some energy savings still resulted due to a reduction in operating hours. The installation with the 101% ratio operated 24/7 in the post-retrofit case but with a constant demand reduction.

There are is no summer kW reduction because the pumps do not operate during the summer and those realization ratios are 0% for all three cases. The winter kW realization ratios are 15%, 30%, and 120%, again due to the reduction in operating hours.

The data collected for all three of the hot water pumps at this site were used as part of the VSD burden analysis.

A.3 Site ID: 7

Elementary/High School

Project Description

DMI metered two 15-hp supply fan motors at this site, a public school. One meter was installed on each motor on 3/27/12. The VSDs were reportedly installed on 6/16/2012 but it is not evident in the metering data because the drives were bypassed. DMI returned to the site on 11/16/2012 to retrieve the kW loggers. At this time, DMI observed that the VSDs had been installed but were off. The facility operator reported that the VSD controls had not been programmed and the fans had continued to operate as they had prior to the retrofit.

Discussion of Results

Energy savings for both of the supply fans at this site are close to zero, with realization ratios of -2% and 6%. The near-zero ratios are due to the VSDs being bypassed following the retrofits. Prior to the VSD installations, there were some slight variations in power demand that caused the differences. Since the VSDs were observed to be off and operating with a bypass, the difference in savings is not due to a VSD burden. Operating hours were nearly identical in the pre- and post-retrofit cases.

A.4 Site ID: 8

University /College

Project Description

DMI metered one 30-hp chilled water pump at a university.

DMI contacted the site prior to the installation of the VSD, and gathered pre-retrofit metering data from 5/18/11 until 6/20/11.

Once the VSD had been installed, DMI visited the site on 8/7/12 to reinstall a meter on the same chilled water pump. DMI observed that the drive had been installed. It appeared that automated controls were in place, as the drive was observed to operate at an approximate minimum speed of 15 Hz when it was started.

DMI returned to the site on 12/11/12 to remove the meter. Based on the data, it appears that the pump was shut down for the season in mid-October.

Discussion of Results

The 30-hp chilled water pump was observed to operate at a relatively constant input kW of 16.88 for the one-month duration in May and June prior to the VSD installation. After the VSD and controls were installed, the pump was observed to operate at the minimum VSD speed of 15 Hz for the duration of the metering period. The average input kW was a relatively constant 2.03 kW from August to November.

Since the VSD appears to always operate at minimum speed with the VSD installation, it seems that the pump must be significantly oversized for the existing chilled water loads.

This application saves 407% of the energy savings claimed by the TRM. The summer kW reduction is 915% of the TRM. The constant demand reduction results in higher demand reductions during the summer peak periods than predicted by the TRM. The winter kW reduction is 0% of the TRM because the pump is shut down during winter months in both the pre- and post-retrofit cases.

A.5 Site ID: 9

Office

Project Description

DMI metered one 40-hp hot water pump at a large office complex. DMI contacted the site prior to the installation of the VSD, and gathered pre-retrofit metering data from 4/9/11 until 6/19/11.

After the VSD installation, DMI visited the site to verify that the power meter was not disconnected and still collecting good data. The VSD was observed to be operating at fixed speed of 45 Hz. No automatic controls were in place.

DMI returned to the site on 7/25/11 to remove the meter. The VSD was observed to be operating at 60 Hz at this time.

During the initial metering site visit, the evaluating engineer observed the motor to operate at an amperage exceeding the full-load amount shown on the nameplate. This was later confirmed with the long term power data, as the 40-hp motor operated at constant 35 kW for the duration of the pre-retrofit period. Facility personnel were asked about this during a later site visit after the VSD was installed. It was reported that balancing had never been performed after the system was originally installed, so it is expected that all balancing valves were at 100% position and the pump was providing excessive flow.

Once the VSD was installed it was observed to operate at a fixed speed. Facility personnel selected the anticipated worst-case load and set the VSD speed to achieve the appropriate temperature differential, essentially using the VSD to balance the system. This approach could have been performed using the existing balancing valves instead of the VSD. It is expected that doing so would have resulted in much of, but not all of, the energy savings that were observed to result from the VSD balancing approach.

Discussion of Results

The 40-hp hot water pump was observed to operate at a relatively constant input of 35.16 kW for the 10 week duration from April to June prior to the VSD installation. After the VSD was installed and the speed set to 45 Hz, the pump was observed to operate an input of approximately 12.5 kW.

Just prior to the meter removal, the motor appears to have been operating at an input kW corresponding to a VSD speed of 60 Hz, which was also observed at meter retrieval. Facility personnel were not able to explain why the VSD was operating at this speed.

The post-retrofit input kW is the average of the entire post-installation period, including both 45 Hz and 60 Hz operation, which equates to 15.24 kW. It is uncertain if the VSD speed would be reset back to a lower speed, or if the VSD would continue to operate at 60 Hz indefinitely. It could be argued that the post-retrofit kW should correspond only to the 45 Hz VSD speed, the 60 Hz VSD speed, or some point in between. The methodology chosen was an attempt to be consistent with the analyses for other applications.

Unlike hot water pumps in other applications, this pump does operate 12 months per year.

This application saves 133% of the energy savings claimed by the TRM and is due largely to the pre-retrofit kW being so high. The summer kW reduction is 934% of the TRM. The constant demand reduction results in higher demand reductions during the summer peak periods than predicted by the TRM. The winter kW reduction is 124% of the TRM.

A.6 Site ID: 10

Warehouse

Project Description

DMI metered one 25-hp hot makeup air fan at a warehouse.

DMI contacted the site prior to the installation of the VSD, and gathered pre-retrofit metering data from 8/19/11 until 9/22/11.

After the VSD installation, no controls were installed and VSD operation was fixed at 60 Hz. Eventually the site reduced the VSD speed and it was allowed to operate constantly at this point. There is no plan to install automatic controls.

Discussion of Results

The 25-hp makeup air fan was observed to operate at a relatively constant input of 14.04 kW for the 5 week duration in August and September prior to the VSD installation. The small amount of input kW variation appeared to be due to changes in ambient temperature. After the VSD was installed and the speed reduced, the fan was observed to operate an input of approximately 7.88 kW.

This application saves 67% of the energy savings claimed by the TRM. The summer kW reduction is 94% of the TRM and the winter kW reduction is 95% of the TRM. It appears the TRM assumes the demand reductions would be lower during the peak periods, which seems reasonable because loads are often higher during these periods.

A.7 Site ID: 11

Retail

Project Description

DMI metered two 20-hp supply fans at a retail facility.

DMI contacted the site in early 2012, prior to the installation of VSDs on two supply fans. The planned installation data for the VSDs was in the early spring. Meters were installed from February to November 2012.

Upon retrieval of the meters following post-installation metering in November, it was discovered that the pre-retrofit system had VSDs installed. The supply fans are part of a VAV system, and the original VSDs were expected to fail and in need of replacement. Facility personnel reported that it was decided by an account executive that these applications would receive an incentive because the facility never received an incentive for the original VSD installation.

One of the meters retrieved from this site did not produce useable post-retrofit data. DMI reinstalled the power meter in an attempt to collect useable data for this motor, but unfortunately the data was again found to be corrupt.

Only new VSDs were installed as part of these applications. The pre-existing controls sequences are used to control the new VSDs.

Discussion of Results

These applications should not save energy because the pre- and post-retrofit conditions are identical. Both cases include VSD control with the same control sequences. Therefore, these applications save 0% of the energy savings and summer/winter kW reductions claimed by the TRM.

Data for one of the units monitored did suggest the potential for savings; however, this is most likely due to the short pre-retrofit metering period (one week). The input power prior to the VSD replacement was observed to operate steadily at 9.68 kW, and the input power was reduced to 7.49 kW for the post-retrofit case. Operating hours were observed to be approximately 45% of the pre-retrofit hours in both cases. DMI interviewed facility personnel following the data review and confirmed that only the physical VSDs were changed and that no modifications were made to control sequences, dampers, or any other parameter. The VSDs operate exactly as they operated in the pre-retrofit case. Minor input kW differences may exist due to the VSD burden varying, but this is expected to be insignificant relative to the total power demand.

Post-retrofit power demand shows unusual operating characteristics in which the motor operates at a relatively constant input kW for extended periods of time, up to several weeks long. It is unclear why this input kW would result based on the facility personnel description of the installed control sequences. The VSDs are programmed to maintain static pressure setpoints as VAV box dampers modulate to maintain space temperature setpoints. Variation in power demand over the course of each day would be expected. This behavior results in energy savings (24% of the TRM) if the typical analysis tool approach is used to evaluate this installation, but no energy savings (or very little) should exist. As the pre- and post-retrofit metering periods approach infinity, it is expected that the energy savings would approach zero.

Both applications save 0% of the energy savings claimed by the TRM because VSDs were installed in both the pre- and post-retrofit cases. Summer and winter kW reductions are therefore 0% as well. These savings are based on expected theoretical values and are not based on metered data due to issues collecting sufficient data.

A.8 Site ID: 12

Office

Project Description

DMI metered the following equipment this office facility:

- 25-hp chilled water pump (CHWP-4)
- 7.5-hp chilled water pump (CHWP-3)
- 10-hp cooling tower fan (Equipment Tag Unknown)

DMI contacted the site prior to the installation of any VSDs, and installed meters before VSDs were installed. On 8/9/11 DMI installed three meters. DMI returned to the site on 10/24/11 after the VSDs had been installed to reinstall the meters. Data was gathered until approximately 12/6/11, when the meters were removed because the cooling season had ended. The data gathered during this metering period proved to be insufficient because cooling loads were small due to low ambient temperatures and VSDs operated near minimum speeds. DMI returned to the site on 7/12/12 to reinstall the meters during periods of higher cooling loads. DMI removed the meters on 12/11/12.

The facility shuts down the chilled water plant in the winter, from roughly November to April, depending on ambient conditions.

Discussion of Results

The 25-hp chilled water pump was observed to operate at an average input kW of 15.92 for the 11 week duration from August to October prior to the VSD installation. In this case there was some variation in power demand, which may be due to specific chilled water users being shut down. For example, there may be a particular air handling unit serving a part of a building that was vacant. This would allow the unit to be shutdown, causing a reduction in chilled water flow and pumping power.

Automatic controls were installed with the VSD, resulting in variation in post-retrofit input kW. The variation appeared to have a relationship with ambient temperature, but the trend fit did not produce a strong enough r-squared value for the analysis, and weekday/weekend approach was used. The average post-retrofit input kW was observed to be 8.43 kW.

This application saves 63% of the energy savings claimed by the TRM because the average demand reduction is less than was expected. The summer kW reduction is 615% of the TRM. Even though some

variation in power demand was observed, the weekday/weekend approach causes a relatively constant demand reduction resulting in higher demand reductions during the summer peak periods than predicted by the TRM. The winter kW reduction is 0% of the TRM because the chilled water pump does not operate in the winter.

The 7.5-hp chilled water pump was observed to operate at a relatively constant input kW of 5.75 for the 3 week duration in August and September prior to the VSD installation.

Automatic controls were installed with the VSD, resulting in variation in post-retrofit input kW. The variation appeared to have a relationship with ambient temperature, but the trend fit did not produce a strong enough r-squared value for the analysis and weekday/weekend approach was used. The average post-retrofit input kW was observed to be 2.44 kW.

This application saves 94% of the energy savings claimed by the TRM. The summer kW reduction is 1000% of the TRM. Similar to 25-hp pump, the constant demand reduction of the weekday/weekend approach results in higher demand reductions during the summer peak periods than predicted by the TRM. The winter kW reduction is 0% of the TRM because the chilled water pump does not operate in the winter.

The 10-hp cooling tower fan was observed to operate at an average input kW of 5.28 kW for the 7 week duration in August and September prior to the VSD installation. In this case there was some variation in power demand, which is likely due to the fan motor operating at two speeds to maintain a condenser water temperature set point. Ambient air temperature variations may cause a small difference in power demand. The fan also cycled off frequently, only operating for 4.36% of the pre-retrofit sample period.

Automatic controls were installed with the VSD, resulting in variation in post-retrofit input kW. The variation appeared to have a relationship with ambient temperature, but the trend fit did not produce a strong enough r-squared value for the analysis and weekday/weekend approach was used. The average post-retrofit input kW was observed to be 1.93 kW. In this post-retrofit case, the fan did not cycle off as frequently, operating for 18.95% of the sample period. The post-retrofit fan operated over four times the pre-retrofit operating hours.

This application saves -10% of the energy savings claimed by the TRM. The increase in energy consumption is the result of the fan operating four times longer than the pre-retrofit case, even at the reduced average input kW. The summer kW reduction is 321% of the TRM. Like the other motors at this site, the constant demand reduction of the weekday/weekend analysis approach results in higher demand reductions during the summer peak periods than predicted by the TRM. The winter kW reduction is 0% of the TRM because the chilled water pump does not operate in the winter.

A.9 Site ID: 13

University/College

Project Description

DMI metered two 75-hp cooling water pumps (P-2 and P-4) at a university. DMI contacted the site prior to the installation of the VSD, and gathered pre-retrofit metering data from 6/15/11 until 9/30/11.

DMI returned to the site on 6/30/12 to remove the meter. One VSD was observed to be operating at slightly below 60 Hz at this time. Automatic controls were reportedly installed.

These two cooling water pumps circulate condenser water at the university's central chilled water pump. The pumps are two of four identical pumps at the site, all of which were retrofit with VSDs and received incentives. They are staged based on chilled water loads and rotated to maintain equivalent lifetime operating hours. Amperage loggers were installed on the other two pumps to observe operating hours.

Discussion of Results

The amperage loggers that were installed on the other condenser water pumps, P-1 and P-3, showed little (5%) or no (0%) operation. The motors that were randomly chosen for kW metering operated significantly more, close to 50% of the time. Only two motors could be included in the evaluation, so random selection was used in an effort to provide an unbiased result. The analysis methodology assumes that each application operates for the hours that were observed. Had P-1 or P-3 been chosen for kW metering, the operating hours would have been significantly less, causing a significant reduction in energy savings.

However, it should be noted pumps P-2 and P-4 (that were included in this study) were observed to operate for approximately 55% and 98% of the metering periods. The average, 76%, extrapolates to 6,700 hours per year. This is significantly above the prescriptive VSD requirement of 2,000 hours per year and largely offsets the minimal use of pumps P-1 and P-3. The argument could be made that the average pump operates very close to the required 2,000 hours per year and that the incentives were appropriate for all four installations; the issue is that the site does not appear to be rotating the pumps as uniformly as it could be.

75-hp cooling water pump P-2 was observed to operate at a relatively constant input kW of 47.81 for a 15 week duration from June to September prior to the VSD installation. After the VSD was installed with automatic controls, the pump was observed to operate an input kW of approximately 45.20. There was less variation in power demand than expected for a condenser water pump with automatic control.

This application saves 40% of the energy savings claimed by the TRM because the demand reduction is less than expected.. The summer kW reduction is 324% of the TRM. The constant demand reduction results in higher demand reductions during the summer peak periods than predicted by the TRM. The winter kW reduction is 0% of the TRM because the pumps do not operate during winter months.

75-hp cooling water pump P-4 was observed to operate at a relatively constant input kW of 48.69 for the 15 week duration from June to September prior to the VSD installation. After the VSD was installed with automatic controls, the pump was observed to operate an input kW of approximately 45.38. There was less variation in power demand than expected for a condenser water pump with automatic control.

This application saves 50% of the energy savings claimed by the TRM because the demand reduction is less than expected.. The summer kW reduction is 130% of the TRM. The constant demand reduction results in higher demand reductions during the summer peak periods than predicted by the TRM. The winter kW reduction is 0% of the TRM because the pumps do not operate during winter months.

A.10 Site ID: 14

Elementary/High School

Project Description

DMI metered one 40-hp supply fan motor at this site, a public school. One meter was installed on 3/27/12 to monitor the pre-installation case. The new VSD installation was performed on 5/16/2012. DMI returned to the site on 11/16/2012 to retrieve the kW logger.

There was already a VSD in place prior to the installation of the VSD associated with this application; the new VSD was to replace an existing VSD that was failing. This supply fan serves an existing VAV system and the original VSD was observed to operate between 40 and 50 Hz at the time of the original meter installation. DMI used a more frequent logging interval of 1-minute to capture any additional variation in kW that may exist.

Discussion of Results

There was a significant reduction in power demand resulting from the VSD installation, even with the post-retrofit VSD replacing an existing VSD. The average input kW prior to the replacement was 17.5 kW and only 3.53 kW afterwards. Operating hours were observed to increase by 50% after the replacement. It is unclear if these differences are due to the failing VSD, an improvement in controls that was made at the same time, or some other factor. The very low post-installation input kW suggests that the VSD must be operating at a speed very near its minimum.

This application saves 65% of the energy savings claimed by the TRM, which is likely due to the pre-retrofit case including a VSD that was observed to operate between 40 and 50 Hz. The summer kW reduction is 179% of the TRM. The constant demand reduction results in higher demand reductions during the summer peak periods than predicted by the TRM. The winter kW reduction is 38% of the TRM.

Since a VSD was in place prior to the new VSD, this application should have been ineligible for an incentive.

A.11 Site ID: 15

Elementary/High School

Project Description

DMI metered two supply fans at this site including a 10-hp and 7.5-hp fan. DMI gathered pre-retrofit metering data beginning on 5/23/11 and post-retrofit data from 7/27/11 to 1/25/12.

Both supply fan VSDs were manually set to reduced speeds and operated constantly at these points.

Discussion of Results

The 10-hp supply fan was observed to operate at a relatively constant input kW of 3.46 for a 3 week duration in May and June prior to the VSD installation. After the VSD was installed, the fan was observed to operate an input kW of approximately 2.58. Some variation does exist in the post-retrofit case but there is no pattern or relationship with ambient temperature and the weekday/weekend trend was used. This fan is used 12 months per year.

This application saves 81% of the energy savings claimed by the TRM. Savings may be lower than expected because the pre-retrofit kW was relatively low for the size of the motor. The summer kW reduction is 134% of the TRM. The constant demand reduction results in higher demand reductions during the summer peak periods than predicted by the TRM. The winter kW reduction is 111% of the TRM.

The 7.5-hp supply fan was observed to operate at a relatively constant input kW of 4.34 for a 7 week duration from May to July prior to the VSD installation. After the VSD was installed, the fan was observed to operate an input kW of approximately 2.70. Some variation does exist in the post-retrofit case but there is no pattern or relationship with ambient temperature and the weekend/weekday trend was used. This fan is used 12 months per year.

This application saves 192% of the energy savings claimed by the TRM. Savings are higher for this motor because the pre-retrofit kW was higher relative to the size of the motor. The summer kW reduction is 256% of the TRM. The constant demand reduction results in higher demand reductions during the summer peak periods than predicted by the TRM. The winter kW reduction is 104% of the TRM.

A.12 Site ID: 16

Health

Project Description

DMI metered a 20-hp supply fan motor at this site, a health facility. DMI installed a meter on 6/7/12, prior to the installation of the VSD. Installation of the VSD occurred approximately on 6/29/12. DMI removed the meter on 11/26/12, during which time it was confirmed that the VSD was installed, and that it appeared that the unit was operating under automated control.

Discussion of Results

This 20-hp supply fan was observed to operate at a relatively constant input kW of 13.80 for a 3 week duration in June prior to the VSD installation. After the VSD was installed, the fan was observed to operate an input kW of approximately 9.11. Some variation does exist in the post-retrofit case but there is no pattern or relationship with ambient temperature. The fan operates 24/7 in both cases.

This application saves 139% of the energy savings claimed by the TRM. The summer kW reduction is 370% of the TRM. The constant demand reduction results in higher demand reductions during the summer peak periods than predicted by the TRM. The winter kW reduction is 207% of the TRM.

A.13 Site ID: 17

University/College

Project Description

DMI metered what is categorized as one 7.5-hp hot water circulation pump at a health facility.

DMI contacted the site prior to the installation of the VSD, and gathered pre-retrofit metering data from 3/31/11 until 4/21/11. Post-retrofit data was gathered from 5/13/2011 to 6/16/2011.

It was found that even though this motor was categorized as a hot water circulation pump, it is actually a swimming pool circulation pump, which would not be expected to be controlled in the same manner.

After the VSD installation, DMI visited the site to verify that the power meter was not disconnected and still collecting good data. The VSD was observed to be operating at fixed speed. No automatic controls were in place. Facility personnel reported that the VSD speed would be tweaked to maintain proper chemical levels within the pool.

Discussion of Results

The 7.5-hp pump was observed to operate at a relatively constant input kW of 4.66 for the 3 week duration in March and April prior to the VSD installation. After the VSD was installed, the pump was observed to operate at an average input kW of approximately 2.20. The pump operates 24/7 in both cases.

This application saves 117% of the energy savings claimed by the TRM. The summer kW reduction is 62% of the TRM. The summer kW is lower because the TRM does not expect a hot water pump to operate at a high input kW during summer months. The winter kW reduction is 67% of the TRM.

Site ID: 1
Facility Type: Elementary/High School
Motor Type: ReturnFan
Motor Size: 10 hp

Pre-VFD Installation Metering Period

Start	5/3/12 8 AM
End	7/27/12 11 AM
Weeks	12
Average Operational kW	4.98
% Operating Time	33.37%
Average kW/hp	0.50
Operational Threshold	0.10

Notes:

Post-VFD Installation Metering Period

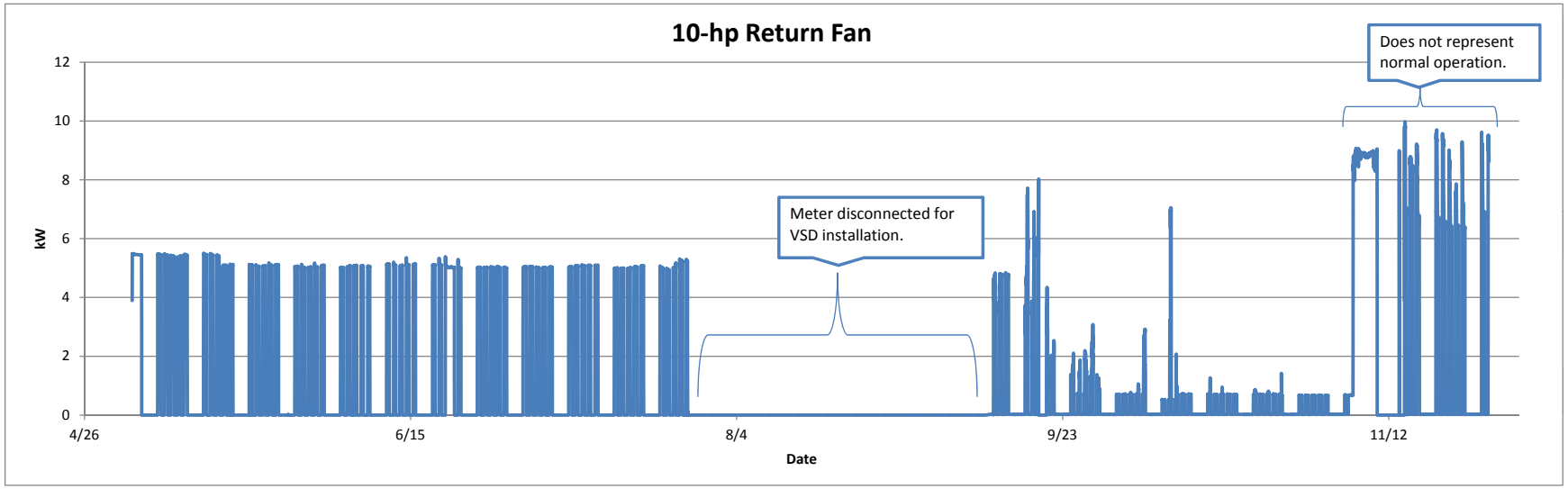
Start	9/12/12 9 AM
End	11/6/12 12 PM
Weeks	8
Average Operational kW	1.33
% Operating Time	32.52%
Average kW/hp	0.13
Operational Threshold	0.10

Notes:

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	14,476	3,896	10,581	-
Summer kW	5.01	1.62	3.39	-
Winter kW	2.51	0.04	2.47	-
Total kWh/HP	1,448	390	1,058	1.20
Summer kW/HP	0.50	0.16	0.34	3.32
Winter kW/HP	0.25	0.00	0.25	2.18

Trend Type: Weekday/Weekend



Site ID: 1
Facility Type: Elementary/High School
Motor Type: Supply Fan
Motor Size: 30 hp

Pre-VFD Installation Metering Period

Start	5/3/12 8 AM
End	7/25/12 5 PM
Weeks	12
Average Operational kW	20.23
% Operating Time	34.04%
Average kW/hp	0.67
Operational Threshold	0.10

Notes:

Post-VFD Installation Metering Period

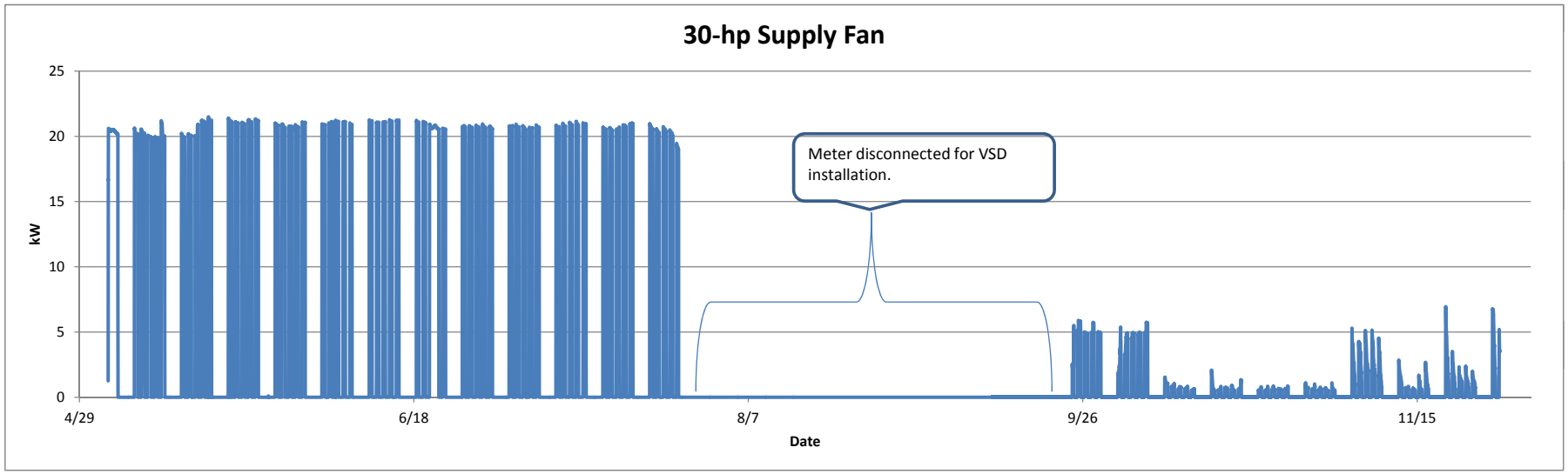
Start	9/24/12 10 AM
End	11/27/12 8 AM
Weeks	9
Average Operational kW	2.00
% Operating Time	33.12%
Average kW/hp	0.07
Operational Threshold	0.10

Notes:

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	59,987	6,016	53,971	-
Summer kW	20.32	1.88	18.43	-
Winter kW	10.32	0.03	10.29	-
Total kWh/HP	2,000	201	1,799	2.14
Summer kW/HP	0.68	0.06	0.61	9.60
Winter kW/HP	0.34	0.00	0.34	3.03

Trend Type: Weekday/Weekend



Site ID: 2
Facility Type: Elementary/High School
Motor Type: Supply Fan
Motor Size: 20 hp

Pre-VFD Installation Metering Period

Start	5/3/12 9 AM
End	7/16/12 4 PM
Weeks	11
Average Operational kW	11.00
% Operating Time	29.16%
Average kW/hp	0.55
Operational Threshold	0.10

Notes:

Post-VFD Installation Metering Period

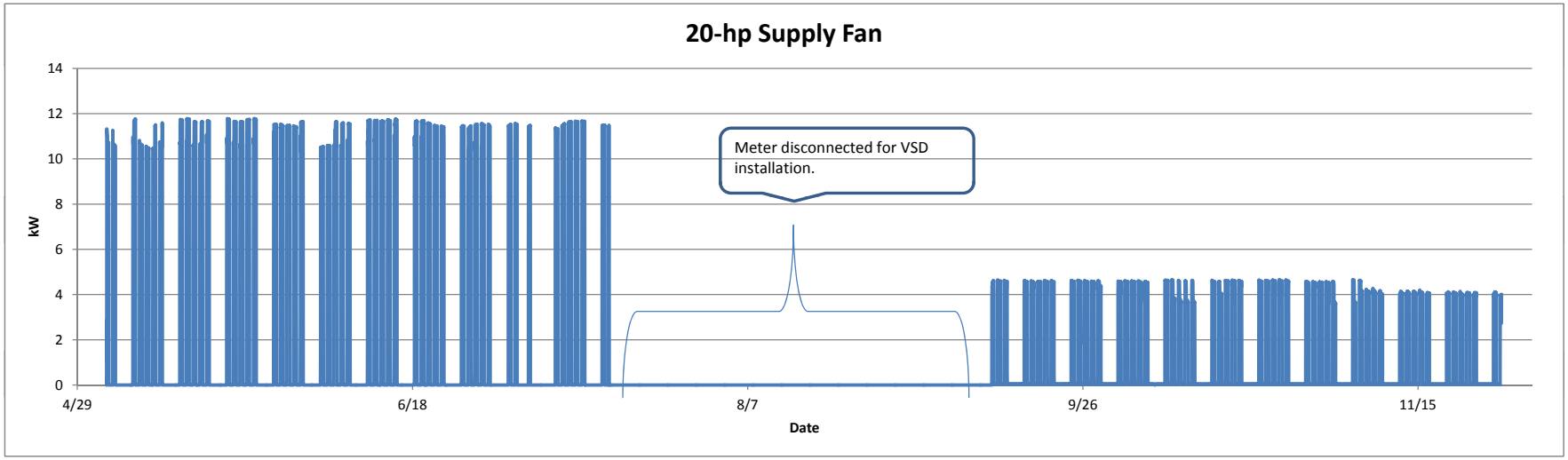
Start	9/12/12 11 AM
End	11/27/12 10 AM
Weeks	11
Average Operational kW	4.17
% Operating Time	33.11%
Average kW/hp	0.21
Operational Threshold	0.10

Notes:

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	28,312	12,306	16,006	-
Summer kW	10.17	4.15	6.02	-
Winter kW	0.02	0.06	-0.04	-
Total kWh/HP	1,416	615	800	0.95
Summer kW/HP	0.51	0.21	0.30	4.70
Winter kW/HP	0.001	0.003	-0.002	-0.02

Trend Type: Weekday/Weekend



Site ID: 3
Facility Type: University/College
Motor Type: Exhaust Fan
Motor Size: 5 hp

Pre-VFD Installation Metering Period

Start	5/17/11 12 AM
End	5/24/11 12 AM
Weeks	1
Average Operational kW	2.14
% Operating Time	100.00%
Average kW/hp	0.43
Operational Threshold	0.10

Notes:

Post-VFD Installation Metering Period

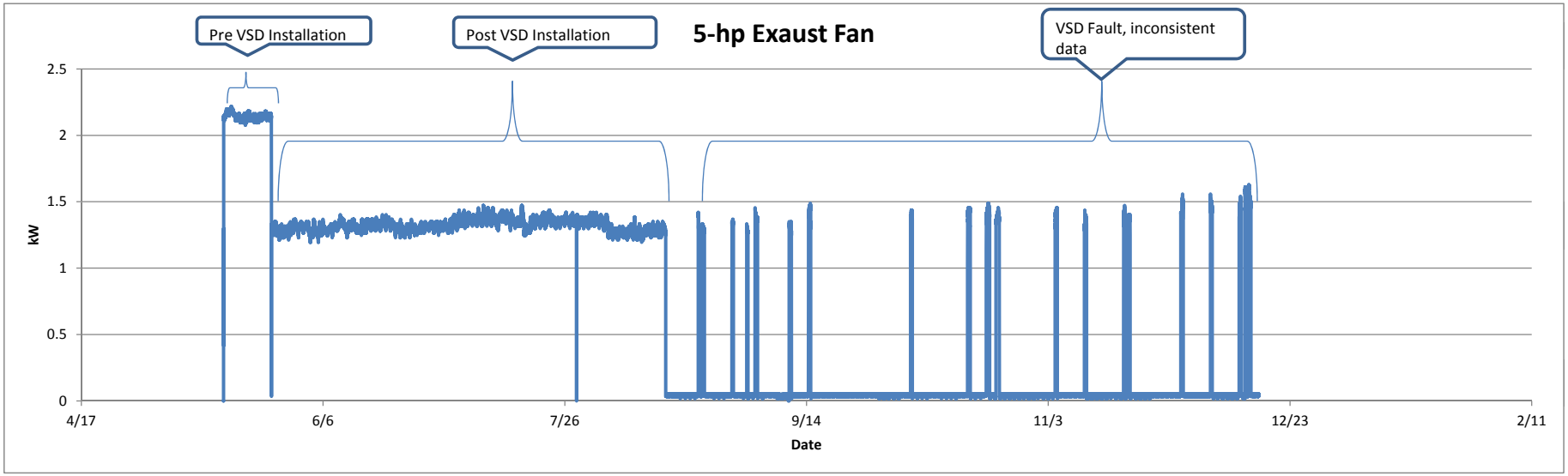
Start	5/26/11 12 AM
End	8/13/11 12 AM
Weeks	11
Average Operational kW	1.33
% Operating Time	99.99%
Average kW/hp	0.27
Operational Threshold	0.10

Notes:

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	18,764	11,614	7,150	-
Summer kW	2.15	1.33	0.81	-
Winter kW	2.15	1.32	0.83	-
Total kWh/HP	3,753	2,323	1,430	0.39
Summer kW/HP	0.43	0.27	0.16	1.49
Winter kW/HP	0.43	0.26	0.17	0.44

Trend Type: Weekday/Weekend



Site ID: 3
Facility Type: University/College
Motor Type: Supply Fan
Motor Size: 10 hp

Pre-VFD Installation Metering Period

Start	5/17/11 12 AM
End	5/24/11 12 AM
Weeks	1
Average Operational kW	7.81
% Operating Time	100.00%
Average kW/hp	0.78
Operational Threshold	0.10

Notes:

Post-VFD Installation Metering Period

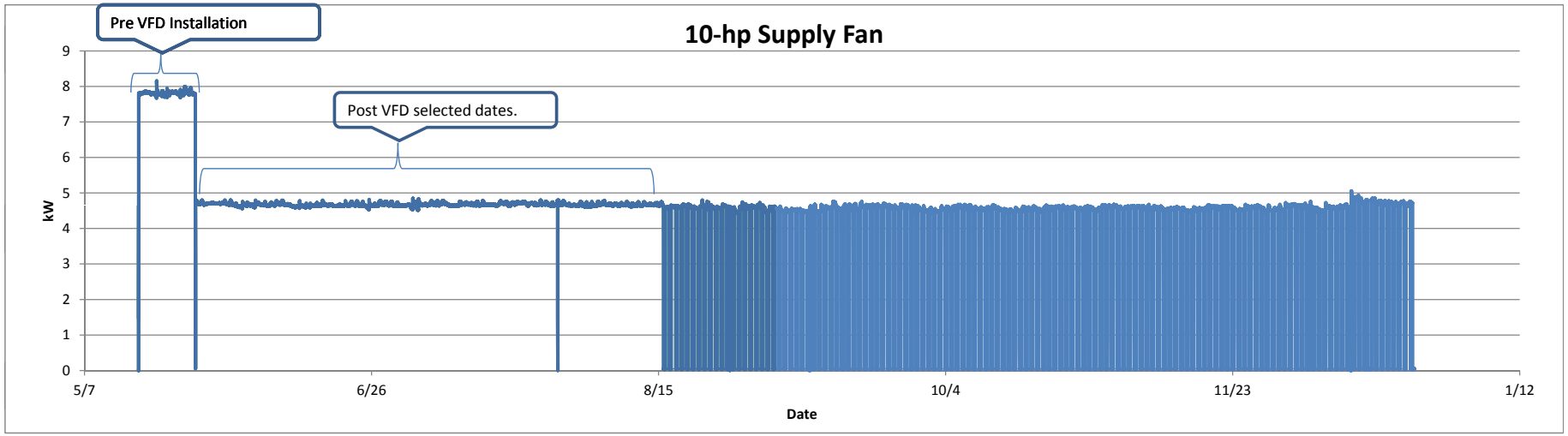
Start	5/26/11 12 AM
End	8/13/11 12 AM
Weeks	11
Average Operational kW	4.69
% Operating Time	99.99%
Average kW/hp	0.47
Operational Threshold	0.10

Notes:

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	68,385	41,062	27,323	-
Summer kW	7.82	4.70	3.12	-
Winter kW	7.82	4.67	3.15	-
Total kWh/HP	6,839	4,106	2,732	2.67
Summer kW/HP	0.78	0.47	0.31	4.88
Winter kW/HP	0.78	0.47	0.31	2.79

Trend Type: Daily



Site ID: 3
Facility Type: University/College
Motor Type: Supply Fan
Motor Size: 10 hp

Pre-VFD Installation Metering Period

Start	5/17/11 12 AM
End	5/24/11 12 AM
Weeks	1
Average Operational kW	7.81
% Operating Time	100.00%
Average kW/hp	0.78
Operational Threshold	0.10

Notes:

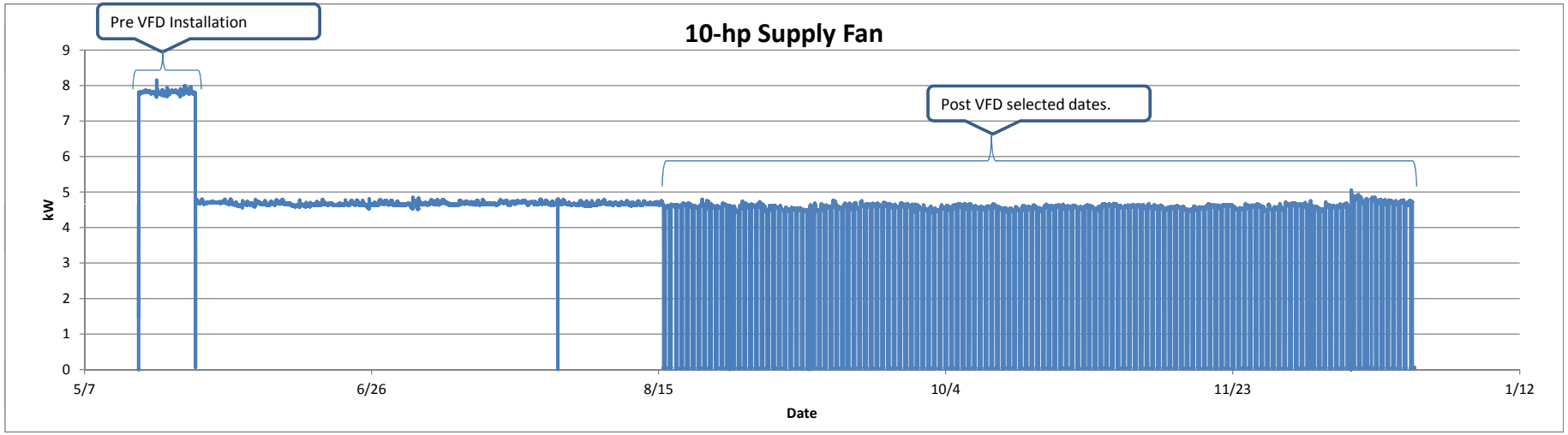
Post-VFD Installation Metering Period

Start	8/15/11 12 AM
End	2/14/12 8 AM
Weeks	26
Average Operational kW	4.58
% Operating Time	69.77%
Average kW/hp	0.46
Operational Threshold	0.10

Notes:

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	68,385	28,144	40,241	-
Summer kW	7.82	4.56	3.26	-
Winter kW	7.82	4.57	3.25	-
Total kWh/HP	6,839	2,814	4,024	3.93
Summer kW/HP	0.78	0.46	0.33	5.09
Winter kW/HP	0.78	0.46	0.32	2.87
Trend Type: Daily				



Site ID: 6
Facility Type: University/College
Motor Type: HWCP
Motor Size: 7.5 hp

Pre-VFD Installation Metering Period

Start	2/18/11 11 AM
End	3/4/11 11 AM
Weeks	2
Average Operational kW	5.13
% Operating Time	100.00%
Average kW/hp	0.68
Operational Threshold	0.10

Notes:

Post-VFD Installation Metering Period

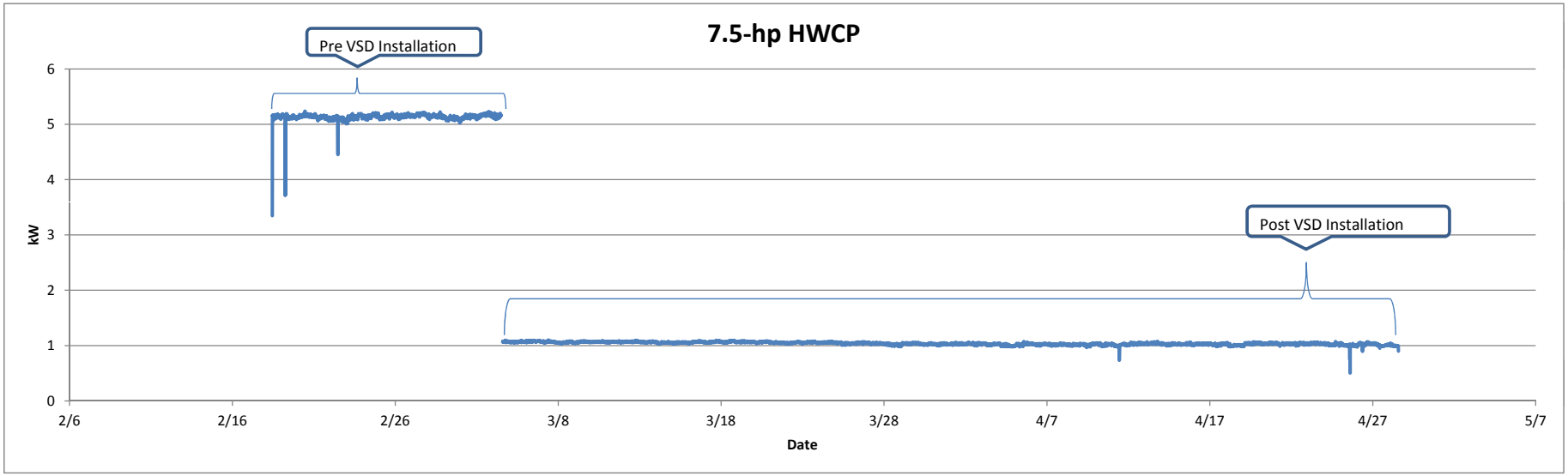
Start	3/4/11 2 PM
End	4/28/11 1 PM
Weeks	8
Average Operational kW	1.04
% Operating Time	100.00%
Average kW/hp	0.14
Operational Threshold	0.10

Notes:

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	22,309	4,513	17,796	-
Summer kW	0.00	0.00	0.00	-
Winter kW	5.15	1.04	4.11	-
Total kWh/HP	2,975	602	2,373	1.01
Summer kW/HP	0.00	0.00	0.00	0.00
Winter kW/HP	0.69	0.14	0.55	1.20

Trend Type: Weekday/Weekend



Site ID: 5
Facility Type: University/College
Motor Type: I ² / t
Motor Size:мл hp

Pre-VFD Installation Metering Period

Start	2/18/11 1 PM
End	3/30/11 11 AM
Weeks	6
Average Operational kW	4.05
% Operating Time	100.00%
Average kW/hp	0.40
Operational Threshold	0.10

Notes:

Post-VFD Installation Metering Period

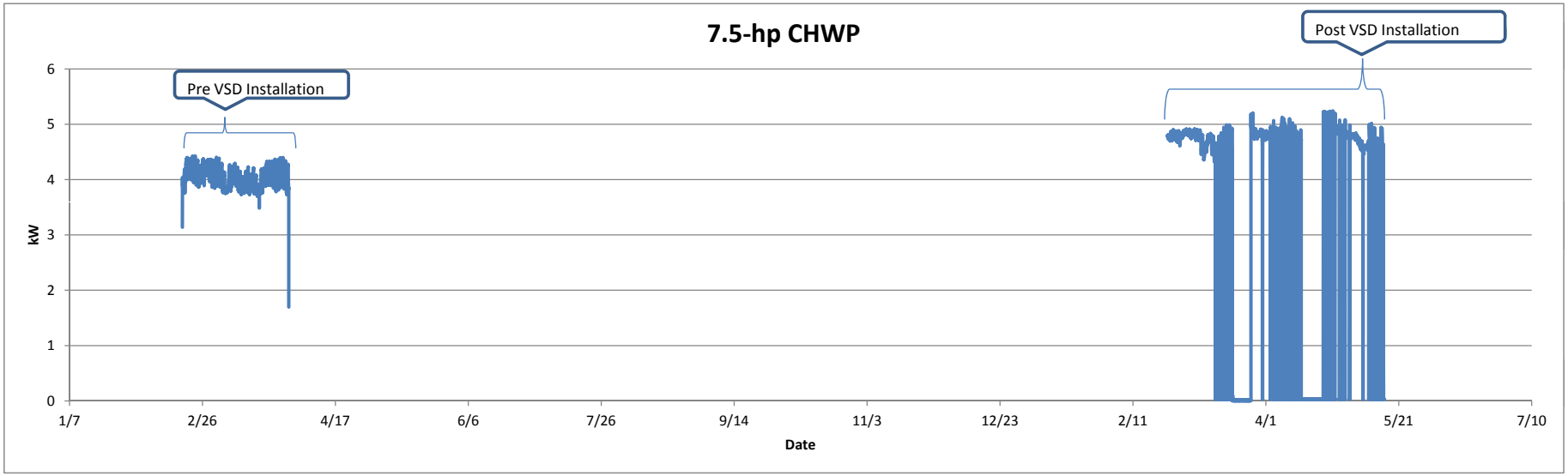
Start	2/24/12 1 AM
End	5/15/12 10 AM
Weeks	12
Average Operational kW	4.74
% Operating Time	63.98%
Average kW/hp	0.47
Operational Threshold	0.10

Notes:

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	17,573	13,234	4,339	-
Summer kW	0.00	0.00	0.00	-
Winter kW	3.88	2.50	1.38	-
Total kWh/HP	1,757	1,323	434	0.19
Summer kW/HP	0.00	0.00	0.00	0.00
Winter kW/HP	0.39	0.25	0.14	0.30

Trend Type: Weekday/Weekend



Site ID: 4
Facility Type: University/College
Motor Type: HWCP
Motor Size: 15 hp

Pre-VFD Installation Metering Period

Start	2/21/11 9 AM
End	3/24/11 1 PM
Weeks	4
Average Operational kW	9.32
% Operating Time	95.00%
Average kW/hp	0.62
Operational Threshold	0.10

Notes:

Post-VFD Installation Metering Period

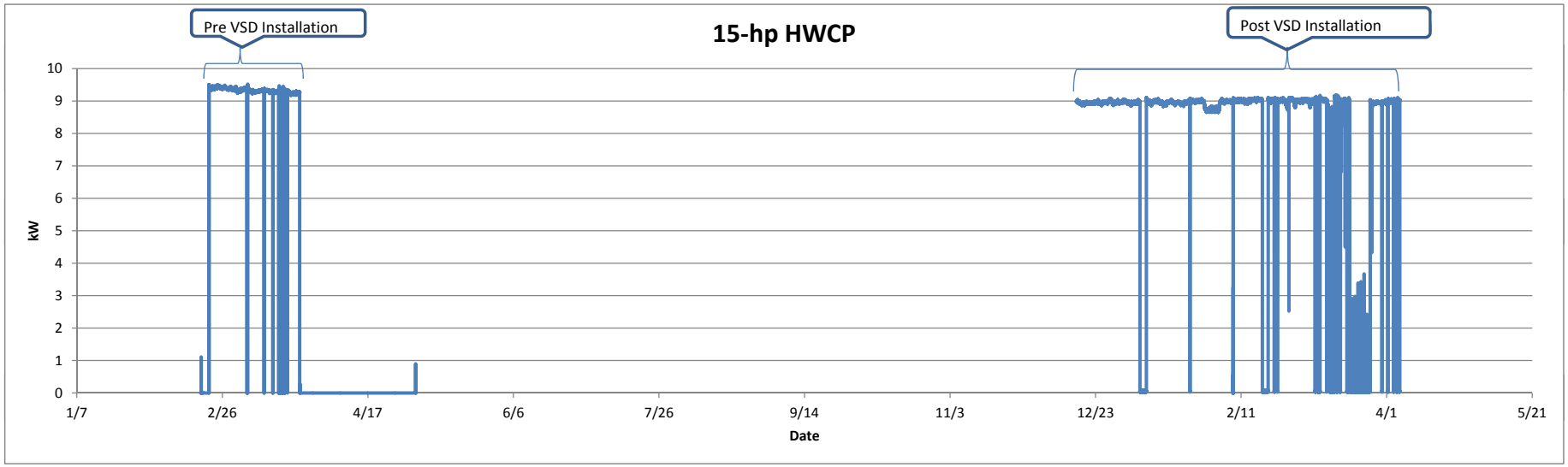
Start	12/16/11 11 AM
End	4/14/12 5 AM
Weeks	17
Average Operational kW	8.95
% Operating Time	83.92%
Average kW/hp	0.60
Operational Threshold	0.10

Notes:

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	38,361	32,757	5,605	-
Summer kW	0.00	0.00	0.00	-
Winter kW	8.41	7.80	0.61	-
Total kWh/HP	2,557	2,184	374	0.16
Summer kW/HP	0.00	0.00	0.00	0.00
Winter kW/HP	0.56	0.52	0.04	0.09

Trend Type: Weekday/Weekend



Site ID: 7
Facility Type: Elementary/High School
Motor Type: Supply Fan
Motor Size: 15 hp

Pre-VFD Installation Metering Period

Start	3/27/12 11 AM
End	6/16/12 12 PM
Weeks	12
Average Operational kW	4.14
% Operating Time	25.47%
Average kW/hp	0.28
Operational Threshold	0.10

Notes:

Post-VFD Installation Metering Period

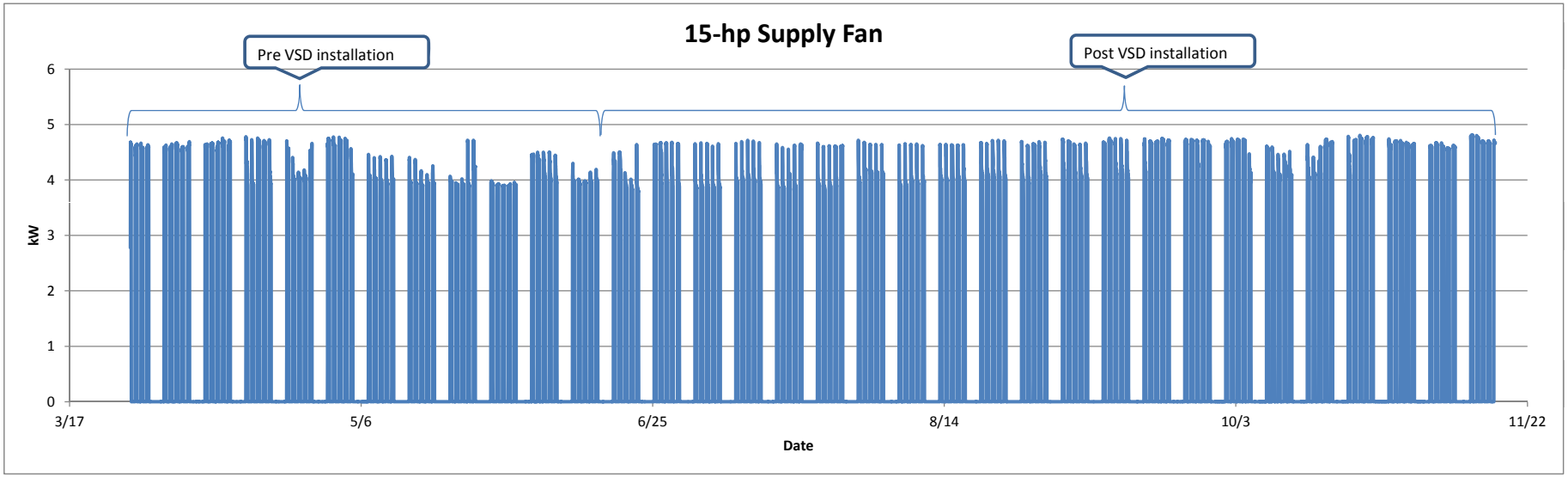
Start	6/16/12 1 PM
End	11/16/12 11 AM
Weeks	22
Average Operational kW	4.25
% Operating Time	25.65%
Average kW/hp	0.28
Operational Threshold	0.10

Notes:

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	9,162	9,473	-311	-
Summer kW	1.22	1.62	-0.41	-
Winter kW	0.00	0.00	0.00	-
Total kWh/HP	611	632	-21	-0.02
Summer kW/HP	0.08	0.11	-0.03	-0.42
Winter kW/HP	0.00	0.00	0.00	0.00

Trend Type: Weekday/Weekend



Site ID: 7
Facility Type: Elementary/High School
Motor Type: Supply Fan
Motor Size: 15 hp

Pre-VFD Installation Metering Period

Start	3/27/12 11 AM
End	6/16/12 3 AM
Weeks	12
Average Operational kW	5.52
% Operating Time	25.15%
Average kW/hp	0.37
Operational Threshold	0.1
Notes:	

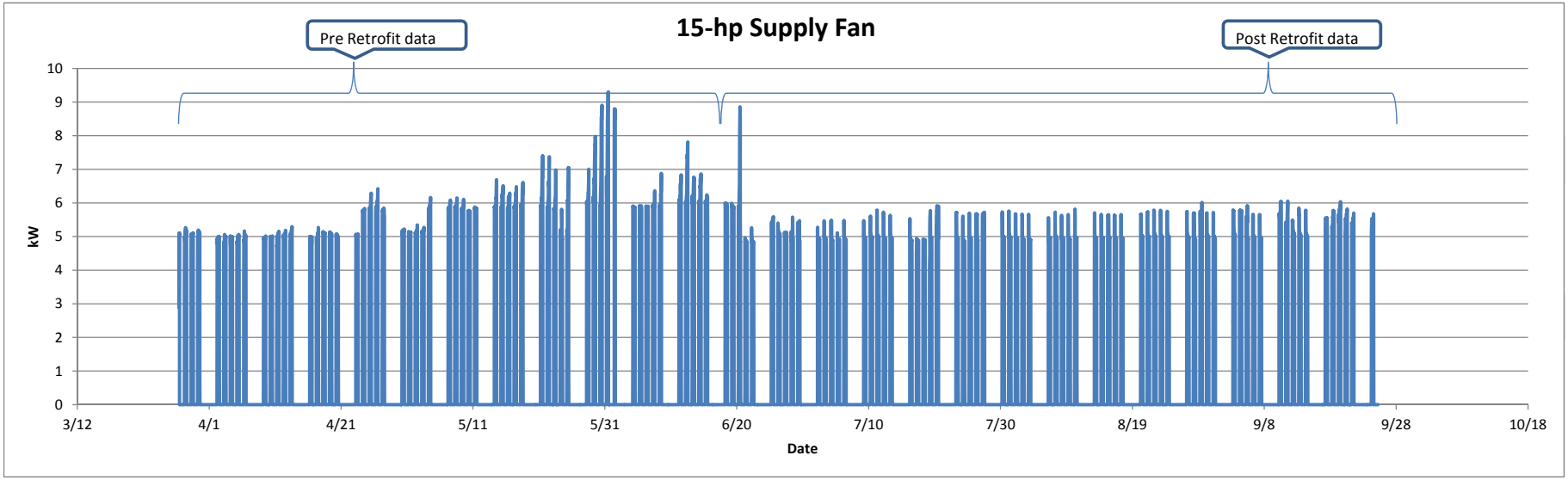
Post-VFD Installation Metering Period

Start	6/16/12 4 AM
End	9/25/12 5 AM
Weeks	14
Average Operational kW	5.08
% Operating Time	24.79%
Average kW/hp	0.34
Operational Threshold	0.1
Notes:	

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	11,945	11,184	761	-
Summer kW	1.50	1.68	-0.18	-
Winter kW	0.00	0.00	0.00	-
Total kWh/HP	796	746	51	0.06
Summer kW/HP	0.10	0.11	-0.01	-0.19
Winter kW/HP	0.00	0.00	0.00	0.00

Trend Type: Weekday/Weekend



Site ID: 8
Facility Type: University/College
Motor Type: CWP
Motor Size: 30 hp

Pre-VFD Installation Metering Period

Start	5/18/11 12 PM
End	6/20/11 9 AM
Weeks	5
Average Operational kW	16.88
% Operating Time	99.75%
Average kW/hp	0.56
Operational Threshold	0.10

Notes:

Post-VFD Installation Metering Period

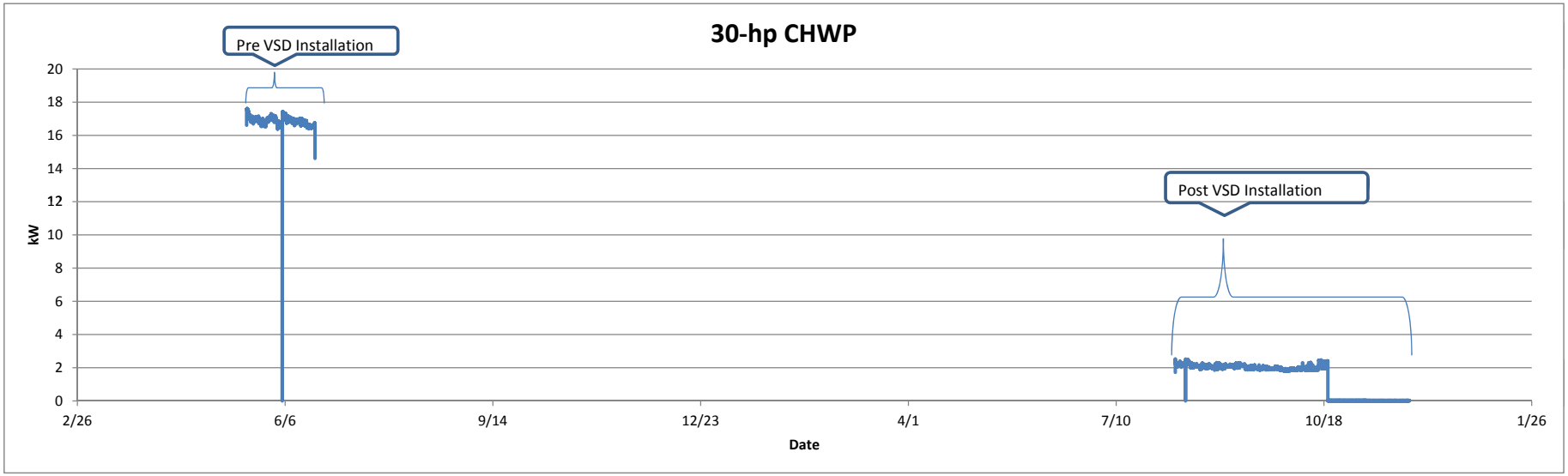
Start	8/7/12 12 PM
End	11/28/12 8 PM
Weeks	16
Average Operational kW	2.03
% Operating Time	65.10%
Average kW/hp	0.07
Operational Threshold	0.10

Notes:

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	98,636	7,753	90,883	-
Summer kW	16.81	1.43	15.38	-
Winter kW	0.00	0.00	0.00	-
Total kWh/HP	3,288	258	3,029	4.07
Summer kW/HP	0.56	0.05	0.51	9.15
Winter kW/HP	0.00	0.00	0.00	0.00

Trend Type: Weekday/Weekend



Site ID: 9
Facility Type: Office
Motor Type: HWCP
Motor Size: 40 hp

Pre-VFD Installation Metering Period

Start	4/9/11 12 AM
End	6/19/11 2 PM
Weeks	10
Average Operationa kW	35.16
% Operating Time	100.00%
Average kW/hp	0.88
Operational Threshold	0.10

Notes:

Post-VFD Installation Metering Period

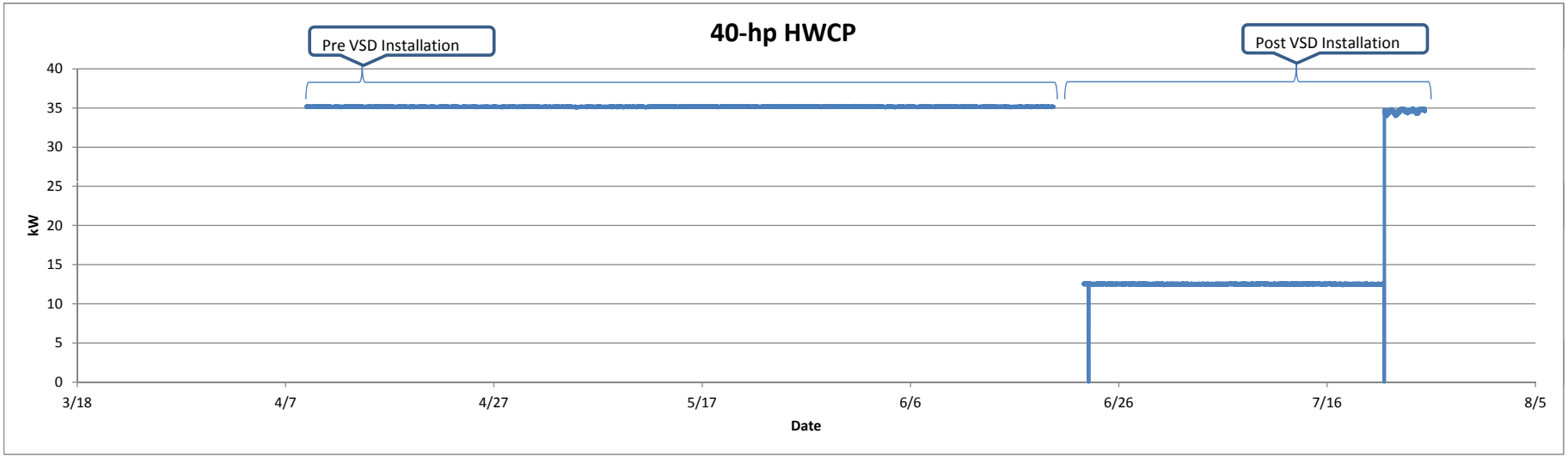
Start	6/23/11 12 PM
End	7/25/11 10 AM
Weeks	5
Average Operational kW	15.24
% Operating Time	99.96%
Average kW/hp	0.38
Operational Threshold	0.10

Notes:

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	300,440	128,130	172,310	-
Summer kW	35.16	14.24	20.92	-
Winter kW	35.17	14.43	20.74	-
Total kWh/HP	7,511	3,203	4,308	1.33
Summer kW/HP	0.88	0.36	0.52	9.34
Winter kW/HP	0.88	0.36	0.52	1.24

Trend Type: Daily



Site ID: 10
Facility Type: Warehouse
Motor Type: MAF
Motor Size: 25 hp

Pre-VFD Installation Metering Period

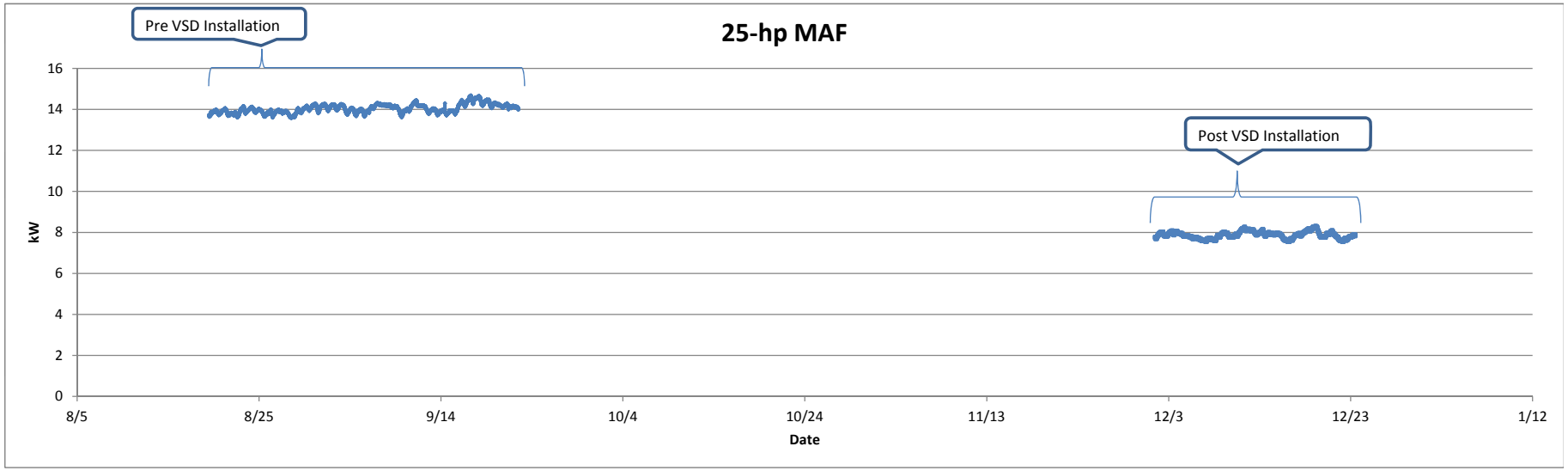
Start	8/19/11 12 PM
End	9/22/11 12 PM
Weeks	5
Average Operational kW	14.04
% Operating Time	100.00%
Average kW/hp	0.56
Operational Threshold	0.1
Notes:	

Post-VFD Installation Metering Period

Start	12/1/11 12 PM
End	12/23/11 12 PM
Weeks	3
Average Operational kW	7.88
% Operating Time	100.00%
Average kW/hp	0.32
Operational Threshold	0.1
Notes:	

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	122,977	69,059	53,918	-
Summer kW	13.92	7.78	6.14	-
Winter kW	13.98	7.80	6.18	-
Total kWh/HP	4,919	2,762	2,157	0.67
Summer kW/HP	0.56	0.31	0.25	0.94
Winter kW/HP	0.56	0.31	0.25	0.95
Trend Type: Daily				



Site ID: 11
Facility Type: Retail
Motor Type: Supply Fan
Motor Size: 20 hp

Pre-VFD Installation Metering Period

Start	2/3/12 12 PM
End	2/12/12 6 PM
Weeks	1
Average Operational kW	9.68
% Operating Time	42.79%
Average kW/hp	0.48
Operational Threshold	0.1

Notes:
VFD installed in pre-retrofit case (replacement)
Insufficient pre-retrofit data for accurate extrapolation

Post-VFD Installation Metering Period

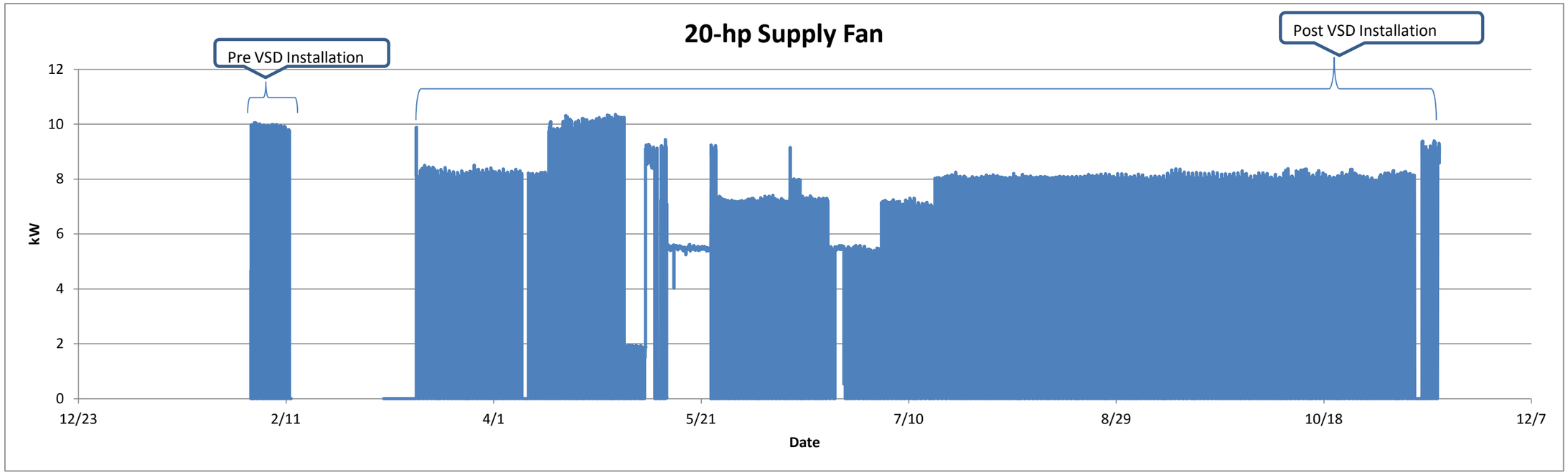
Start	3/5/12 12 PM
End	11/14/12 5 PM
Weeks	36
Average Operational kW	7.49
% Operating Time	46.96%
Average kW/hp	0.37
Operational Threshold	0.1

Notes:

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	30,744	30,744	0	-
Summer kW	7.39	7.39	0	-
Winter kW	7.43	7.43	0	-
Total kWh/HP	1,537	1,537	0	0.00
Summer kW/HP	0.37	0.37	0	0.00
Winter kW/HP	0.37	0.37	0	0.00

Trend Type: Weekday/Weekend



Site ID: 11
Facility Type: Retail
Motor Type: Supply Fan
Motor Size: 20 hp

Pre-VFD Installation Metering Period

Start	2/3/12 12 PM
End	2/12/12 6 PM
Weeks	1
Average Operational kW	11.95
% Operating Time	45.94%
Average kW/hp	0.60
Operational Threshold	0.1

Notes:

Post-VFD Installation Metering Period

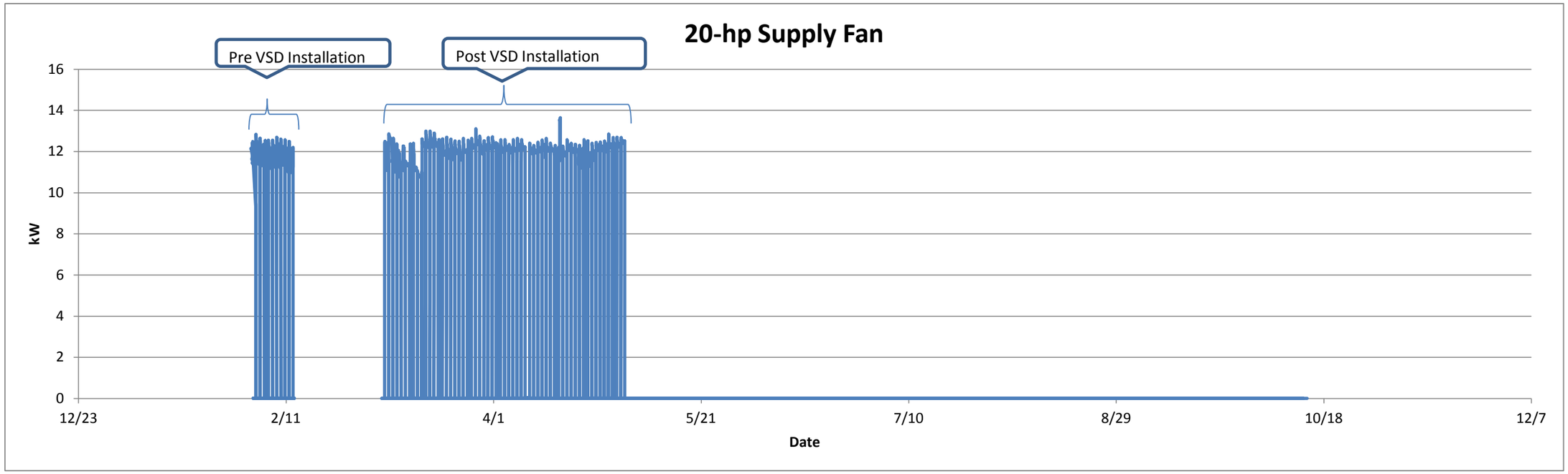
Start	3/5/12 12 PM
End	11/14/12 5 PM
Weeks	36
Average Operational kW	11.95
% Operating Time	9.94%
Average kW/hp	0.60
Operational Threshold	0.1

Notes:
Inaccurate kW data collected. This VSD replaced an existing VSD.
No other changes were made. Realization ratios assumed to be 1.00

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	47,482	47,482	0	-
Summer kW	12.12	12.12	0.00	-
Winter kW	12.02	12.02	0.00	-
Total kWh/HP	2,374	2,374	0	0.00
Summer kW/HP	0.61	0.61	0.00	0.00
Winter kW/HP	0.60	0.60	0.00	0.00

Trend Type: Weekday/Weekend



Site ID: 12
Facility Type: Office
Motor Type: CWP
Motor Size: 25 hp

Pre-VFD Installation Metering Period

Start	8/9/11 10 AM
End	10/24/11 8 AM
Weeks	11
Average Operational kW	15.92
% Operating Time	38.95%
Average kW/hp	0.64
Operational Threshold	0.1

Notes:

Post-VFD Installation Metering Period

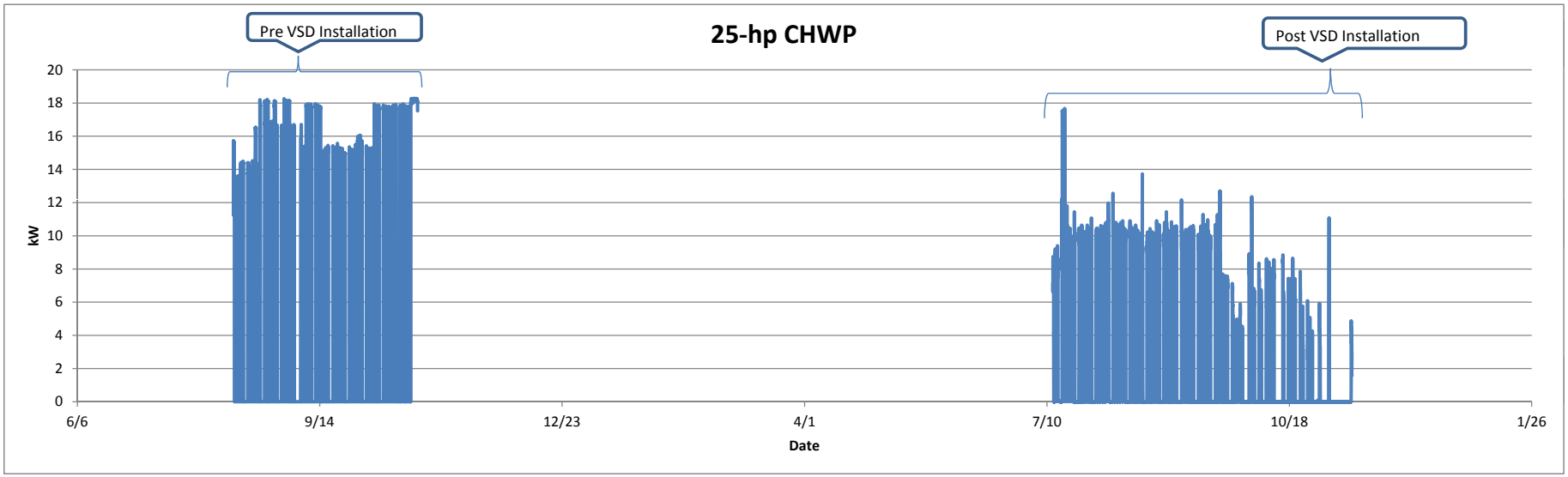
Start	7/12/12 11 AM
End	11/12/12 6 PM
Weeks	18
Average Operational kW	8.43
% Operating Time	30.64%
Average kW/hp	0.34
Operational Threshold	0.1

Notes:

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	36,490	15,069	21,420	-
Summer kW	15.53	6.92	8.61	-
Winter kW	0.00	0.00	0.00	-
Total kWh/HP	1,460	603	857	0.63
Summer kW/HP	0.62	0.28	0.34	6.15
Winter kW/HP	0.00	0.00	0.00	0.00

Trend Type: Weekday/Weekend



Site ID: 12
Facility Type: Office
Motor Type: CWP
Motor Size: 7.5 hp

Pre-VFD Installation Metering Period

Start	8/9/11 12 PM
End	9/1/11 6 PM
Weeks	3
Average Operational kW	5.75
% Operating Time	43.57%
Average kW/hp	0.77
Operational Threshold	0.1

Notes:

Post-VFD Installation Metering Period

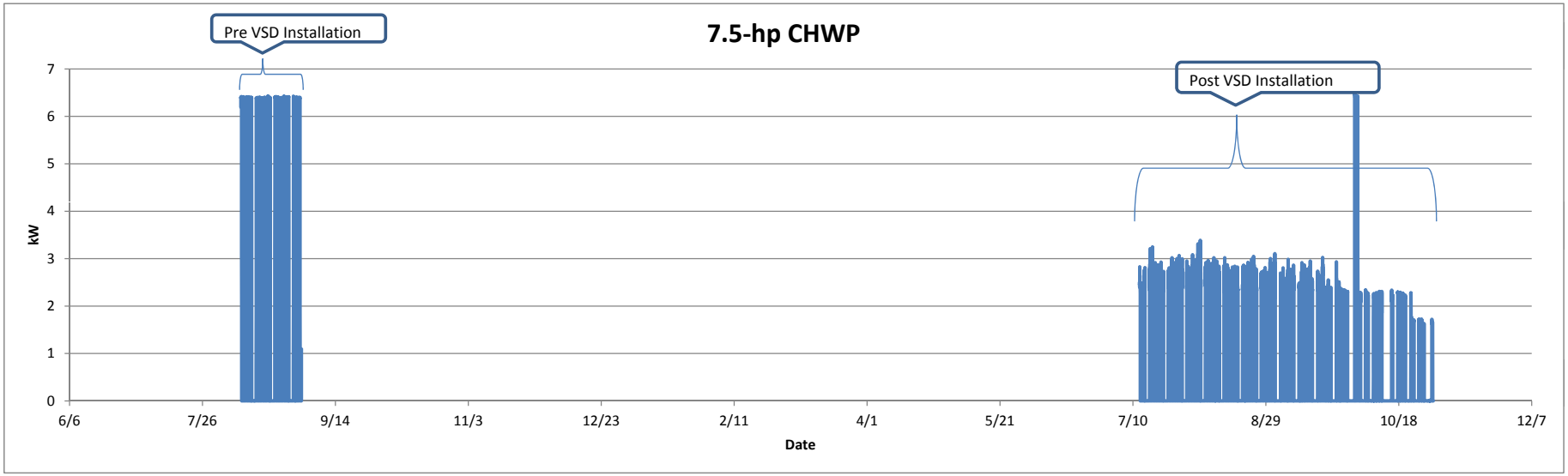
Start	7/12/12 12 PM
End	10/30/12 5 PM
Weeks	16
Average Operational kW	2.44
% Operating Time	30.90%
Average kW/hp	0.32
Operational Threshold	0.1

Notes:

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	13,996	4,373	9,624	-
Summer kW	6.40	2.20	4.20	-
Winter kW	0.00	0.00	0.00	-
Total kWh/HP	1,866	583	1,283	0.94
Summer kW/HP	0.85	0.29	0.56	10.00
Winter kW/HP	0.00	0.00	0.00	0.00

Trend Type: Weekday/Weekend



Site ID: 12
Facility Type: Office
Motor Type: CTF
Motor Size: 10 hp

Pre-VFD Installation Metering Period

Start	8/9/11 10 AM
End	9/27/11 2 PM
Weeks	7
Average Operational kW	5.28
% Operating Time	4.36%
Average kW/hp	0.53
Operational Threshold	0.10

Notes:

Post-VFD Installation Metering Period

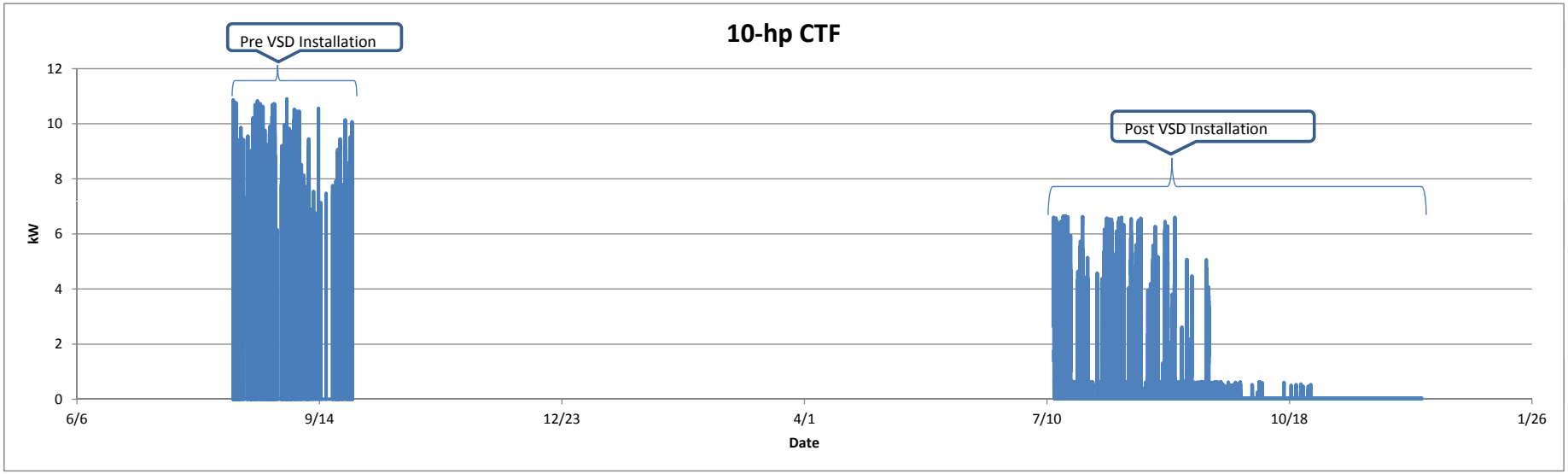
Start	7/12/12 12 PM
End	12/11/12 11 AM
Weeks	22
Average Operational kW	1.93
% Operating Time	18.95%
Average kW/hp	0.19
Operational Threshold	0.10

Notes:

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	1,330	2,252	-922	-
Summer kW	0.65	1.39	-0.74	-
Winter kW	0.00	0.00	0.00	-
Total kWh/HP	133	225	-92	-0.10
Summer kW/HP	0.07	0.14	-0.07	3.21
Winter kW/HP	0.00	0.00	0.00	0.00

Trend Type: Weekday/Weekend



Site ID: 13
Facility Type: University/College
Motor Type: CHWP
Motor Size: 75 hp

Pre-VFD Installation Metering Period

Start	6/15/11 11 AM
End	9/30/11 11 PM
Weeks	15
Average Operational kW	47.81
% Operating Time	59.15%
Average kW/hp	0.64
Operational Threshold	1.00

Notes:

Post-VFD Installation Metering Period

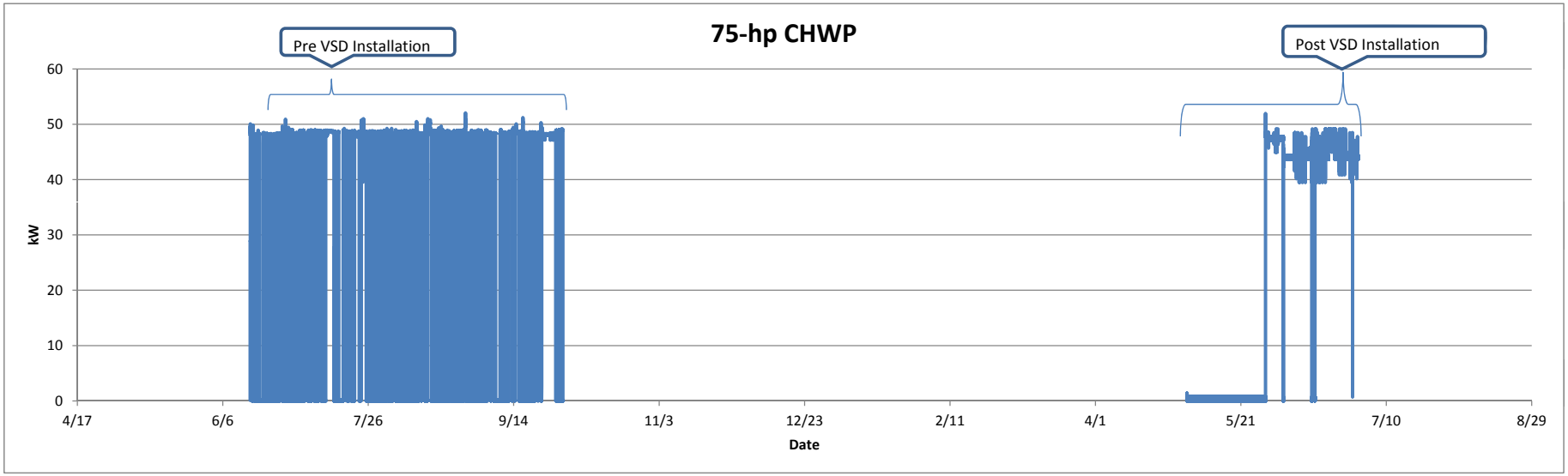
Start	5/2/12 12 PM
End	6/30/12 6 AM
Weeks	8
Average Operational kW	45.20
% Operating Time	53.97%
Average kW/hp	0.60
Operational Threshold	1.00

Notes:

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	166,137	143,520	22,617	-
Summer kW	38.80	25.20	13.60	-
Winter kW	0.00	0.00	0.00	-
Total kWh/HP	2,215	1,914	302	0.40
Summer kW/HP	0.52	0.34	0.18	3.24
Winter kW/HP	0.00	0.00	0.00	0.00

Trend Type: Weekday/Weekend



Site ID: 13
Facility Type: University/College
Motor Type: CWP
Motor Size: 75 hp

Pre-VFD Installation Metering Period

Start	6/16/11 12 PM
End	9/30/11 12 AM
Weeks	15
Average Operational kW	48.69
% Operating Time	99.88%
Average kW/hp	0.65
Operational Threshold	1.00
Notes:	

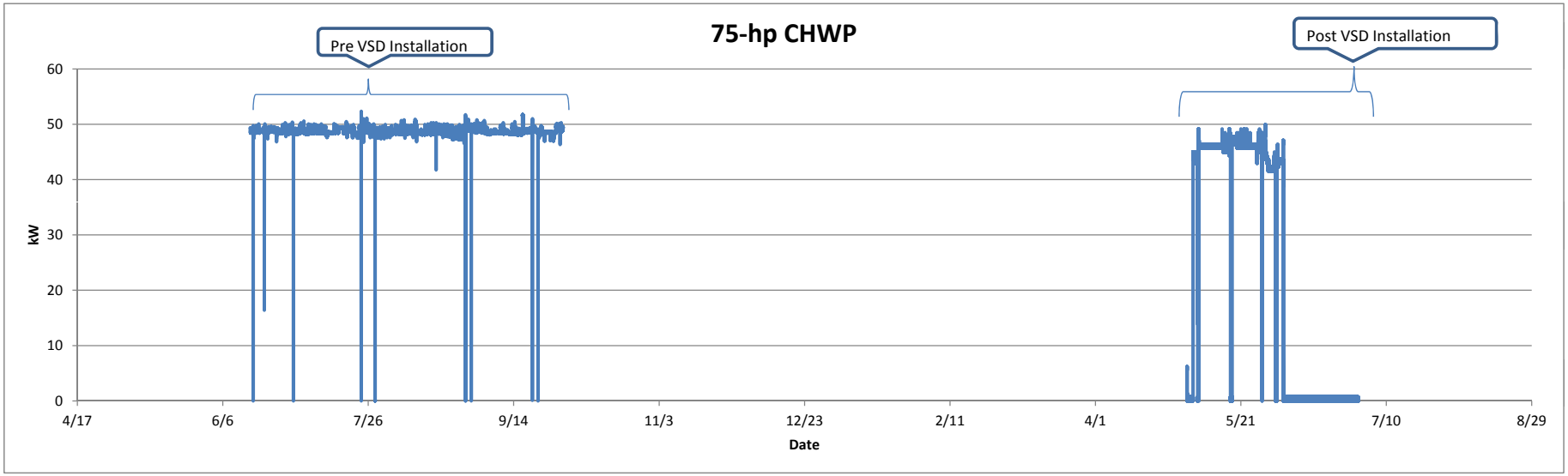
Post-VFD Installation Metering Period

Start	5/4/12 1 PM
End	6/4/12 12 PM
Weeks	4
Average Operational kW	45.38
% Operating Time	96.61%
Average kW/hp	0.61
Operational Threshold	1.00
Notes:	

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	284,779	256,777	28,002	-
Summer kW	48.57	43.10	5.47	-
Winter kW	0.00	0.00	0.00	-
Total kWh/HP	3,797	3,424	373	0.50
Summer kW/HP	0.65	0.57	0.07	1.30
Winter kW/HP	0.00	0.00	0.00	0.00

Trend Type: Weekday/Weekend



Site ID: 14
Facility Type: Elementary/High School
Motor Type: Supply Fan
Motor Size: 40 hp

Pre-VFD Installation Metering Period

Start	3/27/12 10 AM
End	5/19/12 1 AM
Weeks	8
Average Operational kW	17.47
% Operating Time	21.69%
Average kW/hp	0.44
Operational Threshold	0.1

Notes:

Post-VFD Installation Metering Period

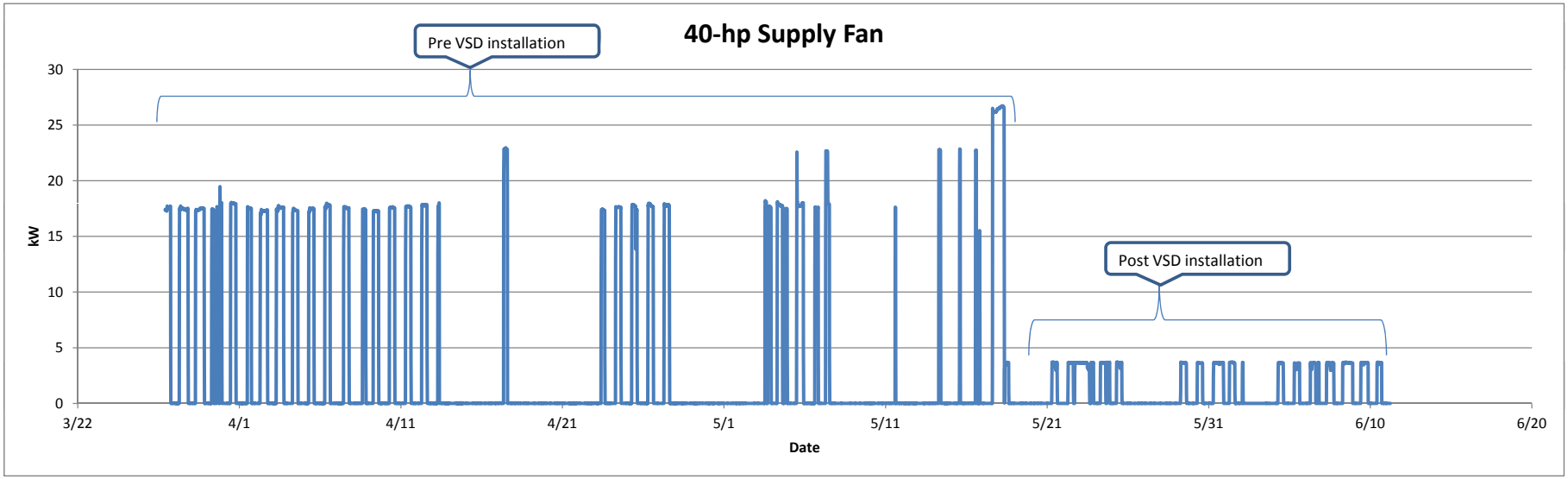
Start	5/19/12 3 AM
End	6/11/12 5 AM
Weeks	3
Average Operational kW	3.53
% Operating Time	31.86%
Average kW/hp	0.09
Operational Threshold	0.1

Notes:

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	32,474	10,680	21,794	-
Summer kW	6.77	2.18	4.58	-
Winter kW	3.12	1.43	1.70	-
Total kWh/HP	812	267	545	0.65
Summer kW/HP	0.17	0.05	0.11	1.79
Winter kW/HP	0.08	0.04	0.04	0.38

Trend Type: Weekday/Weekend



Site ID: 15
Facility Type: Elementary/High School
Motor Type: Supply Fan
Motor Size: 10 hp

Pre-VFD Installation Metering Period

Start	5/23/11 3 PM
End	6/15/11 4 PM
Weeks	3
Average Operational kW	3.46
% Operating Time	46.79%
Average kW/hp	0.35
Operational Threshold	0.1
Notes:	

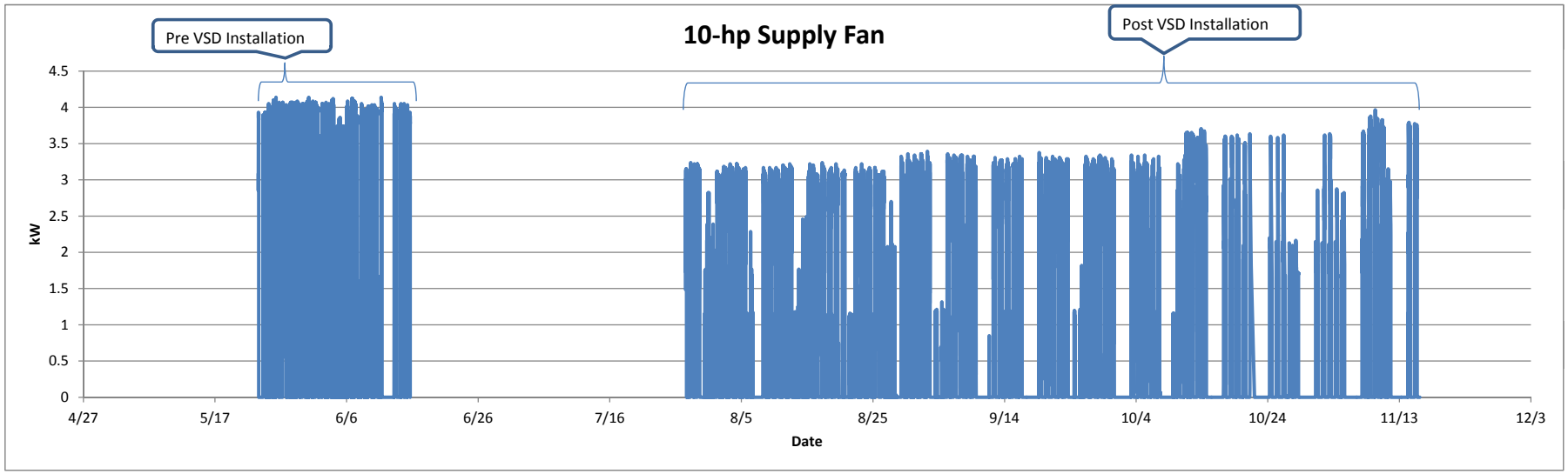
Post-VFD Installation Metering Period

Start	7/27/11 11 AM
End	1/25/12 1 PM
Weeks	26
Average Operational kW	2.58
% Operating Time	31.22%
Average kW/hp	0.26
Operational Threshold	0.1
Notes:	

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	13,822	7,058	6,764	-
Summer kW	3.16	2.31	0.86	-
Winter kW	1.39	0.14	1.26	-
Total kWh/HP	1,382	706	676	0.81
Summer kW/HP	0.32	0.23	0.09	1.34
Winter kW/HP	0.14	0.01	0.13	1.11

Trend Type: Weekday/Weekend



Site ID: 15
Facility Type: Elementary/High School
Motor Type: Supply Fan
Motor Size: 7.5 hp

Pre-VFD Installation Metering Period

Start	5/23/11 2 PM
End	7/9/11 4 AM
Weeks	7
Average Operational kW	4.34
% Operating Time	60.01%
Average kW/hp	0.58
Operational Threshold	0.10

Notes:

Post-VFD Installation Metering Period

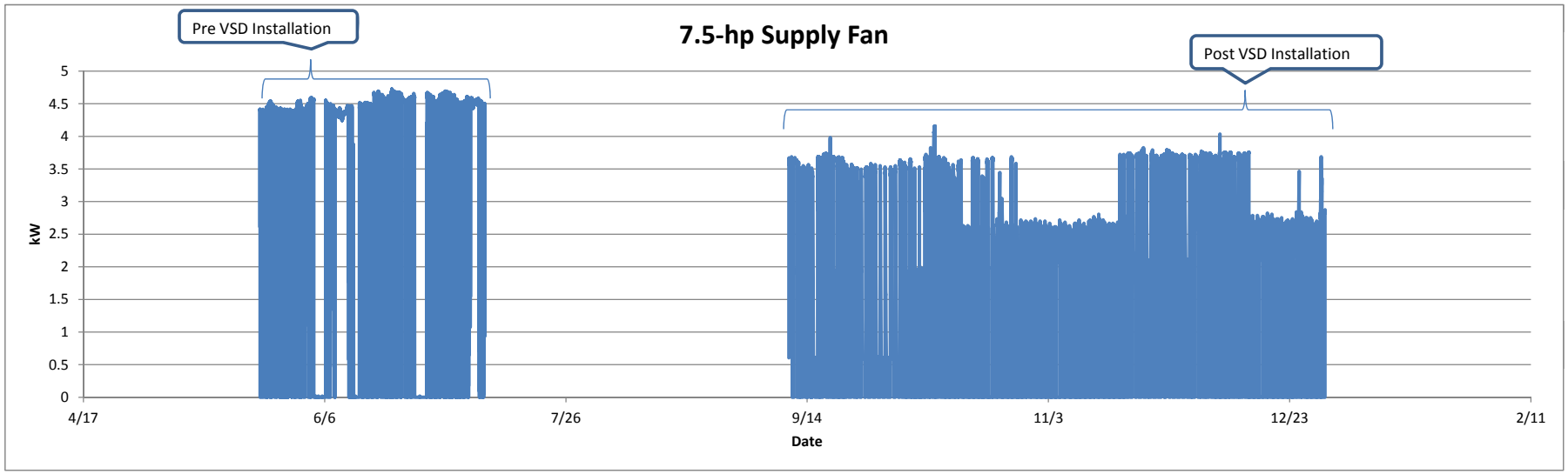
Start	9/10/11 6 AM
End	1/25/12 1 PM
Weeks	20
Average Operational kW	2.70
% Operating Time	43.67%
Average kW/hp	0.36
Operational Threshold	0.10

Notes:

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	22,326	10,246	12,080	-
Summer kW	2.86	1.63	1.23	-
Winter kW	0.94	0.07	0.88	-
Total kWh/HP	2,977	1,366	1,611	1.92
Summer kW/HP	0.38	0.22	0.16	2.56
Winter kW/HP	0.13	0.01	0.12	1.04

Trend Type: Weekday/Weekend



Site ID: 16
Facility Type: Health
Motor Type Supply Fan
Motor Size: 20 hp

Pre-VFD Installation Metering Period

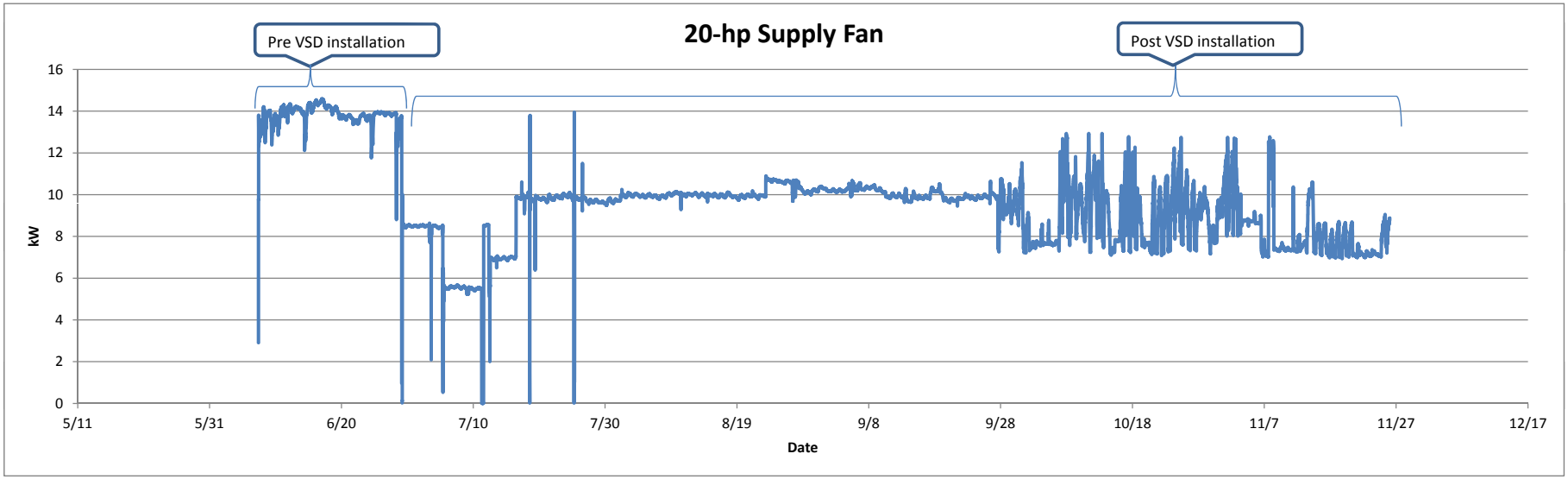
Start	6/7/12 10 AM
End	6/29/12 4 AM
Weeks	3
Average Operational kW	13.80
% Operating Time	99.90%
Average kW/hp	0.69
Operational Threshold	0.1
Notes:	

Post-VFD Installation Metering Period

Start	6/29/12 5 AM
End	11/26/12 1 AM
Weeks	21
Average Operational kW	9.11
% Operating Time	99.76%
Average kW/hp	0.46
Operational Threshold	0.1
Notes:	

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	120,920	79,720	41,200	-
Summer kW	13.67	8.94	4.73	-
Winter kW	13.77	9.09	4.69	-
Total kWh/HP	6,046	3,986	2,060	1.39
Summer kW/HP	0.68	0.45	0.24	3.70
Winter kW/HP	0.69	0.45	0.23	2.07
Trend Type: Daily				



Site ID: 17 **Facility Type: University/College** **Motor Type:** HWCP
Motor Size: 7.5 hp

Pre-VFD Installation Metering Period

Start	3/31/2011
End	4/22/2011
Weeks	3
Average Operational kW	4.66
% Operating Time	99%
Average kW/hp	0.62
Operational Threshold	0.10

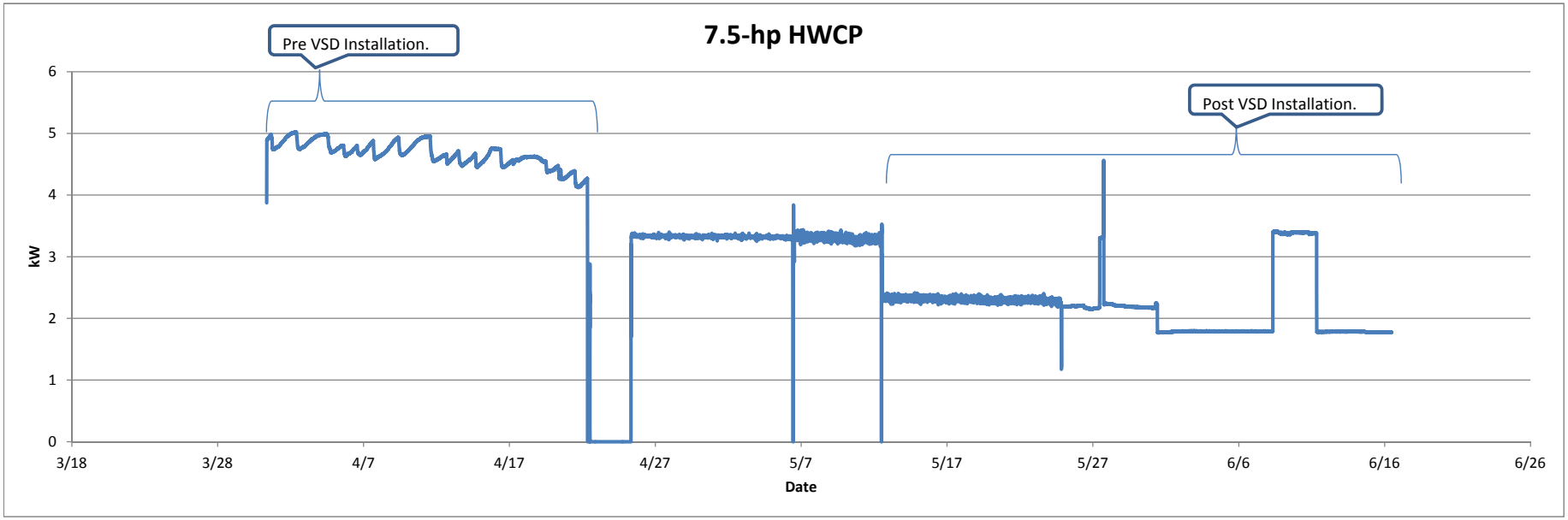
Notes:

Post-VFD Installation Metering Period

Start	5/13/2011
End	6/16/2011
Weeks	5
Average Operational kW	2.20
% Operating Time	100%
Average kW/hp	0.29
Operational Threshold	0.10

Notes:

Calculated Results

Parameter	Base	Installed	Savings	RR
Total kWh	39,369	18,826	20,543	-
Summer kW	4.41	2.28	2.13	-
Winter kW	4.58	2.28	2.30	-
Total kWh/HP	5,249	2,510	2,739	1.17
Summer kW/HP	0.59	0.30	0.28	0.62
Winter kW/HP	0.61	0.30	0.31	0.67

Trend Type: Daily