THESIS

EVALUATING HIGH SCHOOL ELECTRICITY CONSUMPTION AND EXPENDITURE INTENSITY IN THE POUDRE SCHOOL DISTRICT OF NORTHERN COLORADO

Submitted by

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WE HEREBY RECOMMEND THAT THE THESIS PERPARED UNDER OUR SUPERVISION BY JONATHAN W. ELLIOTT ENTITLED EVALUATING HIGH SCHOOL ELECTRICTY CONSUMPTION AND EXPENDITURE INTENSITY IN THE POUDRE SCHOOL DISTRICT OF NORTHERN COLORADO BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

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ABSTRACT OF THESIS

EVALUATING HIGH SCHOOL ELECTRICITY CONSUMPTION AND EXPENDITURE INTENSITY IN THE POUDRE SCHOOL DISTRICT OF NORTHERN COLORADO

With the exception of personnel-related expenditures, utilities represent the largest cost in school budgets, but are one area where expenses can be trimmed without compromising educational quality (Consortium for Energy Efficiency, 2005). In the Poudre School District of Northern Colorado, Fort Collins High School (FCHS) and Fossil Ridge High School (FRHS) have similar building attributes (square footage, mechanical systems, and architectural capacities). In contrast to FCHS (built 1995), FRHS (built 2005) has many energy efficiency features and is LEED-Silver and Energy-Star (2009) certified. Yet in recent years, the electricity costs and electric use intensities (EUIs) were comparable. The purpose of this study was, therefore, to evaluate electricity consumption to understand electric use patterns at these schools.

Overall analysis indicated significantly more electricity use for lighting at FCHS (44.04% of total) when compared to FRHS (36.90% to total). Also, HVAC represents 33.16% at FCHS compared to 29.17% at FRHS. However, plug loads account for 24.99% of use at FRHS but only 16.35% at FCHS.

Comparing energy performance using whole-building EUI (total annual electric consumption divided by total conditioned floor area) ignores secondary building

characteristics that influence consumption. In order to improve the whole building EUI and identify areas of high consumption, individual workspace EUIs were separated for analysis. Variations in workspace specific floor areas and workspace EUIs were seen at both schools. Workspace EUI values ranged from 2.60 kWh/ft^2/yr in closet/storage spaces to 40.68 kWh/ft^2/yr in the kitchen workspaces.

Further, workspace EUIs were partitioned into their HVAC, lighting, plug load, food service and residual components for analysis. Component EUI analysis indentified major consumptive differences at the two schools: High for lighting in the trades classrooms and gymnasium at FCHS and high for plug loads in the computer labs at FRHS. Since both high schools have the same educational goals, overly consumptive component EUIs (in one school compared to the other) indicate workspaces where reductions in electric consumption may be possible without detrimental effects on education quality.

Educational workspace distribution and the amount of electricity-consuming equipment vary between the schools and hence traditional whole-building EUI (total consumption/total conditioned floor space) must be interpreted with caution. Major differences in the component EUIs observed between the two schools indicated that the high-wattage lighting in the trades classroom and gymnasium at FCHS and the computer density at FRHS should be investigated for possible renovations to reduce electric use at these schools.

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Introduction

The escalating cost of energy is forcing businesses and institutions to look for ways to increase energy efficiency and reduce consumption. This is particularly important for public-sector organizations, like K-12 school districts, where expenditures are subject to public scrutiny and approval. With the exception of personnel costs, schools spend more on energy than any other expense (Consortium for Energy Efficiency (CEE), 2005). According to the U.S. Department of Energy (USDOE, 2008), the annual energy bill to run primary and secondary school buildings in the United States in 2007 was $6 billion, more than the total expenditures for textbooks and computers combined (Energy Star, 2008). As energy costs increase, reducing energy consumption is one way to control a school's operating cost without compromising educational quality (CEE, 2005). If the nation's schools were to reduce energy expenditures by 25% the resultant savings (~$1.5 billion) could pay for 30,000 new teachers or 40 million new textbooks each year (CEE, 2005).

Recent increases in energy costs and the proliferation of sustainable design and building concepts have brought energy consumption to the forefront for public schools. School districts working with limited budgets funded by taxpayer dollars must maintain financial transparency with the public and therefore must justify their energy consumption costs. While proactive school districts have been tracking energy consumption for decades, recently developed scoring systems for sustainability and energy consumption have provided methods by which all schools can be compared to a national standard.

Since the inception of energy usage benchmarks for K-12 school buildings, several school districts have adopted the Energy Star system as a tool for monitoring and improving energy performance. The Poudre School District (PSD) of Fort Collins, Colorado has used the Energy Star management system as a tool to identify high use and reduce energy consumption and operational costs. The PSD has been tracking energy usage for each of its schools (and associated buildings) for the past 16 years and has used the Energy Star benchmark as a measuring tool since its inception in 2000 (Reeve, personal communication, May 29, 2009). As of 2008, PSD operates 46 schools, of which 26 have been recognized by the United States Department of Energy (DOE) and Environmental Protection Agency (EPA) with the Energy Star label (Energy Star, 2009).

In addition to Energy Star labeling, PSD has pursued the Leadership in Energy and Environmental Design (LEED) certification for several of its new construction projects. Currently PSD has two LEED-certified schools: Fossil Ridge High School (FRHS), constructed in 2005, was the first school in Colorado to achieve the LEED for New Construction (LEED-NC) Silver certification; and Bethke Elementary, constructed in 2008, was the first school in the nation to achieve the LEED for Schools Gold certification (USGBC, 2009). According to the United States Green Building Council (USGBC), FRHS is 60% more energy efficient than comparable buildings within the district because of its innovative sustainable design (USGBC, 2009). Preliminary review of energy use data provided by PSD indicates that in 2008, FRHS made up 8.2% of the total square footage of all district schools but accounted for only ~5.5% of total energy consumption.

If FRHS were constructed as a conventional high school, meeting only the minimum requirement for American Society for Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) 90.1 standard, its energy consumption would increase by approximately 59% (Bradley, Dunbar and Plaut, 2006). This additional energy consumption at FRHS would equate to an overall increase of 3.0% in total energy usage for PSD. The energy consumption of newly constructed schools, which is being addressed by PSD using the LEED evaluation system, clearly has an impact on total energy use. However, the majority of the district's energy consumption occurs in existing buildings. Therefore, something must be done to reduce the energy consumption in existing schools to have a major impact on total district energy use.

PSD recognizes the need to go beyond achieving sustainability certifications such as LEED for its new construction projects. Targeting the energy consumption of existing school buildings is paramount in order to reduce energy use and cost throughout the school district. PSD has an active program and staff that works to achieve energy consumption and cost reductions in their existing schools through several techniques, including reducing HVAC runtimes, optimizing HVAC system temperature set-points (70° F for cooling, 65° F heating), changing lighting ballast, integrating web-based HVAC control systems and increasing student awareness. Through the use of these and other techniques, PSD had been able to reduce the electricity consumption of Fort Collins High School (FCHS) by an average of 130,006 kWh per year since 2000. This reduction represents a total of 1,040,000 kWh or 36% reduction in annual electricity from 2000 at

FCHS. Table 1 shows the electricity and gas usages for FCHS and FRHS for 2008. In terms of total energy, FRHS used ~61% of the amount used at FCHS. But, it is noted that most (~84%) of the total energy difference between the two schools is due to lower natural gas usage at FRHS. Only about 16% of the superior energy performance at FRHS is due to a lower consumption of electricity.

Both high schools experience the same climate and have similar building attributes (square footage, mechanical systems, and architectural capacities) and student enrollments. Whereas FRHS is LEED Silver/Energy Star certified, FCHS is not. Yet, the 2006-2008 average

Table 1: Distribution of energy use at FCHS and FRHS for 2008 (kBTU/yr)

High School	Gas (% of total)	Electricity (% of total)	Total
Fort Collins	12,692,690 (62.2%)	7,399,933 (37.8%)	20,396,793
Fossil Ridge	6,438,633 (50.1%)	6,220,735 (49.9%)	12,470,013
Difference	6,254,057 (84.1%)	1,179,198 (15.9%)	7,433,255

electric use intensity (EUI) was similar: 6.46 kWh/ft^2/yr at FRHS and 7.93 kWh/ft^2/yr for FCHS. Moreover, the annual 2005-2008 average electricity costs were comparable ($0.43 and $0.46 per ft^2 for FRHS and FCHS, respectively). FRHS, built in 2005, has certain energy efficiency features (perimeter daylighting, off-peak ice production for cooling, photovoltaic panel systems, newer HVAC equipment with energy wheels) that are not present at FCHS (built 1995).

The comparable electricity consumption values raise some interesting questions. On the basis of similar gross energy performance parameters (e.g., Electric Use Intensity

(EUI) and annual electricity cost per ft^2), it could be concluded that the schools are not substantially different in terms of electricity use efficiency. However, despite similar total building square footage values, the use of the educational workspace could be significantly different. This issue can be addressed by a detailed evaluation and comparison of the way in which electricity is used in FRHS and FCHS.

Therefore, the overall purpose of this investigation is to analyze electricity end-use profiles of FCHS and FRHS and provide insight into the annual electricity use at these two high schools. Specific research questions for this thesis are:

Research Questions:

1. What are the major uses of electricity (HVAC, lighting, food service, plug loads) at FCHS and FRHS and how much do they contribute to total energy consumption?
2. What are the major non-HVAC electricity consumers in the different types of educational workspace (classrooms, administrative, computer laboratories, kitchen, commons, storage, theater, etc.) for FCHS and FRHS?
3. Is overall EUI, total electricity use per total area (i.e., kWh/ft^2), an accurate stand-alone measure for comparing the electric performance of FRHS and FCHS?

Beyond the critical analysis of electricity consumption at these two high schools, the study aims to provide insight into reliable methods for quantifying energy performance in schools based on differential workspace usage. Findings should be useful for design decisions for new construction and targeting electricity conservation efforts for future improvements in energy performance in existing buildings. Ultimately, it is hoped that the study results will assist school districts in lowering energy consumption thereby freeing funds for investments which directly improve educational quality.

Literature Review

Energy Use in Schools

Aside from salaries and benefits, most public school budgets include more utility expenditures than any other single line item (CEE, 2005). As energy costs become larger and less predictable, school district must invest in retrofits and ongoing maintenance to gain control over their utility expenditures; yet school districts perpetually struggle to budget appropriately for operations, maintenance and capital improvement projects (Energy Star, 2006). Gaining funding for capital improvement projects can be difficult within school districts because operations and capital investments budgets are often separate making it difficult to link retrofit capital dollars with savings in school operation budgets (CEE, 2005). In addition, cuts in high-dollar capital project and maintenance budgets are traditionally more palatable to school boards then reductions in teaching staff or instructional materials (Energy Star, 2006).

Based on national averages, the distribution of electricity consumption in K-12 schools is weighted heavily toward three areas: space cooling (26%); lighting (26%); and plug load for office equipment, computers, etc (20%); while the vast majority of natural gas consumption is linked to space heating (82%) (Energy Star, 2006) (Figure 1). The annual Energy Intensity (EI) (BTU/ft^2) for a specific school building can vary greatly (ranging from 10,000 BTU/ft^2 to as much as 500,000 BTU/ft^2) due to factors including weather, building size, classroom seating capacity, and the presence of on-site food service facilities (Energy star, 2006). There are limitations associated with expressing energy usage solely on a floor-area basis since other building parameters, such as ceiling height and glass-to-wall ratio affect heating requirements (Szalay, 2008). Without considering variations in building characteristics, a national sampling of K-12 schools collected by EPA/Energy Star indicated that the median energy usage from all energy sources is 68,700 BTU/ft^2 (Energy Star, 2006) (Figure 2).

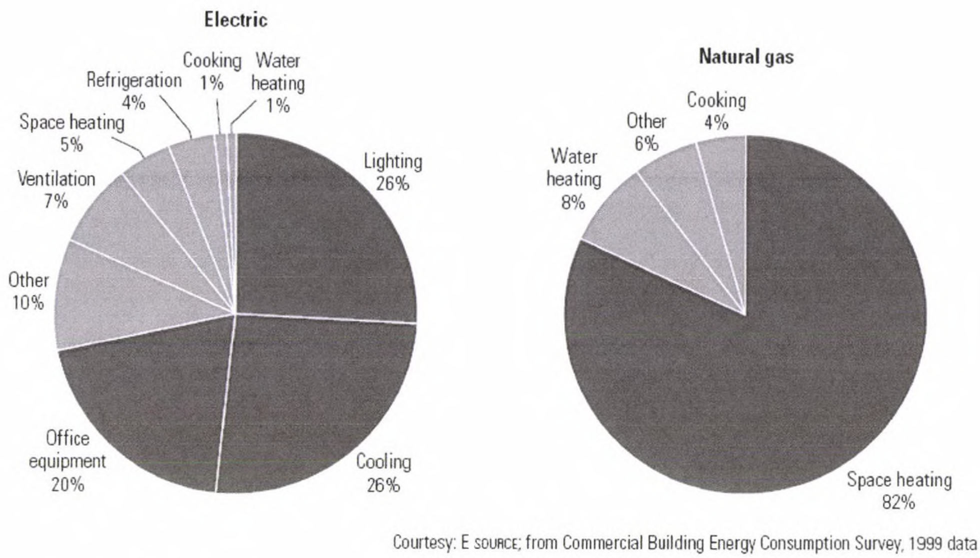

Figure 1: K-12 National Average Electricity and Natural Gas Usage Distribution

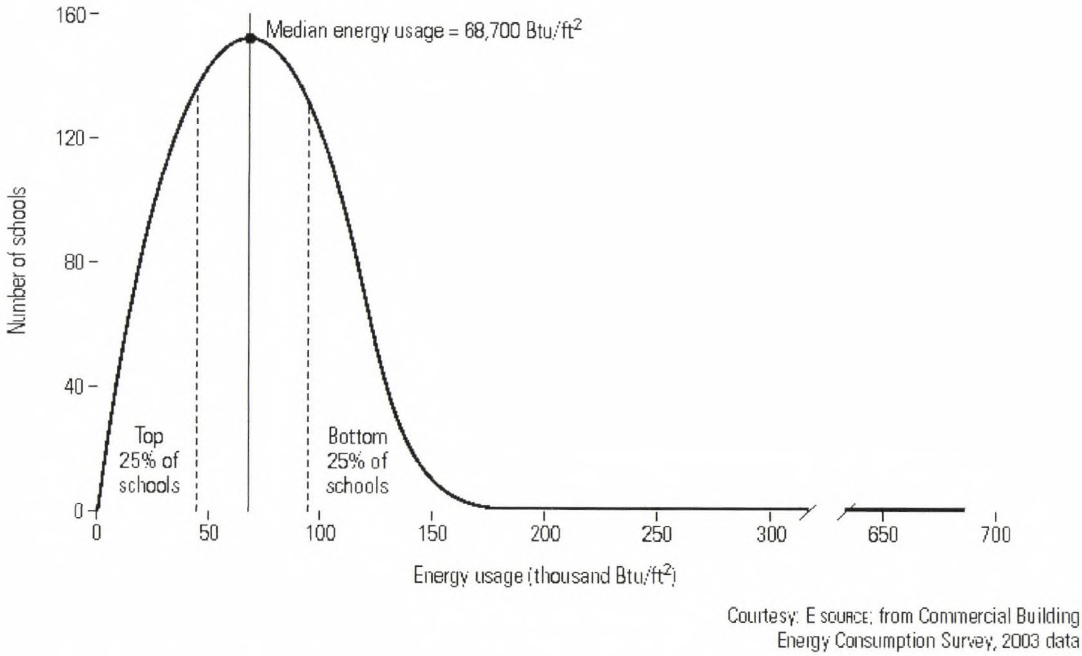

Figure 2: K-12 Schools Annual Energy Intensity Distribution

According to the U.S. House of Representatives, "The country is experiencing an energy crisis characterized by rapid and drastic price increases as well as threatened shortages" (U.S. Congress, 2006). The United States Energy Information Administration (USEIA) indicates that electricity expenses for commercial buildings have increased by 23% from an average cost of $0.0726 per kWh in 1999 to $0.0965 per kWh in 2007. The current trends show electricity costs are increasing by an average 2.35% percent per year with increases as high a 7% seen between 2000 and 2001(USEIA, 2009) (Table 2). In light of energy cost trends, school districts have several options to compensate for increasing cost of operation. They can reduce their energy consumption, increase funding through taxes or other programs to increase capital or make budget cuts in other areas which ultimately lower educational quality.

Table 2: National Average Electricity Retail Prices (cents/kWh) 2007-1996

Average Retail Price (cents per kilowatthour)	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996
Residential	10.65	10.40	9.45	8.95	8.72	8.44	8.58	8.24	8.16	8.26	8.43	8.36
Commercial	9.65	9.46	8.67	8.17	8.03	7.89	7.92	7.43	7.26	7.41	7.59	7.64
Industrial	6.39	6.16	5.73	5.25	5.11	4.88	5.05	4.64	4.43	4.48	4.53	4.60
Transportation	9.70	9.54	8.57	7.18	7.54	NA	NA	NA	NA	NA	NA	NA
Other	NA	NA	NA	NA	NA	6.75	7.20	6.56	6.35	6.63	6.91	6.91
All Sectors	9.13	8.90	8.14	7.61	7.44	7.20	7.29	6.81	6.64	6.74	6.85	6.86

Energy Information Administration/Electric Power Annual 2007

In general, energy expenditures can be lowered in commercial buildings in two ways; first by reducing the amount of energy used (consumption), and second by operating equipment during off-peak generation times (demand) (Reeve, personal communication, May 29, 2009). Commercial building electric cost is charged in two parts, consumption and demand. Consumption is based on the actual electricity used in kilowatt-hours (kWh). The demand component is the maximum number of kWh per hour, or kilowatts consumed (SBU, 2009). Commercial building energy bills take both the consumption and peak demand (Maximum kW consumption in a given time period) into account when determining cost. Commercial energy customers are charged for the consumption portion of their bill by taking the actual kWh of electricity used multiplied by the current rate of \$/kWh. The demand portion of the bill is charged based on the building peak demand in kilowatts used in a given month (E. Source Companies Inc., 2002). School districts should make an effort to reduce peak demand changes whenever possible as demand can be as high \$20 per kilowatt-month, comprising a large portion of the commercial buildings total energy bills (E. Source Companies Inc., 2002).

On average, K-12 schools in the United States annually spend \$0.67/ft^2 on electricity and \$0.16/ft^2 on natural gas (E. Source Companies Inc., 2002). In the 2004-2005 academic year, PSD was below the 2002-2003 academic year national average for electricity, spending an average of \$0.31/ft^2 in elementary schools, \$0.39/ft^2 in middle schools and \$0.41/ft^2 in high schools. However, PSD came in well over the average in gas expenditures at \$0.32/ft^2 in elementary schools, \$0.33/ ft^2 in middle schools and \$0.27/ft^2 in high schools. While gas usage is higher, the average annual total energy expenditure for all PSD schools was \$0.68/ft^2 or \$0.15/ft^2 below the national average of \$0.83/ft^2. Specifically, FCHS (2003-2004) exhibited slightly higher expenditure than the PSD average at \$0.45/ft^2 for electricity and \$0.35/ft^2 for natural gas. FRHS (2005-2006, first year of operation) demonstrated electricity expenditure similar to the PSD average at \$0.41/ft^2 but much lower gas expenditure at \$0.17/ft^2. Overall, between 2005 and 2008, PSD's average annual energy cost was \$0.82/ft^2 to operate FCHS, \$0.01/ft^2 below the national average and only \$0.59/ft^2 to operate FRHS which equates to \$0.24/ft^2 less than the national average energy expenditure in K-12 schools.

Climate and Energy Use

When comparing schools to the national average K-12 energy use rates, it is important to consider several location-driven factors which affect energy consumption. One of the most important complicating factors influencing energy use in building is weather (Eto, 1988, Energy Star 2006). Further, the consumption of energy for space heating and cooling is strongly related to temperature (Warren and LeDuc, 1981). To better quantify energy use, degree-day-based techniques such as Heating Degree Days (HDD) and Cooling Degree Days (CDD) can be used to isolate weather-related effects on building energy consumption (Eto, 1988). The number of HDD or CDD is defined as the difference between the reference temperature value of 65°F and the average outside temperature for a given day (Valor, Meneu and Caselleres, 2001). The HDD are calculated using the base temperature minus on the average ambient outside temperature for that day. The HDD for a given time period is the summation of HDD for each day during a given time period. For example, if the average ambient outside temperature is 45 °F on a given day, then that day would account for 20 HDD (base temperature – average ambient outside temperature). If that same average ambient outside temperature of 45 °F was observed for seven days that total HDD for that time period would be 140 HDD (HDD/day * duration).

According to the USEIA, PSD falls in to "Climate Zone 1" (See Figure 3) which in a typical year has more than 7000 HDD and less that 2000 CDD per year, indicating that PSD has greater heating requirements than many regions of the county. The PSD uses natural gas exclusively for space heating requirements and electricity for its air conditioning needs (Reeve, personal communication, May 29, 2009). School buildings in warmer climates will tend to show a larger percentage of electricity used for space cooling than school in cooler climates (Energy Star, 2006). Hence, Northern Colorado's climate may explain the heavier gas usage and lower electric use at PSD when compared to the national average. In contrast, Florida's Orange County Public Schools (OCPS) is in Climate Zone #5 with less than 4000 HDD and more than 2000 CDD per year. OCPS consumes an average of 15.7 kWh/ft^2/year in elementary, middle and high schools (OCPS, 2009) which is more than three times greater electricity consumption when compared to PSD's average of 5.9 kWh/ft^2/year for all schools in the district.

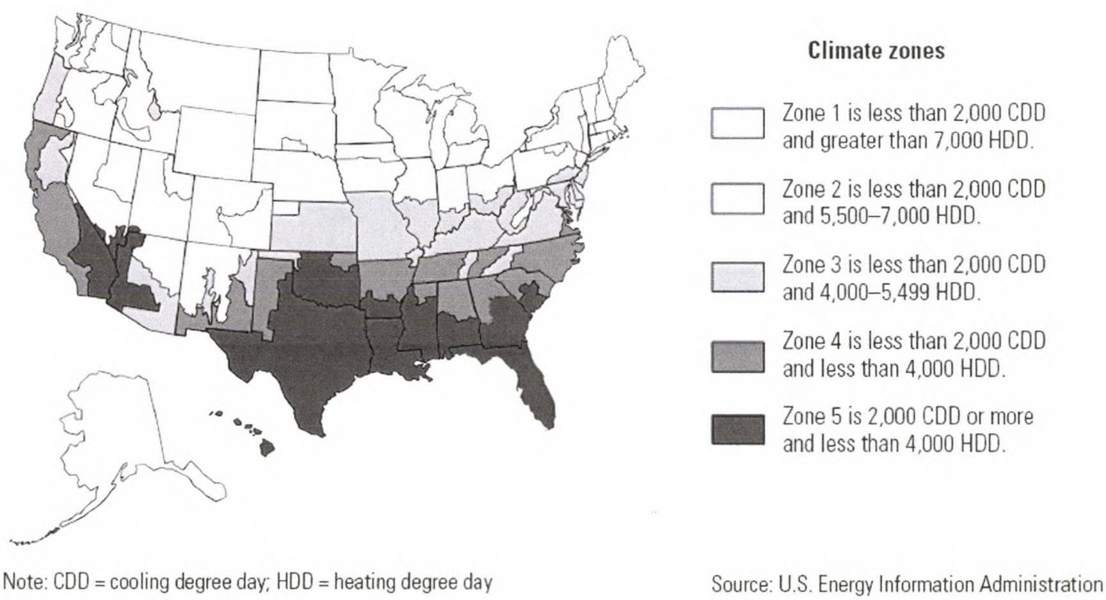

Figure 3: U.S. Energy Information Administration Climate, HDD and CDD Zones (USEIA, 2009)

In order to achieve below-average energy consumption and demand costs, PSD has made substantial efforts in the areas of sustainable design, construction and building operation at FRHS. Electricity usage is reduced at FRHS through a well-insulated building envelope, operable windows to allow for natural ventilation, daylighting, motion sensors to ensure that electric lighting is used only when necessary and a photovoltaic (PV) system to lower electricity purchased from the grid (Building Green, 2007). The high school's cooling system generates and stores ice during off-peak nighttime hours (USBGC, 2009), which reduces the load on the local infrastructure and the monthly demand cost for the school district (Reeve, personal communication, May 29, 2009).

Through diligent effort, PSD has been able to reduce electricity consumption by an average of 130,006 kWh per year since 2000 at FCHS (built 1995) through implementing reductions in HVAC runtimes, optimizing HVAC system temperature set-points, lighting ballast changes, integrated web-based HVAC control systems and increased occupant awareness (Reeve, personal communication, May 29, 2009). While these techniques directly affect reductions of electricity consumption, they have less of an impact on electricity demand cost due to the limitations imposed by school operating hours. Hence, in existing buildings like FCHS, it is generally more difficult to drastically reduce demand costs (without major HVAC system changes) to take advantage of operating during off-peak hours.

Tools for Assessing and Comparing Energy Performance

Sustainable building advocates calculate that buildings are responsible for the consumption of 72% of electricity in the United States and 40% of the world's raw material (USGBC, 2010). Of the 72% of all electric consumption is split almost evenly between commercial (35.97%) and residential structures(36.97%) (USEIA, 2008). In light of the statistics, the U.S. building market has taken a turn toward sustainability through the incorporation of the USGBC LEED practices. Although the number is ever increasing, as of May of 2007 there were 851 completed LEED-certified projects and 6,500 LEED projects under construction in the United States (Holowka, 2007). However, according to Tom Hicks, Vice president of LEED at the USGBC, "We are adding one billion square feet of new commercial office building space to the existing building stock each year in the U.S. Even if all of the new buildings constructed reduced their energy consumption by 75%, it would equal just a one percent change in the energy consumed by buildings due to the large number of existing structures which don't currently meet LEED standards" (Horst, 2006). This statement by the USGBC acknowledges the need to address the existing building stock of the United States more closely in order to adequately address sustainability (Horst, 2006).

Reduction in the energy consumption of existing buildings represents a market with the potential for a much larger impact on the environment (Restivo, 2005). The USGBC states that as much as 75% of the building's energy is consumed during the operation and maintenance phase of its life cycle. In addition, existing buildings consume 40% of our energy, add 40% to atmospheric emissions, consume 68% of electricity and 88% of potable water, produce 40% of our solid waste, and use 40% of our wood and natural resources (Green Building on the Move, 2004). Currently the USGBC is investigating new technologies that would help incorporate the inclusion of life cycle assessment (LCA) into the standards for certification, which should be released with the latest version on LEED 3.0 (Holowaka, 2007). There are nearly 100 times as many existing buildings (which the USGBC defines as two years or older) as new in the United

States. Therefore, applying measures to reduce the energy consumption of this larger market has the potential to impact sustainability and energy consumption to an extent several orders of magnitude greater than that of LEED-NC (Green Building on the Move, 2004).

While their new school buildings are designed and built to meet or exceed LEED standards, the PSD is active in collecting, monitoring, analyzing and benchmarking the energy consumption in its 46 elementary, middle and high school buildings. All of PSD's existing schools are annually or biannually assessed and given Energy Star Scores. The Energy Star Scores are used for comparison to other schools within the district and for comparison to national energy consumption averages for K-12 schools (Reeve, personal communication, February 17, 2009).

The Energy Star program was introduced in 1992 by the DOE as a voluntary program intended to identify and promote energy efficient consumer products and reduce greenhouse gas emissions (Energy Star, 2008). As the program expanded, it included more consumer and business products. In 1996, the EPA partnered with the DOE to recognize energy-efficient residential, commercial, and industrial buildings with the Energy Star label.

Energy Star provides consumers and building owners with technical information and tools to aid in the selection of energy-efficient products and management practices. In 2000, the EPA and DOE added energy benchmarks for K-12 schools to the national energy efficiency rating system for buildings (Energy User News, 2000). The Energy Star system rates building performance on a scale of 0-100; an Energy Star Score (ESS) of 50 points represents a building with an average energy performance compared to buildings of similar function and region. Buildings that have an ESS of 75 or better can apply for the Energy Star Certification, assuming they meet other prerequisites related to ventilation, lighting, and indoor air quality. Thus, school buildings which receive an ESS between 75 and 100 perform in the top 25% of school buildings nationwide. In order to normalize the ESS for building in different locations, ESS is calculated using a combination of factors including the buildings use, location/ climate, physical features and energy consumption (Energy User News, 2000). According to PSD data, in 2008 FCHS received an ESS of 59 and FRHS received an ESS of 87.

A building's ESS takes total energy use from both fossil fuel and electric consumption in each building into account by using BTU/ft^2/year as a common unit of quantification. In comparing FRHS to FCHS using total energy consumption, it was noted that FRHS was more efficient on an overall basis and that 84.1% of the total energy saved at FRHS was due to lower natural gas consumption (See Table 2). To further investigate electric consumption at the school, electric use can be isolated and analyzed by determining each building EUI.

EUI (often referred to as Energy Use Index, average power level or power density) which is typically expressed in kBTU/ft^2/year for combined fossil fuel and electric consumption or kWh/ft^2/Year for electric use only, is a common parameter used to reflect a building's energy use (Sharp, 1998). Many benchmarking tools such as Energy Star and the Lawrence Berkeley National Laboratory's Cal-Arch distributional model use whole-building EUI for comparing annual electricity consumption of buildings of similar types (Matson and Piette, 2005).

Electricity specific whole-building EUI is calculated by dividing the total annual electricity usage by the building's conditioned floor space. Nationally the median whole-building EUI for all schools is 8.9 kWh/ft^2, with the 25th and 75th percentiles being 4.9 kWh/ft^2 and 13.9 kWh/ft^2 respectively (USEIA, 2003). EUI values can vary greatly between schools; while PSD's average EUI between 2005-2008 was 6.2 kWh/ft^2 for all its schools, New York's state average between 2003 and 2006 was 5.9 kWh/ft^2 (NYSERDA, 2006) and Florida's OCPS averaged 15.7 kWh/ft^{2}in 2008 (OCPS, 2009). Whole-building EUI (a single EUI representing all energy used in a building) is an attempt to normalize different building energy consumption relative to its primary determinant, building floor area. However EUIs continue to vary widely from building to building and may be considered uncertain indicators of an individual buildings energy performance (Sharp, 1998)

The possible limitation to the use of whole-building EUI is the assumption of similar floor space usages between buildings. This limitation is investigated in detail in this thesis through the determination of education workspace (classrooms, common areas, library, etc.) specific EUI values.

Methodology

Dataset Acquisition: Historical Records

The quantitative data for this study was provided by PSD Facilities Services Department (PSD Facilities). PSD Facilities is responsible for the planning, design, construction, maintenance and operations of all buildings within the district. For the past 16 years, PSD has been monitoring the natural gas and electricity consumption for each of its schools with the intent to identify and reduce energy consumption. The information has been compiled into several data sets containing the annual usage data for each utility from 2004 through 2008, and monthly high school electric use from 2000-2008. The data sets contain the floor area, student enrollment and architectural capacity for each school. As part of the effort, PSD facilities has calculated the Energy Star Score (ESS) for each school based on the energy usage (kBTU/ft^2/yr) for each given year. For comparison of building performance using for ESS calculations, electricity (kWh/ft^2/yr) and natural gas (CCF/ft^2/yr) usages are combined using heating units (kBTU/ft^2/yr) as the common factor by PSD and is included as part of the database. To accomplish this, a kilowatt-hour of electricity (1 kWh = 3412 BTU) and a cubic foot of natural gas (1 CF = 1029 BTU) were converted to their BTU equivalents (USEIA, 2010). In this database kBTU/ft^2/yr is used to normalize and compare each building's energy consumption. For this study, the ESS will only be used as a tool for general comparison as ESS is calculated based on total energy consumption and this case study investigates only electricity consumption for FRHS and FCHS.

The energy use information provided by PSD serves as the foundational database for this study. Although the PSD has been quantifying and tracking energy consumption for nearly two decades, this study was restricted to 2006-2008. It was important to avoid the 2005-commissioning year for FRHS that would not be considered representative of typical energy consumption due to building operation adjustments and calibration. Furthermore, major energy conservation strategies at FCHS had been implemented prior to the 2006-2008 time period.

A list of plugged office equipment including computers, coffee makers, space heaters, microwaves, etc. was also provided for each high school. The data, in conjunction with the construction design documents, was used to determine office equipment and appliance quantities. Plugged equipment and appliance running and standby power consumption values, obtained from the DOE and the Lawrence Berkeley National Laboratory, were used to calculate the plug load consumption rates for FRHS and FCHS allocated by workspace type. Theater and performance lighting specifications and spreadsheets were provided by PSD facilities for use in calculating the kWh consumption for lighting for these areas of the building.

Dataset Acquisition: Construction Documents

In addition to energy consumption data, PSD facilities provided detailed construction drawings for FRHS and FCHS. The architectural drawings were used to obtain floor areas for each educational workspace type. Electrical, mechanical, kitchen and performance equipment floor plans were used to quantify food service, HVAC equipment and light fixtures in a given area. Building equipment and lighting schedules were used to gather electricity consumption information for HVAC, food service equipment and light fixtures. All building equipment and lighting electricity consumption information that could not be gained from the drawings was gathered from the specifications, manufacturer's product data, and record documents from each building.

Data Collection

A computerized estimating program from On Center Software called On-Screen Takeoff (OST) was used to quantify floor areas for workspace types as well as quantify

HVAC, equipment, food service equipment, and light fixtures. OST allows the user to quantify building components on the scaled construction drawing, while simultaneously tallying the totals for each component (workspace area, light fixture type, or piece of equipment) thereby limiting calculation and quantification errors. During the quantification process, OST highlights and color codes each building component thereby avoiding accidental over-counting or exclusion of building components and thus increasing the accuracy of the quantity takeoff.

Analysis and Treatment

In order to conduct a detailed analysis of electric use, each school's total electricity consumption was broken down into the major consuming systems: HVAC, lighting, food service, plug loads, and residual loads. The methods used to isolate and quantify the electric usage for each of these components is described below.

Investigating school electricity consumption on an annual basis required that several variables including the weather patterns, number of daylight hours, and school occupancy patterns during the academic year and vacation periods be considered and normalized. Based on the historical electric consumption data, each building consumed less electricity during the summer months when school was not in session and HVAC systems were shutdown. It was also found that more electricity was consumed during the school-year months with few vacation days. Normalization of the data based on these variables was accomplished by using each school's 2006-2008 average monthly electricity consumption and identifying the month of highest consumption for each building. The months of highest consumption (month of full electric use) were identified as October for FCHS and January for FRHS. Electricity consumption factors for the other months were determined by dividing the month's 2006-2008 average electric consumption by the month of highest consumption. These monthly factors represent seasonal and occupancy level variations observed during the study's time frame. Calculations were aimed at quantifying electricity consumption of the highest month. The summation of all monthly adjustment factors produced an estimated annual electric consumption for each building; 10.23 for FRHS and 10.55 for FCHS. Adjustment factors are shown in Table 3.

Table 3: Monthly and Annual Electric Consumption Adjustment Factors

FCHS			FRHS		
Month	2006-2008 Average Consumption (kW)	Adjustment Factor	Month	2006-2008 Average Consumption (kW)	Adjustment Factor
July	120,958	0.56	July	108,720	0.58
Aug.	191,860	0.89	Aug.	151,246	0.81
Sep.	213,785	0.99	Sep.	170,650	0.91
Oct.	**215,326**	**1.00**	Oct.	181,870	0.97
Nov.	203,415	0.94	Nov.	174,897	0.93
Dec.	194,132	0.90	Dec.	173,080	0.92
Jan.	213,487	0.99	**Jan.**	**187,356**	**1.00**
Feb.	204,781	0.95	Feb.	176,281	0.94
Mar.	185,476	0.86	Mar.	162,077	0.87
Apr.	195,328	0.91	Apr.	160,222	0.86
May	204,720	0.95	May	164,830	0.88
June	129,196	0.60	June	104,535	0.56
Annual Adjustment Factor:		10.554	Annual Adjustment Factor:		10.225

Electrical equipment runtimes and use requirements change based on a building's occupancy patterns which are changing during a entire month. Therefore calculating the month of highest electric consumption required that an accurate number of academic days and weekend/holiday days were determined for October and January between 2006 and 2008. The average number of academic days and weekend days for October was calculated as 21.67 and 8.33 days respectively for FCHS. The average number of academic days and weekend days for January was calculated as 21 and 10 respectively for FRHS.

Whole-Building Overall Electricity Consumption

1) What are the major uses of electricity (HVAC, lighting, food service, plug loads, etc.) at FCHS and FRHS and how much do they contribute to total energy consumption?

Quantifying HVAC Electric Consumption

In this study, HVAC components in PSD were defined as the equipment required to provide space heating, space cooling and ventilation for each high school. In PSD, where electricity is not used for direct (resistance type) space heating, pumps and fans within the HVAC system are the major components which consume electricity. Generally, pumps are used to move cooled or heated liquids through mechanical equipment and fans are used to move cooled or heated air to/from conditioned spaces. HVAC fans and pumps have a specified full load horsepower (HP) listed in the mechanical schedule in the contract documents. In this study, HP for each piece of equipment was converted to its kW equivalent (kW = 0.746 * HP) (USEPA, 2009) and multiplied by the runtime (hours) for each piece of equipment to determine total electricity consumption (kWh). When HP was not provided, voltage, amperage, and phase (volts * amps * square root of the phase = Watts) (Brevard, 2002) were used to calculate electric consumption for each piece for equipment. The total, full load, electric consumption for each high school was calculated as the summation of electrical use for all HVAC equipment, pumps, and fans.

Pump and fan motor sizes are often specified according to worst-case operating conditions (full-load) while normal operating loads and electric consumption on these pieces of equipment are much smaller than the full load (USDOE, 2008). The simple HP to kW calculation mentioned above is used to determine electric consumption when a pump or fan is under full load, based solely on the design horsepower for each piece of equipment. However, HVAC system pumps and fans often operate over a wide range of conditions; ventilation fans for example may experience variable electric consumption due to changes in ambient conditions, occupancy, and production demands (USDOE, 2003). As loads on a pump or fan change, the motor efficiency also changes. As motor efficiency rating decreases electrical input (kW) increases. (Bonneville Power Administration, 1991). To account for the fact that a motor usually does not operate at its full load capacity, its average load factor must be estimated (USDOE, 2008). Load factor is the ratio of the average load the piece of equipment draws while operating compared to the possible load it could draw at full load (Capehart, 2000).

Many publications that provide electrical load calculations do not include the term load factor, while few motors actually run at, or even close to, full load capacity (Capehart, 2004). According the R. Hoshide, less than one quarter of motors run with load factors above 60% of their full load capacity, with half of all motor running with load factor between 30% and 60% of full load capacity and the remaining quarter of motor running with load factors below 30% of full load capacity (Capehart and Capehart, 2004). In manufacturing facilities, the load factor for pumps and fans has been correctly identified as between 30% and 40% of full load capacity. (Capehart and Capehart, 2004). In this study, the full load capacity of pumps and fans was multiplied by a load factor of 0.35 to account for variables in electrical input to HVAC equipment running in differing conditions and motor efficiencies.

The use of variable frequency drives (VFDs) at both schools required that adjustments were made in the electric consumption of pumps and fans controlled by a VFD. Through optimizing pump and fan RMPs, VFDs can reduce a pump's electric consumption by up to 45% and fan electricity consumption by as much a 30% when pumps are running at 20% lower capacity due to the use of a VFD (VFDC, 2009). However the degree to which VFDs reduce consumption is directly related to the operating speed of the fan or pump. It is noted that the benefits of VFDs are minimized on motors that continually operate at or near full speed and the VFDs themselves add a small increase to the electrical load (Focus on Energy, 2009). Since electricity consumption reductions vary based on many factors, a flat reduction of 25% in electricity consumption was used for all equipment that was identified as VFD controlled in the equipment schedules from the construction documents. The use of VFDs was more extensive at FRHS where 18 Air Handling Unit (AHU) as well as pumps over 15 HP (4 total) were controlled by VFDs; whereas only 1 AHU, pumps over 25 HP (4 total) and the chiller were VFD-controlled at FCHS.

As previously stated, HVAC runtimes were required to determine the electric consumption (kWh) for HVAC equipment in each high school. Based on discussions with PSD Facilities energy manager Stu Reeve, the following runtime assumptions were used to quantify electric use for each school: During the month of highest electric consumption, it was assumed that during every academic day, each piece of HVAC equipment was running continuously for 8 hours per day, the system then shutdown for 2 hours at FCHS and 4 hours at FRHS to reach unoccupied building set-back temperature (S. Reeve, personal communication, November 25, 2009). After the HVAC system shutdown period, it would modulate on for 15 minutes per hour until startup the next day in order to maintain minimum temperature requirements in the buildings. The shorter 2-hour shutdown (coast) at FCHS was used because the building envelope is not as tight as FRHS, allowing more heat to escape from the building causing the HVAC system to turn on more quickly (S. Reeve, personal communication, November 25, 2009). Weekend day HVAC runtimes were calculated as 15 minutes of runtime per hour for a 24-hour period. Therefore total HVAC runtime for a 24-hour period was calculated as 11.5 hours at FCHS and 11 hours at FRHS for each academic day and 6 hours for each school on weekends.

Total electric use for each school was calculated as the summation of all HVAC equipment loads times using the appropriate runtimes and factors addressed above. HVAC electricity usage was compared to the total building electric consumption in order to determine the percentage of electricity dedicated to HVAC for each high school.

Quantifying Lighting Electric Consumption

The light fixtures in each high school were identified and tallied based on the fixture types specified in the light fixtures schedule in the construction drawings.

Electricity consumption for each light fixture type was calculated based on the quantity and wattage of bulbs/ballast in each light fixture multiplied by the fixture runtime. Total electricity consumption for light fixtures was calculated as the summation of all light fixture wattages multiplied by the fixture runtimes. In this study, egress lighting was isolated from other lighting due to the 24-hour use requirements for these fixtures. When egress lighting was accomplished by utilizing a portion of a light fixture (e.g. one of five total bulbs in a fixture) for 24-hour operation, fixture wattage was calculated based on the number of bulbs running for 24-hours plus the remaining switch-activated bulbs Wattages multiplied by the operation runtimes. For example, if a light fixture with a switched operation runtime of 8 hours contained four 32W T8 bulbs, with one of the four bulbs being used for egress lighting, the fixture daily wattage was calculated as follows:

*(1 bulb * 32 Watts * 24 hours)+(3 bulbs * 32 Watts * 8 hours)=1536 Wh/Day*

While, electricity consumption for egress lighting was calculated based on a 24-hour period, runtimes for non-egress lighting were a function of light fixture location, i.e. classroom lighting runtimes were based on assumptions discussed and confirmed with PSD facilities. See table for lighting assumptions by workspace area (Table 4).

Exterior building lighting runtimes were based on average sunset time for the month of highest energy consumption and the mandatory shutdown of exterior lights at midnight each evening (S. Reeve, personal communication, November 25, 2009). At FRHS the exterior lighting runtime of 7 hours was calculated based on an average sunset time of 5:00 PM in January through midnight. At FRHS exterior lighting runtime of

5.667 hours was calculated based on an average sunset time of 6:15 PM in October and the mandatory 12:00 AM shutoff time. Motion sensor standby electric consumption was also estimated for FRHS which contains motion sensors while FCHS does not. Motion sensors consume from 0.2 to 1.5W of electricity in standby mode (Australia's Ministerial Council on Energy Forming, 2004). The average of 0.85 Watts per motion sensor device and a runtime of 24 hours per day were used to calculate total electricity consumption for all motion sensors.

Quantifying Food Service Electric Consumption

Since food service equipment typically accounts for approximately 5% of electricity use in K-12 schools on average (Energy Star, 2006) it was necessary to isolate this consumptive use of electricity. In this analysis, food service electricity consumption is considered the electricity required for food preparation for student and employee meals. Food preparation equipment within culinary classrooms will not be included in food service. The electricity consumption in culinary classroom spaces was considered plug load which was isolated and analyzed by workspace type in research question #2. Total food service electricity consumption was calculated as the summation of electric usage by hardwired equipment units (e.g. built-in refrigerators, freezers, ovens, etc.) and receptacle-plugged equipment within the kitchen and cafeteria areas (e.g. microwave ovens, mixers, beverage dispensers, etc.). The electric capacity of each piece of equipment was obtained from the manufacturer's product data or equipment schedules found in the construction drawings and multiplied by the duration of equipment operation. Equipment wattage was calculated based on the amps, voltage, and phase as shown in the formula below.

$$W = A * V * (\text{Square Root of } P)$$

Where W is Watts, A is amperage, V is voltage and P is the phase (Brevard, 2002)

Table 4: FCHS & FRHS Lighting Runtime Assumptions

Educational Workspace	Runtime Assumptions
Administrative	7:00AM – 5:00PM on weekdays during the academic year Egress lighting only on weekends and holidays
Classroom	7:00AM – 4:00PM on weekdays during the academic year Egress lighting only on weekends and holidays
Closet/Storage	One hour/day on all weekdays
Common Areas/Hallways	7:00AM – 4:00PM on weekdays during the academic year Egress lighting only on weekends and holidays
Computer Lab	7:00AM – 4:00PM on weekdays during the academic year Egress lighting only on weekends and holidays
Gymnasium	7:00AM – 6:00PM on weekdays during the academic year Egress lighting only on weekends and holidays
Kitchen	7:00AM – 2:00PM on weekdays during the academic year Egress lighting only on weekends and holidays
Library/Resource Center	7:00AM – 4:00PM on weekdays during the academic year Egress lighting only on weekends and holidays
Mech/Elec/Data Room	One hour/day on all weekdays
Restrooms/Showers	7:00AM – 5:00PM on weekdays during the academic year Egress lighting only on weekends and holidays
Theater	Average 6 hours/weekday during academic year Egress lighting only on weekends and holidays
Trades Classroom	6 hours/day (during academic year) No use in Summer, Weekend (egress lighting only)

*egress lighting is calculated based on continuous 24-hour runtime

Equipment operating time varied based on different types of equipment (Table 5), e.g. freezer may run for 20 minutes per hour for 24-hours per day, while ovens may only be utilized for several hours before school begins through scheduled lunch periods. Varying food service equipment runtimes were addressed through assumptions based on equipment type, use, and operation procedures.

It should be noted that the kitchen equipment at FCHS was renovated in the summer of 2006. The renovation brought FCHS to the same kitchen equipment standards as FRHS (S. Reeve, personal communication, December 4, 2009). A detailed kitchen equipment schedule from the renovation for FCHS was not available for the study. Since the kitchen equipment is used to serve a similar number of students, and is of the same age, it was assumed that the kitchen equipment used at FCHS consumed a similar amount of energy per day as that used at FRHS.

Quantifying Plug Load Electric Consumption

In a broad sense, plug loads are items that are not hardwired in the building electrical system but instead are plugged into electrical receptacles (NEED, 2007). In office buildings, equipment plug loads would typically include office equipment: computers, printers, copiers, servers, telephones, etc. In addition to typical office equipment, educational facility plug load devices include items for vocational training and administrative uses including microwave ovens, coffee makers, refrigerators, projectors, televisions, clothes washer/dryers, etc. For the initial analysis (research question #1) plug loads were grouped into one category, however in the detailed analysis of differential space usage (research question #2) plug loads were separated by specific location. To

Table 5: FCHS & FRHS Food Service Equipment Runtimes

Use	Description	Assumption	Hours per Day
Dish Washing	Disposer	11AM - 2PM (15 minutes per hour)	0.75
Dish Washing	Booster Heater	11AM - 2PM (15 minutes per hour)	0.75
Dish Washing	Dish Machine	11AM - 2PM (75% capacity)	3
Preparation	Hot Water System	7AM -2PM	7
Preparation	Rethemalizer	9AM -1PM (15 minutes/hour)	1
Preparation	Staging Warmer	9AM -1PM (15 minutes/hour)	1
Preparation	Exhaust Hood	9AM -1PM	4
Preparation	Pizza Oven	9AM -1PM	4
Preparation	Cutter Mixer	9AM -1PM (15 minutes/hour)	1
Preparation	Dough Roller	9AM -1PM (15 minutes/hour)	1
Preparation	Hobart Mixer 60qt.	9AM -1PM (15 minutes/hour)	1
Preparation	Steamer	9AM -1PM (15 minutes/hour)	1
Preparation	Slicer	9AM -1PM (15 minutes/hour)	1
Refrigeration	Walk-In Cooler/Freezer	20 minutes/hour (50% capacity)	8
Refrigeration	Cooler Compressor	20 minutes/hour (50% capacity)	8
Refrigeration	Freezer Compressor	20 minutes/hour (50% capacity)	8
Service	Taco Cabinets	11AM - 2PM	3
Service	Refrigerated Counter	11AM - 2PM	3
Service	Heated Cabinets	11AM - 2PM	3
Service	Heat Lamps	11AM - 2PM	3
Service	Deli Case	11AM - 2PM	3
Service	Electric Food Warmer	11AM - 2PM	3
Service	Hot Plate	11AM - 2PM	3
Service	Drink/Ice Dispenser	20 minutes/hour (50% capacity)	8
Service	Cash Registers	7AM -2PM (50% capacity)	7

accomplish this, plug load energy consumption for specific devices were categorized and assigned to the workspace types in which the device is used.

In order to determine the total electricity consumption for plugged equipment, a list of devices was created (from the database provided by PSD) by identifying and enumerating plugged equipment in each high school. National average electricity consumption for both operating and standby or "off" settings were researched and used for each type of device and a daily operating duration for each device was established through assumption. Operating times for equipment were divided into full power and standby mode as needed, e.g. computer and monitor consume an average of 270 Watts/hour while in use (DOE, 2009) and 18.5 Watts/hour in standby mode (LBNL, 2009). Total plug load electricity consumption was calculated as the summation of the plugged device electricity consumptions multiplied by the runtimes and the quantity of each device.

It should be noted that most of the technical training equipment (wood working, metal working, etc) at both schools has been replaced with drafting and computer-aided design curriculum (S. Reeve, personal communication, November 25, 2009). Therefore, much of the trade-specific equipment was not heavily utilized during the 2006-2008 study timeframe and electric use from this equipment was included in the residual electric consumption category described below.

Quantifying Residual Electric Consumption

Residual electric load includes all other electricity consumption from devices not explicitly defined in the four major categories above. In commercial buildings residual electric loads may include, but are not limited to, the following consumptive uses of electricity that could not be easily quantified, e.g. powered open-assist doors, electrified locksets, smoke/fire detection lights/sensors, standby and always-on loads such as clocks, devices w/ internal clocks (not specifically identified in plug loads) , GFCI receptacle lights, etc. This category also includes so-called "phantom" loads due to devices that consume electricity even when switched off which are not specifically identified in the study. Due to the challenge of precisely quantifying these residual loads, the electricity usage for this category was calculated as the difference between the actual annual electricity use minus the sum of the electric use for the previously defined consumption categories.

Residual = Total Electric Usage – (HVAC + Lighting + Food Service + Plug Loads)

In this study, the electricity consumption of the miscellaneous loads included in the residual category was expected to be small, this category will serve as a rough check to evaluate if the sum of the other category values is of reasonable magnitude.

Workspace-Specific Consumption Analysis

2) What are the major non-HVAC electricity consumers in the different types of educational workspace (classrooms, administrative, laboratories, kitchen, corridors, sports fields, maintenance) for FCHS and FRHS?

In order to investigate electricity consumption based on differential educational workspaces, it was necessary to assign the major electricity usages (lighting, food service and plug loads) to the different workspace types. Electricity consumption for HVAC and residual loads was accounted for on a square-footage basis under this objective because these consumptive uses in FRHS and FCHS are independent of educational workspace type, i.e. air handling units (AHU) at FRHS and FRHS service different wings of the building not individual workspaces.

Educational workspaces were divided in the following categories:

Administrative: Offices, student counseling, conference, staff work centers, etc.

Classrooms: Traditional lecture-type classrooms where students work from tables or desks without computers.

Closets/Storage: Storage areas, custodial closets.

Common Areas: Inclusive of all hallways, stairs, vestibules, cafeteria and common space areas.

Computer Laboratories: Classroom spaces with one computer per seat.

Gymnasium/Training/Sports: Gymnasium, locker rooms, training and weight rooms.

Kitchen/Cafeteria: Food preparation and serving areas for student and employee meals.

Library/Resource Center: Library, study spaces, student resource centers.

M/E/D rooms: Mechanical, electrical and data closets.

Restrooms: Restrooms and showers.

Theater: Auditorium, stage, seating areas, dressing, practice, and performance areas.

Trades Classrooms: Technical, trades, art, culinary, drafting, and vocational teaching spaces.

In this study, each educational workspace, regardless of use, was given the same HVAC and residual electric consumption per unit of conditioned floor area (kWh/ft^2). The HVAC electric consumption per square foot was multiplied by the respective floor area of each workspace to determine total electric consumption for HVAC. This method established a direct relationship between workspace floor areas and HVAC electric consumption. While a percentage of HVAC electricity use could be loosely assigned to a building wing, the breakdown of the electricity consumed to supply conditioned air to a specific workspace would be difficult to quantify precisely.

Floor areas for each of these educational workspace categories were determined using OST as described previously in the data collection portion of the methodology. Lighting, food service, and plug load associated electricity use for each workspace type were calculated by breaking down the total electricity consumption for each major category determined in research question #1. Generally, each workspace will have electricity consumption resulting from plug loads, HVAC, and lighting. The electricity consumption for food service was assigned solely to the kitchen workspace. However, a portion of kitchen/cafeteria electricity consumption were associated with lighting and HVAC. As explained in the methodology for research question #1, some of the kitchen equipment is plugged into receptacles; however this electric consumption is included with food service because this plugged equipment is included on the kitchen equipment schedule for each school.

In order to identify electricity consumption for lighting in each workspace, the number of light fixtures within the school were enumerated and separated by room number. All rooms were given a workspace type designation based on the educational use and the total quantity of each light fixture by type in a specific workspace was quantified. The total electricity consumption for lighting in each workspace was calculated as the summation of all light fixtures wattages multiplied by the respective runtimes for lights in that workspace. As previously noted, egress light electricity consumption was calculated based on a 24-hour runtime. Other light fixtures runtimes were adjusted based on occupancy during and after school hours and confirmed through discussion with PSD. See lighting runtime assumption table for list of lighting runtime assumptions (Table 4).

While motion sensor electric consumption was calculated for FRHS, the resultant electric use was so minute, a total 239 kWh for the month of January (0.37% on total lighting consumption) for FRHS, that this electric consumption was distributed equally throughout the building workspace areas which all contain motion sensors. Motion sensors comprise an estimated total of 2450 kWh/per year at FRHS which equates to only 0.14% of the total electric consumption at this school.

It should also be noted that the lighting-related electricity consumption for research question #2 does not include kWh consumption for exterior lighting. Removal of exterior lighting was necessary because exterior lighting is not related to a specific workspace square footage and therefore an exterior lighting EUI (kWh/ft^2/Year) could not be calculated. Exterior lighting consumption is included in the total electricity consumption, comparison and results for research question #1.

Plug load electricity consumption was calculated based on the type and quantity of plugged devices in each workspace area multiplied by an estimated average runtime for these devices. Plugged equipment wattages were determined through manufacturer's product data or, if indeterminate from that method, based on an average wattage for that device type (see list of plugged equipment/wattage, Table 6) e.g. a computer and a monitor consume an average of 270 watts while in use (DOE, 2009) and 18.5 watts in standby mode (LBNL, 2009). The total plug load consumption for each workspace was calculated as the summation of all workspace specific device plug loads multiplied by their respective runtimes (Table 7). The total quantity of plugged equipment in FRHS and

FCHS was provided by PSD facilities; however, several assumptions were made to assign the equipment to each workspace.

While the FRHS architectural drawing indicated the location of computers, projectors and televisions, the FCHS architectural documents did not. Therefore the distribution of computers, television, and projectors in FCHS was based on the same usage shown in the FRHS design. The architectural documents indicate, and PSD facilities confirmed, the existence of one computer, one projector and one television (assumed TV accompanied by VHS/DVD player) in every classroom at both schools (S. Reeve, personal communication, November 25, 2009). An average of 25 computers and monitors were indicated in each computer lab at FRHS. This average was used at FCHS

Table 6: FCHS & FRHS Average Plug Load Equipment Wattages (USDOE, 2009)

Appliance Type	On Watts	Standby or "Off" Watts
Clothes Dryer	3050	0.0
Clothes Washer	425	0.0
Coffee Pots	1050	1.1
Computers	120	12.0
Microwaves	925	2.8
Monitors	150	6.5
Printers	400	16.8
Projector	300	10.0
Ranges	2100	1.3
Refrigerator (16 CF)	150	0.0
Space Heaters	425	0.0
Telephones	2.1	0.0
Toasters	1100	0.0
TVs (36")	133	3.0
VCR/DVD	21	5.4

Table 7: FCHS & FRHS Average Plug Load Equipment Runtime Assumptions

Appliance Type	Educational Workspace(s)	Academic Day Runtime Assumptions
Coffee Pots	Administrative	3 hours on, 0 hours standby
Computers	Administrative	8 hours on, 2 hours standby
Monitors	Administrative	8 hours on, 2 hours standby
Printers	Administrative	2 hours on, 22 hours standby
Refrigerator (16 CF)	Administrative	24 hour operation (20 minutes/hour)
Space Heaters	Administrative	2 hours on, 0 hours standby
Telephones	Administrative	24 hours on, 0 hours standby
Toasters	Administrative	2 hours on, 0 hours standby
Microwaves	Administrative	2 hours on, 22 hours standby
Computers	Classroom	3 hours on, 6 hours standby
Monitors	Classroom	3 hours on, 6 hours standby
Printers	Classroom	1 hour on, 23 hours standby
Projector	Classroom	1 hour on, 23 hours standby
Telephones	Classroom	24 hours on, 0 hours standby
TVs (36")	Classroom	1 hour on, 0 hours standby
VCR/DVD	Classroom	1 hour on, 0 hours standby
Computers	Computer Lab	7 hours on, 2 hours standby
Monitors	Computer Lab	7 hours on, 2 hours standby
Printers	Computer Lab	2 hours on, 22 hours standby
Clothes Dryer	Gymnasium	4 hours on, 0 hours standby
Clothes Washer	Gymnasium	4 hours on, 0 hours standby
Computers	Library	7 hours on, 2 hours standby
Monitors	Library	7 hours on, 2 hours standby
Printers	Library	2 hours on, 22 hours standby
Clothes Dryer	Trades Classroom	4 hours on, 0 hours standby
Clothes Washer	Trades Classroom	4 hours on, 0 hours standby
Microwaves	Trades classroom	2 hours on, 22 hours standby
Ranges	Trades Classroom	2 hours on, 22 hours standby
Refrigerator (16 CF)	Trades Classroom	24 hour operation (20 minutes/hour)

to determine the quantity of computes in each lab at FCHS. The existence of computers in administrative workspaces was calculated as the difference between the total quantity of computers provided by PSD facilities and the computers indicated in the computers labs, classrooms, libraries and commons spaces from the architectural documents at FRHS. Printers were distributed throughout the workspaces based on the assumption of one printer for every five computers (S. Reeve, personal communication, November 25, 2009). In this study it was assumed that each computer in administrative and classroom settings was accompanied by a telephone. Plugged food preparation equipment, inclusive of coffee makers, microwaves and refrigerators was included in the administrative spaces unless clearly indicated in one of the other workspaces, such as trade classrooms, in the architectural drawings.

The data from research question #2 was used to compare the workspace floor area distribution and associated electricity consumption of each workspace at FRHS and FCHS. Workspace specific EUIs were further divided into their component EUI (Lighting, HVAC, Plug Load, Food Service, and Residual) to provide insight into how the workspaces EUI differ in each school based on each electric consumption category. Once tabulated, a better understanding of building square footage utilization was gained and a comparison of different component EUI values based in workspace type and electricity consumption categories was conducted.

Evaluating Overall EUI Validity

3) Is overall EUI, total annual electricity consumption per total area (i.e., kWh/ft^2), an accurate measure for comparing the electric performance of FRHS and FCHS?

A traditional means for determining electricity efficiency for buildings is to calculate the overall EUI as the total annual electricity use (kWh) divided by the total building conditioned floor area (ft^2) (Sharp, 1998). Whole-Building EUI (a single EUI representing all energy used in a building) is an attempt to normalize different building energy consumption relative to its primary determinant, building conditioned floor area. However EUIs continue to vary widely from building to building and may be considered uncertain indicators of an individual buildings energy performance (Sharp, 1998). Therefore, for fair direct overall EUI comparison between buildings, they must have identical workspace usages or be normalized to take different workspaces into account.

In reality, the overall EUI is comprised of the workspace and electricity consumption category specific EUI values multiplied by the corresponding fractional floor space areas as shown in the equation below, where floor area and EUI are evaluated for all workspace categories (i = 1, n).

$$Overall\ EUI = \sum_{i=1}^{n}\left(\frac{Floor\ Area_{\ i}}{Total\ Building\ Area} \times EUI_i\right)$$

Based on 2006-2008 electricity consumption data provided by PSD, the overall EUI was 6.46 kWh/ft^2/yr at FRHS and 7.93 kWh/ft^2/yr at FCHS. Direct comparison of the overall EUI of the two buildings assumes that the floor space usage is distributed similarity. The analysis of component EUI in research question #2 provides different EUI factors for the various categories of educational workspace type at each school.

Workspace specific EUIs were calculated as the summation of Lighting, HVAC, Plug Load, Food Service, and Residual component EUIs generated in research question #2. The workspace specific EUI values were used to determine each building's adjusted EUI to provide comparison of building efficiency normalized for identical workspace distribution (percentage of total floor area) and building efficiencies. The adjusted EUI method for evaluating and comparing the overall EUI was to multiply the square footage values of the each workspace category of FRHS by the corresponding workspace EUIs of FCHS and vice versa. The resultant adjusted EUI values represent the energy consumption of each workspace adjusted for the other buildings workspace distribution and energy efficiency parameters. The summation of the multiplied values for all workspace categories produces an adjusted overall EUI value for each high school. Adjusted EUIs are compared and analyzed in the Results and Discussion section.

Results and Discussion

Whole-Building Electricity Consumption at FCHS and FRHS

The whole-building electricity consumption distributions are shown for the two schools in Figure 4. The data indicate some differences in the manner in which electricity is used at the schools. Notably, 7% more electricity (44.04% compared to 36.9% of total) is used for lighting at FCHS compared to FRHS. Also, HVAC constitutes 33.16% at FCHS while it represents 29.17% at FRHS. However, plug loads account for 24.99% of use at FRHS but only 16.35% at FCHS.

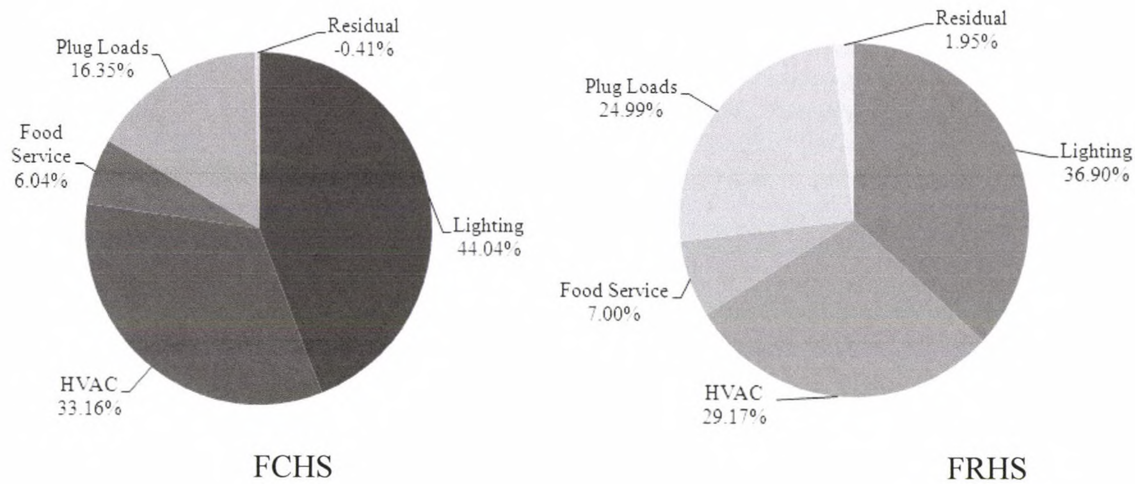

Figure 4: FCHS and FRHS Electric Use by Percentage of Total Consumption

The higher plug load electric use at FRHS may be attributed to the high number of computers and monitors compared to FCHS. FRHS contains 909 computer and monitors compared to 632 at FCHS. The electric use attributed solely to computers and monitors account for an estimated 18.33% (351,173 kWh per year) of the total electric consumption at FRHS and 11.68% (265,523 kWh per year) of the total electric consumption at FCHS. Reducing the computer and monitor quantity at FRHS by one third would equate to an estimated electric saving of 141,800 kWh per year and a reduction is whole-building EUI of 0.50 kWh/ft^2/yr.

The existence of a small negative value in residual electric use suggests modest overestimation of consumption in one or more of the other use categories. One possible reason for the negative residual category may be the overestimation of the lighting component. The quantities of light fixtures were taken from the original design drawings, however limited "de-lamping" (removal of light fixtures or bulbs from existing light fixtures) has been implemented in the main corridors at FCHS since the building was constructed in 1995 (S. Reeve, personal communication, November 25, 2009). In addition, refinement of the study runtime assumptions would improve the accuracy of this assessment.

When comparing the PSD high schools to the national average (Figure 5), both schools have lower percentage of electric use attributed to HVAC and higher percentage of electric use attributed to lighting. In making this comparison, however, one must consider that PSD has made extensive efforts to minimize energy consumption at these schools. The main focus of PSD's effort has been on minimizing energy use through optimizing HVAC runtimes and temperature setpoints in each school. Managing HVAC operation is the main reason electric consumption at FCHS has been reduced by 1,040,000 kWh since 2000 (S. Reeve, personal communication, May 29, 2009). The reduction of HVAC electric consumption at each school would simultaneously cause the other use categories (lighting, plug load, and food service) to account for larger percentages of total energy consumption.

The FRHS plug load consumption (as a percentage of total) is higher than the national average while FCHS's plug load consumption is lower. Similar to the comparison between FRHS and FCHS where computers and monitor quantities have a large effect on total electric consumption at both schools, it is possible that the number of computers and monitors at FRHS may also exceed the national average. Reducing the computer and monitor quantity at FRHS would reduce the plug load electrical consumption percentage, approaching the 20% benchmark indicated as the national average. However, reducing the quantity of computers and monitors may not be feasible based on how FRHS is utilized, the number of technical classes taught, and the numbers of administrative staff in the building who rely on the equipment.

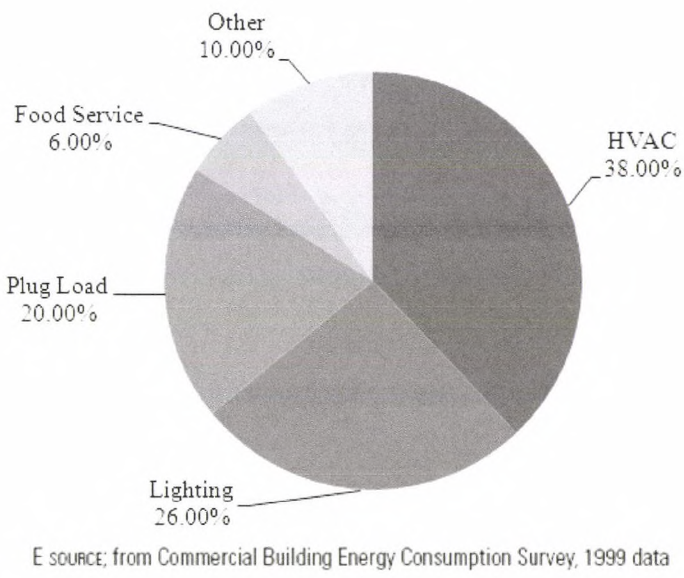

Figure 5: K-12 National Average Electric Use by Percent of Total Consumption (E Source, 2002)

Workspace-Specific Electricity Consumption

Whole-building EUIs are normalized to gross building conditioned floor space, the primary determinant of building energy use (Sharp, 1998). However, there are many secondary building characteristics that affect energy use, for example, occupant density, amount of electronic equipment, or operating hours (Sharp, 1998). In an attempt to improve upon the use of whole-building EUIs for comparing energy performance at FCHS and FRHS, the consumption was partitioned among 13 distinct workspace types. While the HVAC and residual electricity usage were considered to be directly proportional to the floor areas associated with each workspace type, lighting and plug load electricity expenditures were uniquely quantified for each area. The workspace-by-workspace evaluation results of this analysis are provided in Tables 8 (FRHS) and 9 (FCHS).

There are some notable differences in the way floor space is utilized at these schools. FRHS dedicates more workspace area to administration (2,874 ft^2, 16% more), classroom (6,088 ft^2, 10% more), commons (5,420 ft^2, 8% more), theater (2,343 ft^2, 17% more) and trade classroom (7,017 ft^2, 62% more) use than FCHS, while containing less square footage for all other workspace types.

From the analysis whole-building EUIs of 6.89 and 7.76 were estimated for FRHS and FCHS respectively. Based on the actual electric consumption (2006-2008 average values) the whole-building EUIs were 6.46 at FRHS and 7.93 at FCHS. It should be noted that the estimated whole-building EUI does not include exterior building lighting because a square footage is required to determine EUI. For fair comparison, removal of the estimated exterior lighting electric consumption from the actual whole-building EUI is necessary. Excluding exterior lighting, the actual EUIs are 6.40 for FHRS and 7.68 for FCHS.

Table 8: FRHS Floor Area Distribution and Workspace EUI

Work Space Designation	Floor Area Distribution (SF)	% of Total Floor Area (SF)	Workspace EUI (kWh/ft^2/yr)
Administrative	21,237	7.64%	17.40
Classroom	66,331	23.85%	4.85
Closet/Storage	7,960	2.86%	2.76
Commons	76,293	27.44%	4.60
Computer Lab	3,762	1.35%	24.17
Gymnasium	41,057	14.77%	3.82
Kitchen	3,754	1.35%	40.84
Library	10,798	3.88%	7.04
M/E/Data Room	4,717	1.70%	4.24
Restrooms	7,628	2.74%	6.17
Theater	16,217	5.83%	13.27
Trades Classroom	18,309	6.58%	4.98
Whole-Building:	278,063	100%	6.89

Table 9: FCHS Floor Area Distribution and Workspace EUI

Work Space Designation	Floor Area Distribution (SF)	% of Total Floor Area (SF)	Workspace EUI (kWh/ft2/yr)
Administrative	18,363	6.47%	18.96
Classroom	60,243	21.22%	5.54
Closet/Storage	13,347	4.70%	3.54
Commons	70,873	24.96%	6.16
Computer Lab	9,491	3.34%	11.33
Gymnasium	41,554	14.64%	6.61
Kitchen	6,192	2.18%	26.13
Library	18,147	6.39%	5.61
M/E/D Room	12,623	4.45%	2.86
Restrooms	7,894	2.78%	6.17
Theater	13,874	4.89%	13.62
Trades Classroom	11,292	3.98%	10.45
Whole-Building:	283,923	100%	7.76

While whole-building estimated EUIs were similar to actual values, large variations in workspace EUIs were found in both schools. FRHS's workspace EUIs range from 2.76 for closet/storage areas to 40.84 for the kitchen. The EUI at FCHS ranged from 2.86 in mechanical, electrical and data (M/E/D) rooms to 26.13 in the kitchen. It was also found that variation exists within EUI for the same workspace types in both schools. Trade classroom EUI at FCHS is 10.49, while at FRHS it is much lower (4.82). Variation in EUI of specific workspaces at both schools is evaluated in the Workspace Component EUI section and the results are shown in Tables 10 and 11.

It should be noted that the floor area of FCHS's kitchen is approximately two times that of FRHS despite similar kitchen equipment quantities and electric consumption levels at both schools (see Methodology). The original design of FCHS's kitchen allotted 6,192 SF to accommodate four separate food vendors; however, when the kitchen area was renovated (2006) the floor area of the kitchen was not changed. Since Workspace EUI is based on floor area, FCHS has a much lower Kitchen EUI (26.13) even though it consumes approximately the same amount of electricity each year as the FRHS kitchen (EUI of 40.84).

FRHS has 63% less floor area dedicated M/E/D rooms than FCHS. Review of the construction documents indicates that FCHS has 11 dedicated M/E/D rooms, while FRHS has 21. FRHS design incorporates more, but smaller, M/E/D workspaces. While M/E/D rooms are not one of the higher electric-consuming areas, is was noted that the FCHS design, which uses a small number of larger rooms for M/E/D areas, consumes less electric energy per square foot each year. This may be due to the use of fewer light fixtures to supply a larger floor area with adequate light. That is, while one light fixture

Table 10: FRHS Workspace Component EUIs (kWh/ft^2/yr)

Workspace Designation	Lighting	HVAC	Plug Load	Food Service	Residual	Workspace EUI
Administrative	2.19	2.01	13.04	0.00	0.16	17.40
Classroom	2.14	2.01	0.54	0.00	0.16	4.85
Closet/Storage	0.59	2.01	0.00	0.00	0.16	2.76
Commons	1.90	2.01	0.53	0.00	0.16	4.60
Computer Lab	4.57	2.01	17.43	0.00	0.16	24.17
Gymnasium	1.50	2.01	0.15	0.00	0.16	3.82
Kitchen	2.96	2.01	0.00	35.71	0.16	40.84
Library	2.85	2.01	2.02	0.00	0.16	7.04
M/E/D Room	2.07	2.01	0.00	0.00	0.16	4.24
Restrooms	4.00	2.01	0.00	0.00	0.16	6.17
Theater	11.10	2.01	0.00	0.00	0.16	13.27
Trades Classroom	1.44	2.01	1.37	0.00	0.16	4.98
Whole-Building Component EUI	2.54	2.01	1.69	0.48	0.16	6.89

Table 11: FCHS Workspace Component EUIs (kWh/ft^2/yr)

Workspace Designation	Lighting	HVAC	Plug Load	Food Service	Residual	Workspace EUI
Administrative	2.86	2.68	13.46	0.00	-0.03	18.96
Classroom	2.37	2.68	0.53	0.00	-0.03	5.54
Closet/Storage	0.89	2.68	0.00	0.00	-0.03	3.54
Commons	3.52	2.68	0.00	0.00	-0.03	6.16
Computer Lab	3.61	2.68	5.07	0.00	-0.03	11.33
Gymnasium	3.81	2.68	0.15	0.00	-0.03	6.61
Kitchen	1.15	2.68	0.00	22.35	-0.03	26.13
Library	2.05	2.68	0.91	0.00	-0.03	5.61
M/E/D Room	0.21	2.68	0.00	0.00	-0.03	2.86
Restrooms	3.52	2.68	0.00	0.00	-0.03	6.17
Theater	10.98	2.68	0.00	0.00	-0.03	13.62
Trades Classroom	5.61	2.68	2.20	0.00	-0.03	10.45
Whole-Building Component EUI	3.31	2.68	1.32	0.49	-0.03	7.76

may be able to supply adequate light for a 200 ft^2 room, if that room is partitioned into two 100 ft^2 rooms, two light fixtures would be required effectively doubling the EUI for that workspace type. While the effect of partition density is outside the realm of this study, it may be a contributing factor to both workspace specific and whole-building EUI.

Notably FRHS has 60% less computer lab space than FCHS. FRHS allocates the 3,762 ft^2 to four designated computer labs with an average floor area of 940 ft^2, while FCHS has seven computer labs averaging 1,356 SF each. FRHS is designed to provide students with computer access in the common areas of the school in addition to the computer lab spaces, while FCHS has no equivalent design. Twenty five computers were allocated to each computer lab in both schools; FCHS contains 175 computers and monitors in the seven labs, compared to 100 computers and monitors spread across four labs at FRHS. This equates to a computer density of one computer for every 37.6 ft^2 of computer lab at FRHS and one computer for every 54.2 ft^2 of computer lab at FCHS. Since computers and monitors make up the largest percentage of electricity consumption in plug loads, the density of computers in an area can have a significant impact on workspace specific EUI values. At FRHS, where the floor area of computer labs is small and the computer density is high, the computer lab workspace EUI is 24.17. In contrast FCHS, with larger computer labs with lower computer density, has a computer lab workspace EUI of only11.33.

The gymnasium workspaces of FRHS and FCHS are similarly sized, 41,057 ft^2 and 41,554 ft^2 respectively, however electric consumption in this workspace at FCHS (EUI of 6.19) is nearly double that of FRHS (EUI of 3.66). The lighting of the FCHS gymnasium consists of 88 - 400W metal halide lights and 30 - 64W egress lights.

However, at FRHS, 115 - 64W T-5 high–output florescent and 32 - 20W egress lights are used to illuminate the gymnasium. While FRHS has a higher lighting density of one fixture per 279.2 ft^2 compared to one fixture per 352.15 ft^2 at FCHS, the data suggests that lighting wattage in the gymnasium workspaces is a likely cause for the high workspace EUI at FCHS.

The theater areas at both schools represent areas of high electricity consumption as reflected in the theater workspace EUI of 13.62 at FCHS and 13.27 at FRHS. Similar to the gymnasium workspace, theater lighting at both schools use a tremendous amount of electricity. In addition to standard lighting, FCHS has 56 performance and house lights with wattages that range from 500W to 1000W. FRHS has 155 performance and house light with wattages that range from 400W to 675W. Using a 6-hours per day for all academic days (G. Osterhout, Personal Communication, December 4, 2009) runtime theater lighting accounts for 662 kWh/day at FCHS and 789 kWh/day at FRHS. Theater lighting accounts for approximately 9.3% of total electricity consumption at FRHS and 6.76% of total electricity consumption at FCHS.

Workspace-Specific Component EUI

It is useful to partition the 12 workspace specific EUIs into their lighting, HVAC, plug load, food service and residual components in order to gain insight into the variation seen between workspace specific EUIs at both schools. Dividing workspace EUIs into their consumptive components allows for identification of areas for energy cost reductions. Recommendations for areas of renovation or electricity consumption reduction can be made based on the results shown in Tables 10 and 11. It should be noted that the HVAC and residual component EUIs are the same for all areas because the total electricity consumption in these areas was divided by square footage as described in the methodology.

The whole-building component EUIs confirm what was shown in the building electric use charts (Figure 4); specifically that lighting is a larger consumer of electricity at FCHS than FRHS. FRHS's lighting component workspace EUIs are generally lower than those at FCHS with the largest differences seen in the commons and gymnasium with 1.62 kWh/ft^2 and 2.31 kWh/ft^2 less consumption, respectively. However, the lighting components workspace EUIs indicate that consumption in the computer labs, kitchen, library, M/E/D rooms, restrooms and theater are lower at FCHS than at FRHS. Notably, the computer labs, kitchen, and M/E/D room at FCHS consume 0.96 kWh/ft^2, 1.81kWh/ft^2, and 1.86 kWh/ft^2 less electricity, respectively.

The results also show that some of the workspace EUIs are dominated by a single component EUI. Kitchen workspaces represent the highest EUI values at both schools and as expected, the food service component EUIs make up the vast majority of the kitchen workspace EUI (85.53% at FCHS and 87.43% at FRHS). The computer lab workspace EUIs are substantially different at FCHS and FRHS being 11.33 and 24.17 kWh/ft^2/yr, respectively. The computer lab component EUIs demonstrate that the vast majority of the difference (89%) is attributed to the plug load component EUI, presumably due to computer and monitor electric loads. In addition, 6.92% of the electric consumption difference in computer labs at FCHS is due to lighting.

Investigation of the trade classroom workspace EUIs revealed that 52% more electricity is being consumed per ft^2 at FCHS. The component EUI for trade classrooms shows that 76% of the difference between schools can be attributed to lighting.

Considering the shift in trade classroom training towards computer based programs (S. Reeve, personal communication, November 11, 2009), it is possible that the lighting which was required for woodworking, automotive repair, and metal working is no longer needed and was not installed at FRHS. If high-level lighting for hands-on training is no longer needed at FCHS in trade classrooms, this is a possible area to reduce electricity consumption at FCHS without lowering education quality.

Evaluating Overall EUI Validity

Each school's whole-building EUI was normalized to the workspace EUIs of the other school. This was accomplished by multiplying the workspace EUI of one school by the floor space distribution of the other. The adjusted whole-building EUIs represent the estimated electric consumption of each school if it were built to the same standard of energy efficiency but maintained its current workspace square footage distribution. Since the adjusted EUI values do not include exterior light, this consumptive component was removed prior to this comparison process. Results from FRHS and FCHS are shown in Tables 12 and 13 respectively. Based on the estimated electric consumption data, whole-building EUI values (without exterior lighting) would be 6.89 for FRHS and 7.76 for FCHS. Comparison of FRHS adjusted whole-building EUI (7.96) with FCHS estimated whole-building EUI (7.76) indicates that FRHS would consume more electricity than FCHS if it were built to the same efficiency standards while retaining its current floor space configuration. While it was expected that FRHS's adjusted whole-building EUI would be greater than the estimated whole-building EUI, it was somewhat surprising that FRHS's adjusted whole-building EUI was higher than FCHS estimated whole-building

EUI. FRHS would consume more electricity than FCHS because several of the high-electric consumption areas of the building represent large percentages of the building's floor area. While several workspace areas indicate increases in electric consumption when adjusted to FCHS workspace EUIs, the areas with lower workspace EUIs indicated reductions in the adjusted electricity consumption and resultant whole-building EUI of FRHS (See Tables 14 and 15).

The largest increases in electric consumption at FRHS are seen in the commons, gymnasium, and trade classroom workspace areas. The commons and gymnasium represent 76,293 ft^2 and 41,057 ft^2, respectively, at FRHS. If FRHS were built to the efficiency standards of FCHS, the electric use in these workspaces would increase by 1.56 $kWh/ft^2/yr$ (119,223 kWh/yr) in the common areas and by 2.79 $kWh/ft^2/yr$ (114,545 kWh/yr) in the gymnasium.

The trades classroom workspaces illustrate a different phenomenon in which workspaces which make up a small percentage of the total floor area can have large effect on total consumption. This can occur when EUI values and/or floor areas are dramatically different between the two schools. There is approximately 62% more trades classroom floor space at FRHS (18,309 ft^2) than at FCHS (11,292 ft^2); in addition, the trade classroom workspace EUIs are much lower are at FRHS (4.98) than FCHS (10.45). This EUI difference represents an adjusted consumptive use difference of 5.47 $kWh/ft^2/yr$ (100,233 kW/yr) at FRHS. It should be noted that higher workspace EUI matched with lower square footages area (or vice versa) can negate one another, resulting in little difference in adjusted electric consumption in a building.

Table 12: FRHS Adjusted Workspace Consumption and Whole-Building EUI

Workspace Designation	FRHS Floor Area Distribution (SF)	FCHS Workspace EUI (kWh/ft^2/yr)	FRHS Adjusted Electric Consumption (kWh/yr)
Administrative	21,237	18.96	402,692
Classroom	66,331	5.54	367,204
Closet/Storage	7,960	3.54	28,142
Commons	76,293	6.16	470,105
Computer Lab	3,762	11.33	42,610
Gymnasium	41,057	6.61	271,410
Kitchen	3,754	26.13	98,108
Library	10,798	5.61	60,561
M/E/D Room	4,717	2.86	13,469
Restrooms	7,628	6.17	47,030
Theater	16,217	13.62	220,939
Trades Classroom	18,309	10.45	191,417
Totals:	278,063		2,213,687

FRHS Adjusted whole-building EUI - 7.96

Table 13: FCHS Adjusted Workspace Consumption and Whole-Building EUI

Workspace Designation	FCHS Floor Area Distribution (SF)	FRHS Workspace EUI (kWh/ft^2/yr)	FCHS Adjusted Electric Consumption (kWh/yr)
Administrative	18,363	17.40	319,550
Classroom	60,243	4.85	291,988
Closet/Storage	13,347	2.76	36,832
Commons	70,873	4.60	326,140
Computer Lab	9,491	24.17	229,411
Gymnasium	41,554	3.82	158,764
Kitchen	6,192	40.84	252,901
Library	18,147	7.04	127,817
M/E/D Room	12,623	4.24	53,533
Restrooms	7,894	6.17	48,736
Theater	13,874	13.27	184,084
Trades Classroom	11,292	4.98	56,237
Totals:	283,923		2,085,992

FCHS Adjusted whole-building EUI - 7.34

In review of the component EUI values in Tables 10 and 11, the vast majority of the higher electric use is due to lighting in the commons, gymnasium, and trade classroom workspaces. Increases in total electric consumption would be expected at FRHS if the daylighting were removed from the design, the lower wattage lighting was replaced with high wattage lighting, or the building dimming system was removed from the design.

Comparison of FCHS adjusted whole-building EUI (7.34) with FCHS estimated whole-building EUI (6.89) indicates that FCHS would consume more electricity than FRHS if it were built with the same efficiency standards and contained the same plugged equipment densities, while retaining its current floor space configuration. Because the increases in electric consumption are directly related to the workspace EUI of each school, it is not surprising that workspaces in FCHS where consumption decreased when adjusted correspond directly with those that increase when adjusted for FRHS. That is, FCHS adjusted electric consumption quantities decreased in the commons, gymnasium, and trade classroom workspaces based on the differences in lighting, while these same areas increased in FRHS when adjusted whole-building EUI was calculated.

Large increases were seen in the adjusted electric consumption of the computer lab and kitchen workspaces at FCHS. The computer lab area represents only 9,491 ft^2 in FCHS, however, the vastly different workspace EUI values for computer labs (11.33 at FCHS and 24.17 at FRHS) represent an electricity consumption difference of 12.84 kWh/ft^2 which translates to a total consumptive increase of 121,912 kWh/yr for FCHS (Table 15). Investigation of the component EUI indicates that the majority of the workspace EUI difference is associated with plug loads, with a small portion of the

Table 14

FRHS Electric Consumption Increases/Decreases by Workspace (kWh/yr)

Workspace Designation	Estimated Electric Consumption	Adjusted Electric Consumption	Consumption Increase	Consumption Decrease
Administrative	369,563	402,692	33,128	-
Classroom	321,496	367,204	45,708	-
Closet/Storage	21,966	28,142	6,176	-
Commons	351,081	470,105	119,023	-
Computer Lab	90,933	42,610	-	48,323
Gymnasium	156,865	271,410	114,545	-
Kitchen	153,326	98,108	-	55,218
Library	76,055	60,561	-	15,494
M/E/D Room	20,004	13,469	-	6,536
Restrooms	47,093	47,030	-	63
Theater	215,171	220,939	5,768	-
Trades Classroom	91,184	191,417	100,233	-
Totals:	1,914,737	2,213,687		

Table 15

FCHS Electric Consumption Increases/Decreases by Workspace (kWh/yr)

Workspace Designation	Estimated Electric Consumption	Adjusted Electric Consumption	Consumption Increase	Consumption Decrease
Administrative	348,196	319,550	-	28,645
Classroom	333,501	291,988	-	41,513
Closet/Storage	47,188	36,832	-	10,356
Commons	436,708	326,140	-	110,568
Computer Lab	107,498	229,411	121,912	-
Gymnasium	274,696	158,764	-	115,932
Kitchen	161,823	252,901	91,078	-
Library	101,778	127,817	26,038	-
M/E/D Room	36,043	53,533	17,490	-
Restrooms	48,670	48,736	65	-
Theater	189,018	184,084	-	4,935
Trades Classroom	118,056	56,237	-	61,819
Totals:	2,203,175	2,085,992		

increased consumption due to lighting. The large increase in electric consumption appears to be tied to the higher computer and monitor density present in FRHS's computer labs.

The kitchen workspace area also showed significant increase when electric consumption was adjusted for FCHS. The FCHS kitchen area (6,192 ft^2) is approximately twice that of the kitchen at FRHS (3,754ft^2). While the total kitchen workspace-related electric consumption is similar at both schools, when the workspace EUIs are switched, it was found that the size of FCHS kitchen caused the electric consumption to increase dramatically by 91,078 kWh/ft^2/yr.

It should be noted that the renovation of FCHS kitchen, which reduced the electric consumption of the equipment but had no effect on the kitchen square footage, highlights the importance of similar square footage distribution when using EUI for comparison. When building workspace square footages are vastly different, the EUI assumes that electric use is spread evenly across the floor area. The kitchen workspace EUI demonstrates that the design of a space and the existence of unused/unneeded floor area (especially in areas of high electric consumption) can compromise the accuracy of the EUI as a comparison tool.

As an example, the kitchen at FCHS consumes a total of 161,021 kWh/yr of which 84% (138,365 kWh/yr) is consumed by the food service equipment. The kitchen at FCHS consumes a total of 153,325 kWh/yr of which 87% (134,055 kWh/yr) is consumed by the food service equipment. While lighting and HVAC may be loosely dependent on floor area, it appears that food service equipment is not. While both kitchens are designed to service a similar number of students, one has a floor area twice the needed size. The large floor area causes the workspace EUI of the larger kitchen to be much lower, which could be misinterpreted to mean it is more efficient while in actuality the total energy consumption for both kitchens is similar.

Since, in these schools, the kitchen makes up only ~2% of the floor area and consumes ~7% of the total electric energy, the whole-building EUI is not dramatically affected (~0.48 kWh/ft^2/yr) by this difference. However, this could cause significant differences when comparing buildings of small floor areas and high equipment densities. Areas of intense electric consumption should be interpreted with caution when considering the use of EUI as a comparison tool. It appears that one of the shortcomings of EUI is the assumption that all consumptives use of electricity, including those related to food service equipment and computers, are directly dependent on building floor area. From this study it can be seen that equipment, and perhaps more importantly the density of that equipment within the building, are highly sensitive variables which should be considered when comparing buildings using EUI.

Others (Sharp, 1998) have documented the limitation of using the annual whole-building EUI for comparing energy use between schools. While partitioning schools into different workspaces seems to improve the use of EUI for benchmarking school energy use, component EUIs seems to be the most appropriate tool for comparison. Component EUI allows the areas of high consumptive use to be analyzed and targeted for reductions in electric consumption. However, it should be stated that a high workspace EUI does not necessarily equate to poor efficiency, but may be a better indicator of lighting and equipment densities which can be investigated and targeted for possible electricity reductions.

Conclusion

Major Findings

Critical analysis of electricity consumption at the two high schools proved to be a major effort requiring many underlying assumptions. Results could be improved if these assumptions were verified; particularly when the assumptions involve input parameters for which electricity consumption is highly sensitive, for example, the HVAC runtimes and motor load factors. Results of this investigation also underscore the limitations of using the overall building EUI as an energy performance metric. Because secondary building characteristics (floor space usage patterns and amount of electricity-consuming equipment) can be quite variable between buildings, the whole-building EUI must be interpreted with caution.

In the PSD, FCHS and FRHS have similar building attributes (square footage, mechanical systems, and architectural capacities); however, this analysis identified several substantial differences in the workspace distribution and electric consumption at the two schools. It was noted that significantly more electricity is used for HVAC at FCHS (759,822 kW/yr) when compared to FRHS (588,859 kW/yr). Lighting electric expenditure was also higher at FCHS (1,008,999 kW/yr) compared to (706,832 kW/yr) FRHS. The lighting at FRHS consumed 282,634 kW/yr less electricity than FCHS; of that difference, 88.3% was seen in the commons (36.9%), gymnasium (34.2%), and exterior lighting (17.2%).

While FRHS component EUIs demonstrated that the HVAC and lighting systems require less electric energy per square foot than FCHS, several workspaces at FRHS consumed more electricity than their FCHS counterparts. Through analysis of component

EUIs it was clear that higher workspace EUIs were a reflection of significantly higher plug load electric consumption in several workspaces. Overall, plugged equipment at FCHS consumed 96,424 kW/yr less electricity than FRHS. 97.1% of the total plug load consumption difference was seen in the commons (41.7%), administrative (36.6%), and computer lab (18.8%) workspaces. The workspaces which have the highest difference is plug load consumption also have the highest computer and monitor densities. These results highlight the effect of equipment density on whole-building and workspace EUI.

This study indicates that overall EUI is initial tool that can be used for building-to-building comparison and identification of buildings which consume large amounts of electricity per square foot. However, the overall EUI value for a school does not necessarily indicate a building's electric consumption efficiency. While FRHS lighting and HVAC systems consume quite a bit less electricity that FCHS each year, the higher plug load consumption at FRHS increases the overall EUI. Likewise, the low plug load consumption at FCHS lowers the overall EUI despite the higher electric consumption in lighting and HVAC. It is noted that, while the high plug load consumption did not overshadow the reduction seen in HVAC and lighting at FRHS, the overall EUI could be increased in buildings which have efficient mechanical and lighting systems but high equipment densities.

The development of workspace EUI values for each school provided additional insight into each school's overall EUI. Workspace EUI analysis indicated which workspace types consumed the most electricity per square foot in each building. Workspace EUI provides an additional means for comparing building electric consumption on a workspace-to-workspace level. In addition, the identification of workspace types which consume high amounts of electricity allows for targeting of highly consumptive workspaces for future renovations and energy reduction efforts. Through the comparison of workspace EUIs, the computer labs at FRHS had an EUI of 24.01 while FCHS's computer lab EUI was 11.36. In contrast, the trade classrooms at FCHS had a workspace EUI of 10.49 while FRHS's trade classroom EUI was only 4.98. Vastly different EUI values at the two schools indicate that the electricity consumption of computer labs at FRHS and trades classroom workspaces at FCHS should be investigated.

Each workspace EUI was further subdivided into HVAC, lighting, plug load, food service, and residual component EUIs. Understanding workspace electric consumption at the component EUI level provided further insight into which components consume the most electricity and therefore should be targeted for electric consumption reductions. A high consumption workspace component EUI, such as the plug loads (17.43) in the computer labs at FRHS, does not necessarily indicate that the workspace is using more electricity than required. It does, however, provide insight into the workspace EUI and identifies consumptive components with energy reduction potential. The component EUI results from this study will allow PSD to evaluate the use of computers in FRHS computer labs to determine if the computer density is representative of the computer requirements at that school. If PSD determines that computer density is higher than required, reductions in the quantity of computers may be a feasible option for electric consumption reductions at FRHS.

The estimation of adjusted EUIs for each school based on the other school's building parameters and electric consumption, indicated that FRHS would use ~18.4%

(~353,068 kW) more electricity per year if it were built to the specifications of FCHS but maintained the same workspace distribution. The FCHS adjusted EUI indicated that the school would consume ~7.6% (172,670 kW) less electricity per year if it were constructed to the same electric consumption parameters as FRHS. It should be noted that these increases in energy use assume the lower plug load and the higher HVAC and Lighting consumption rates of FCHS. In review of a somewhat small reduction in adjusted EUI at FCHS, one must consider the much higher plug load consumption and computer densities of FRHS. In conjunction with the larger computer labs at FCHS, the high equipment densities for FRHS cause a large increase in consumption and the subsequent adjusted EUI for FCHS.

While adjusted EUIs for both schools provided an interesting method for predicting how each building would perform if built to different specifications, the adjusted EUIs are not necessarily superior energy benchmarks compared to traditional whole-building EUIs. Both adjusted and traditional whole-building EUI values fail to consider highly sensitive variables such as workspace distribution, equipment density, and building occupancy patterns which affect electricity consumption. More rigorous evaluation of buildings can be accomplished through workspace and component EUI comparisons. However, workspace and component EUIs are most useful for identifying high electricity consumption building areas that can be targeted for electric use reductions.

Study Refinement Opportunities

Predicted electricity energy distribution was based on numerous assumptions, and uncertainty in some input parameters has a large impact on the final results. Electricity use estimates were highly sensitive to the runtimes chosen for HVAC and lighting systems. For example, if the HVAC runtimes were increased from 11 to 12 hours per day, the total annual electricity use increased by approximately 6% at FRHS. While this highlights the effectiveness of careful management of runtimes in improving building energy performance, it also underscores the importance of accurate runtime assumptions in energy audits. To improve the accuracy of electric consumption values, in-field verification of HVAC, lighting, plug equipment, and food service equipment runtimes at each school would be beneficial.

Electric consumption from HVAC pumps and fans is also a direct function of the amperage drawn by each motor under actual operating (differential load) conditions. A single load factor assumption of 35% was used for all motors in this analysis based on previous studies (Capehart, 2000). The assumption could be verified by taking actual amperage readings from motors in both schools during different operating conditions. The analysis would likely be improved by using some time-weighted average load factors. Similar to runtimes, electric consumption is highly sensitive to the load factor. Increasing the load factor from 35% to 40% raised the estimated annual electricity increase by 4% (79,873 kW/yr) at FRHS.

Further Research

While whole-building EUI is a metric whereby PSD schools can be compared on a preliminary basis, further investigation of component EUIs by school level could shed additional light on building electric use patterns within PSD. The PSD operates 5 high schools, 9 middle schools, and 31 elementary schools. While this study compared two high schools, middle schools and elementary schools should also be investigated using the component EUI method. It is possible that electric consumption, especially when related to computer density, is affected by student age and grade level. As new technologies which require computer use by students of younger ages are incorporated into curricula, the plug load component EUI may become a large piece of total consumption. Further study of plug load EUI component may help explain increases as they occur.

The load factors used for the HVAC components EUIs for each school could be further investigated. Since HVAC pump and fan loads are a high impact and constantly changing variable in HVAC electric consumption, determination of average load factors for high schools, middle schools and elementary schools in PSD would be helpful in future electricity consumption predictions. Further, average pump and fan load factors could be used by PSD to optimize equipment efficiency and help reduce consumption due to pump and fan over-sizing.

Beyond PSD, the use and validity of component EUIs for commercial buildings should be investigated. While schools have many workspace area designations, office buildings, for example, would generally have fewer and more easily definable workspace types. Commercial buildings component EUIs would be helpful in establishing design (and possibly energy codes or standards) criteria for buildings based on use type. Identification of component EUIs may also increase the accuracy of electricity use predictions for individual buildings during the design phase.

Recommendations

Comparison and evaluation of workspace and component EUIs for both buildings identified that several workspaces at each school should be targeted for electric consumption reductions. At FCHS, the lighting component EUIs in the trade classrooms and gymnasium workspaces are significantly higher than at FRHS. Investigation to determine whether the light fixture intensity is representative of the use of these two workspaces may indicate that a reduction in lighting is possible without detrimentally affecting educational use of the workspaces.

The theater workspaces at both FRHS and FCHS exhibit high lighting component EUI values of 11.10 and 10.99, respectively. Investigation of the use pattern for performance lighting at each school may be helpful in identifying areas of electric consumption improvement. Theater occupant behavior may indicate that performance lighting is being used even when it is not required for all activities which occur in the theater workspace. Since theater lighting is an area of high consumption, reduction in theater lighting runtimes is one area where substantial electricity consumption reduction may be possible.

At FRHS the plug load component EUI for computer labs (17.43) is higher than FCHS (5.07). In addition, FRHS demonstrates computer related plug-load consumption in its common areas while FCHS does not. An evaluation of computer use patterns at FRHS and the need for higher computer densities should be conducted. If the computer density accurately represents the educational computer needs, then computer quantity reduction is not feasible. However, if computers can be removed from the computer labs and commons, reduction in electricity consumption would be possible.

In conclusion, the present study provided a basic understanding of electric energy usage at FCHS and FRHS. Currently both schools are performing better than the median overall EUI of 8.9 $kWh/ft^2/yr$ for all schools in the US (USEIA, 2003). It is hoped that the results of this and further studies can be used to prioritize strategies for indentifying and implementing future energy cost reduction opportunities. The ultimate objective is to redirect energy use resources towards critical and more important educational goals.

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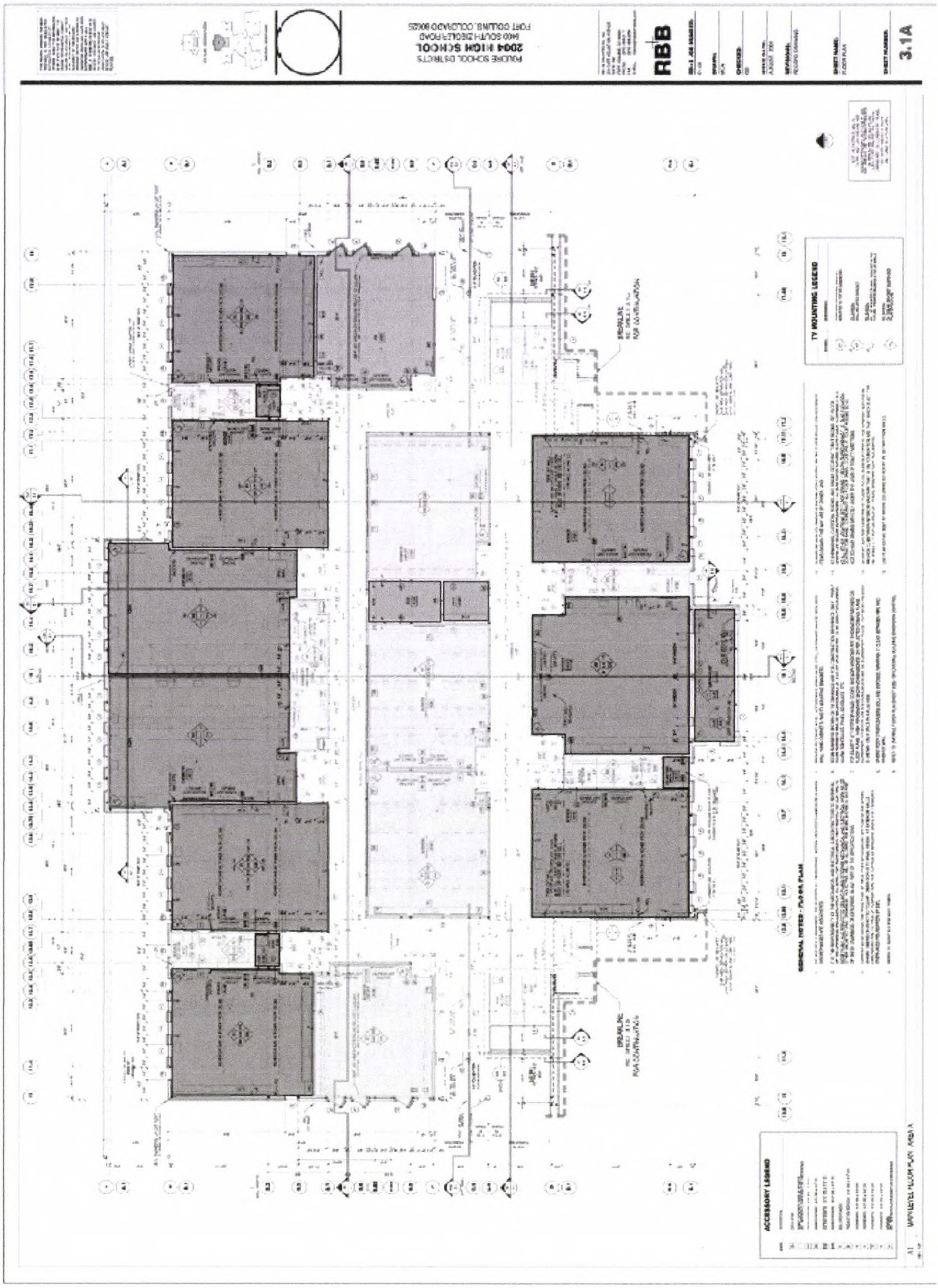
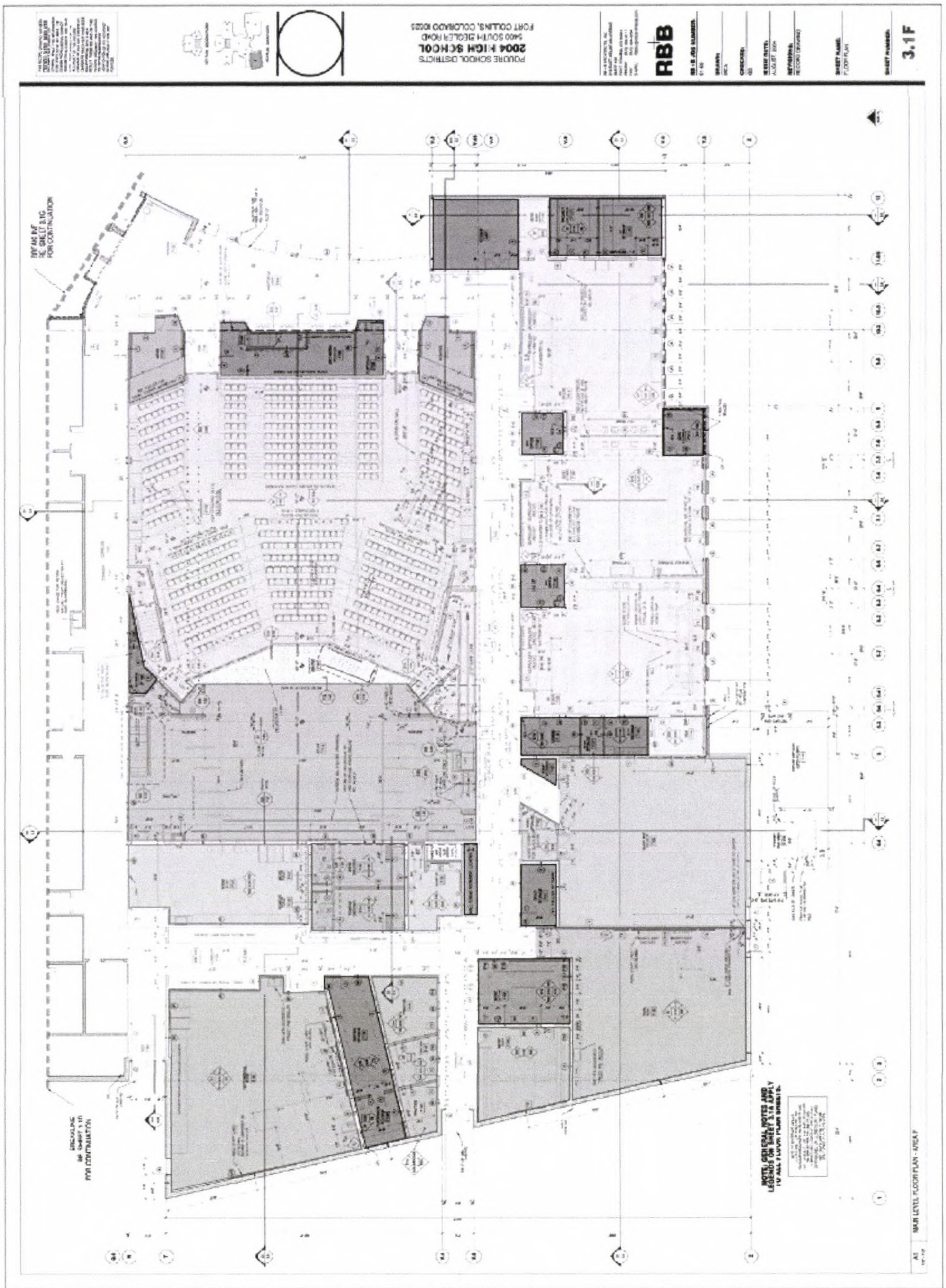
Appendix A

On-Screen Takeoff Floor Area Screenshots and Quantity Table

Example 1 – FRHS First Floor Wing A



Example 2 – FRHS First Floor Wing F



FRHS Floor Space Distribution Table from On-Screen Takeoff

Takeoff Tab

Fossil Ridge - Differential Space Usage

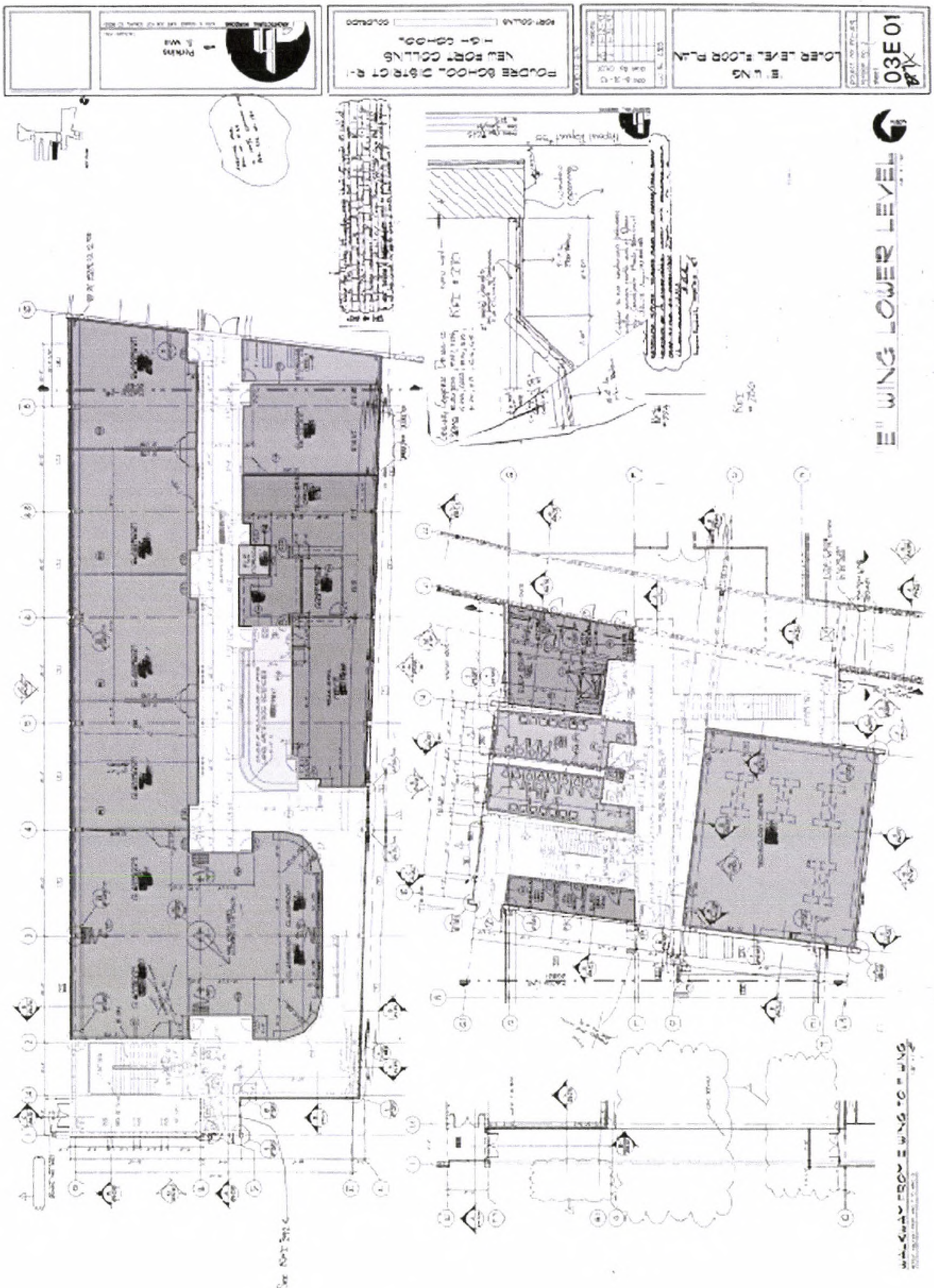
Bid No. 15

No.	Name	Height	Area	Quantity1	UOM1	Quantity2	UOM2	Quantity3	UOM3
(unassigned)									
1	Science Room	0"	(unassigned)	11,843	SF	0		0	
2	Science Prep Room	0"	(unassigned)	1,094	SF	0		0	
3	Business Classroom	0"	(unassigned)	4,112	SF	0		0	
4	Standard Classroom	0"	(unassigned)	42,068	SF	0		0	
5	Mech/Elec/Data Room	0"	(unassigned)	4,717	SF	0		0	
6	Corridor/Vestibule/Stair/Commons	0"	(unassigned)	76,293	SF	0		0	
7	Closet/Storage	0"	(unassigned)	7,960	SF	0		0	
8	Restrooms/Showers	0"	(unassigned)	7,628	SF	0		0	
9	Classroom (Future Comp. Lab)	0"	(unassigned)	1,914	SF	0		0	
10	Admin/Offices	0"	(unassigned)	20,553	SF	0		0	
11	Tech./Trades Lab	0"	(unassigned)	2,713	SF	0		0	
12	Eng. Graphic/Drafting	0"	(unassigned)	1,235	SF	0		0	
13	Tech./Trades Classroom	0"	(unassigned)	2,121	SF	0		0	
14	TV Studio Classrom Lab	0"	(unassigned)	1,796	SF	0		0	
15	Culinary Lab	0"	(unassigned)	4,358	SF	0		0	
16	Computer Lab	0"	(unassigned)	1,848	SF	0		0	
17	Copy Center - Admin	0"	(unassigned)	684	SF	0		0	
18	Spec. Lecture Classroom (Aduitorium)	0"	(unassigned)	1,863	SF	0		0	
19	Library/Resource Center	0"	(unassigned)	10,798	SF	0		0	
20	Kithch/Food Service	0"	(unassigned)	3,754	SF	0		0	
21	Music Classroom	0"	(unassigned)	4,565	SF	0		0	
22	Theater - Stage Area	0"	(unassigned)	3,206	SF	0		0	
23	Theater - Seating	0"	(unassigned)	6,140	SF	0		0	
24	Theater - Misc.	0"	(unassigned)	4,835	SF	0		0	
25	Theater - Black Box	0"	(unassigned)	2,036	SF	0		0	
26	Art Classroom & Kiln (125 SF)	0"	(unassigned)	6,086	SF	0		0	
27	Weights/Lockers/Fitness/Training	0"	(unassigned)	13,515	SF	0		0	
28	Health Classroom	0"	(unassigned)	786	SF	0		0	
29	Gymnasium	0"	(unassigned)	27,542	SF	0		0	

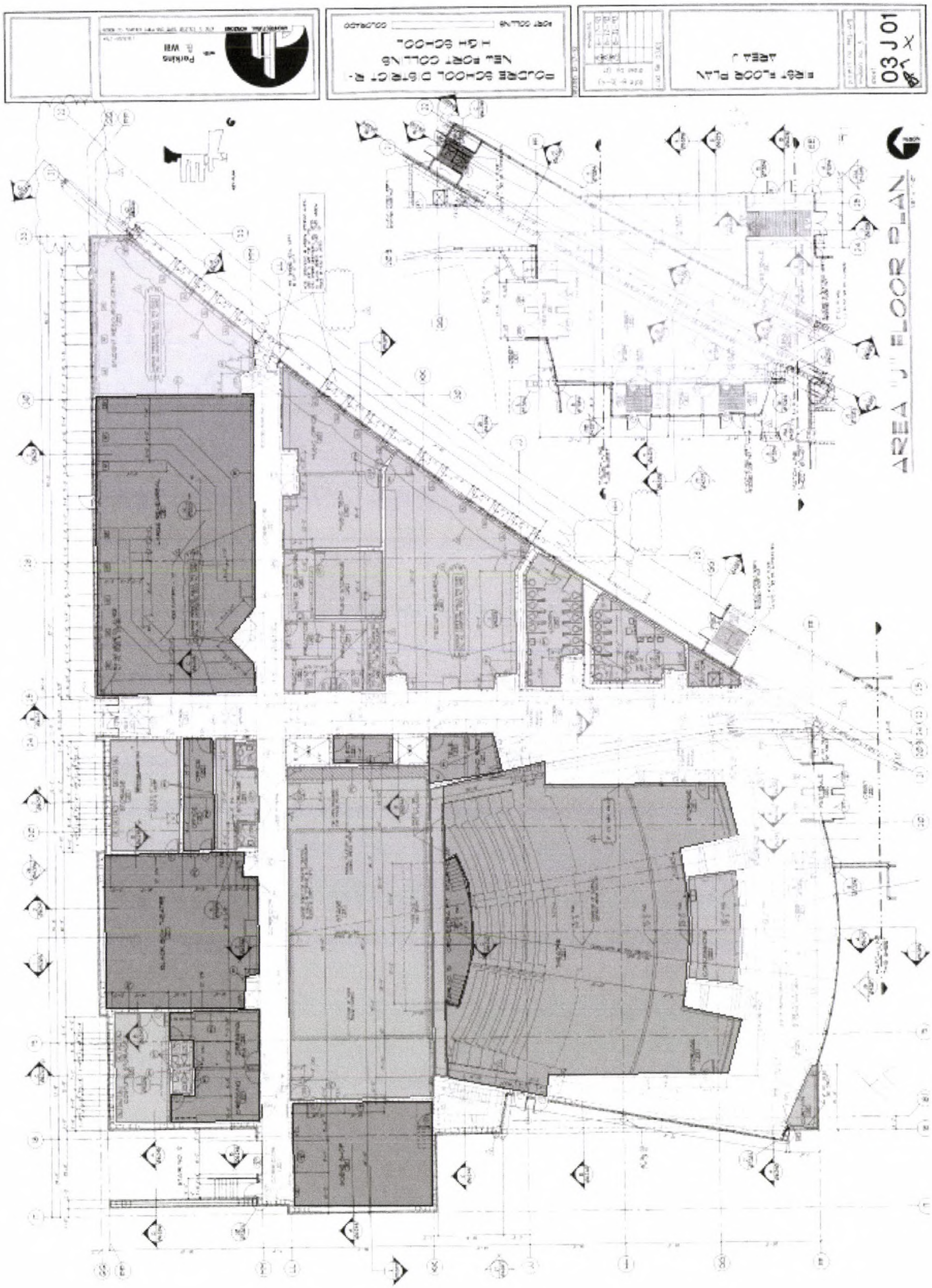
FRHS Floor Space Distribution Table by Twelve Workspace Types

Takeoff Item	Room Designation	General Designation	Floor Area
17	Copy Center - Admin	Administrative	684 SF
10	Admin/Offices	Administrative	20,553 SF
	Administrative Subtotal		21,237 SF
1	Science Room	Classroom	11,843 SF
2	Science Prep Room	Classroom	1,094 SF
3	Business Classroom	Classroom	4,112 SF
4	Standard Classroom	Classroom	42,068 SF
18	Spec. Lecture Classroom (Auditorium)	Classroom	1,863 SF
21	Music Classroom	Classroom	4,565 SF
28	Health Classroom	Classroom	786 SF
	Classroom Subtotal		66,331 SF
7	Closet/Storage		7,960 SF
6	Corridor/Vestibule/Stair/Commons		76,293 SF
9	Classroom (Future Comp. Lab)	Computer Lab	1,914 SF
16	Computer Lab	Computer Lab	1,848 SF
	Computer Lab Subtotal		3,762 SF
27	Weights/Locker Room/Fitness/Training	Gymnasium/Fitness	13,515 SF
29	Gymnasium	Gymnasium/Fitness	27,542 SF
	Gymnasium Subtotal		41,057 SF
20	Kitchen/Food Service		3,754 SF
19	Library/Resource Center		10,798 SF
5	Mech/Elec/Data Room		4,717 SF
8	Restrooms/Showers		7,628 SF
22	Theater - Stage Area	Theater	3,206 SF
23	Theater - Seating	Theater	6,140 SF
24	Theater - Misc.	Theater	4,835 SF
25	Theater - Black Box	Theater	2,036 SF
	Theater Subtotal		16,217 SF
11	Tech./Trades Lab	Trades Classroom	2,713 SF
12	Eng. Graphic/Drafting	Trades Classroom	1,235 SF
13	Tech./Trades Classroom	Trades Classroom	2,121 SF
14	TV Studio Classroom Lab	Trades Classroom	1,796 SF
15	Culinary Lab	Trades Classroom	4,358 SF
26	Art Classroom & Kiln (125 SF)	Trades Classroom	6,086 SF
	Trades Classroom Subtotal		18,309 SF

Example 3 – FCHS First Floor Wing E



Example 4 – FCHS First Floor Wing J



FCHS Floor Space Distribution Table from On-Screen Takeoff

Takeoff Tab

Fort Collins - Differential Space Usage

Bid No. 22

No.	Name	Height	Area	Quantity1	UOM1	Quantity2	UOM2	Quantity3	UOM3
(unassigned)									
21	Theater Misc.	0"	(unassigned)	4,690	SF	0		0	
20	Theater Stage	0"	(unassigned)	3,168	SF	0		0	
19	Theater - Black Box	0"	(unassigned)	1,412	SF	0		0	
18	Theater Seating	0"	(unassigned)	11,187	SF	0		0	
17	Music/Band	0"	(unassigned)	3,009	SF	0		0	
16	Science Classroom	0"	(unassigned)	11,547	SF	0		0	
15	Art Classroom	0"	(unassigned)	4,510	SF	0		0	
14	Culinary Classroom	0"	(unassigned)	1,845	SF	0		0	
13	Trades Classroom	0"	(unassigned)	9,447	SF	0		0	
12	Computer Lab/Technology Center	0"	(unassigned)	9,491	SF	0		0	
11	Library/Resource Center	0"	(unassigned)	18,147	SF	0		0	
10	Standard Classroom	0"	(unassigned)	40,351	SF	0		0	
9	Gymnasium	0"	(unassigned)	30,415	SF	0		0	
8	Weights/Lockers/Fitness/Training	0"	(unassigned)	11,139	SF	0		0	
7	Health Classroom	0"	(unassigned)	826	SF	0		0	
6	Closet/Storage	0"	(unassigned)	13,347	SF	0		0	
5	Kitchen/Food Service	0"	(unassigned)	6,192	SF	0		0	
4	Corridor/Vestibule/Stair/Commons	0"	(unassigned)	70,873	SF	0		0	
3	Restrooms/Showers	0"	(unassigned)	7,894	SF	0		0	
2	Mech/Elec/Data Room	0"	(unassigned)	12,623	SF	0		0	
1	Admin/Office	0"	(unassigned)	18,363	SF	0		0	

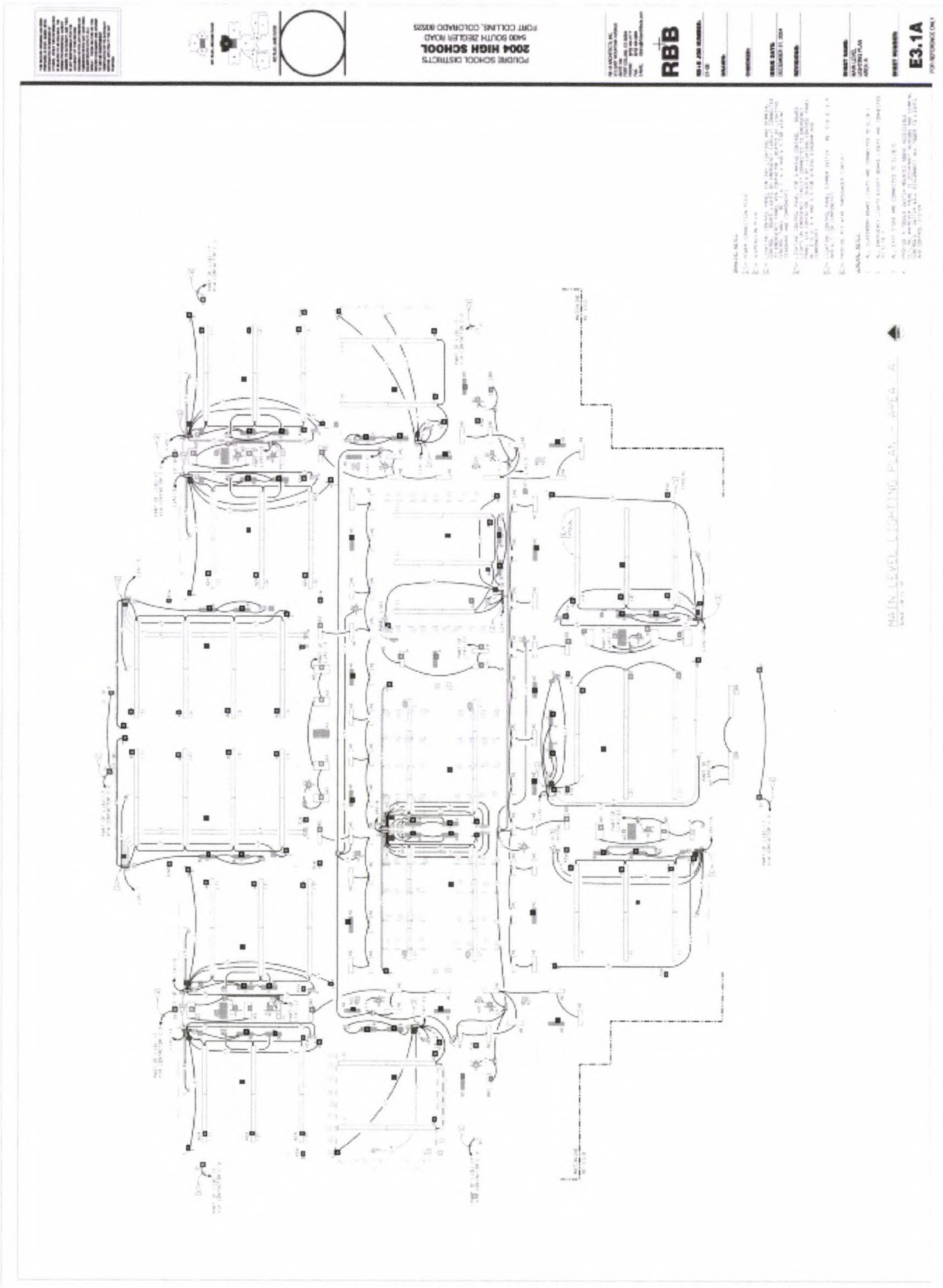
FCHS Floor Space Distribution Table by Twelve Workspace Types

Takeoff Item	Room Designation	General Designation	Floor Area
1	Admin/Office	Adminstrative	18,363 SF
	Administrative Subtotal		18,363 SF
7	Health Classroom	Classroom	826 SF
10	Standard Classroom	Classroom	40,351 SF
17	Music/Band	Classroom	3,009 SF
15	Art Classroom	Classroom	4,510 SF
16	Science Classroom	Classroom	11,547 SF
	Classroom Subtotal		60,243 SF
13	Trades Classroom	Trades Classroom	9,447 SF
14	Culinary Classroom	Trades Classroom	1,845 SF
	Trades Classroom Subtotal		11,292 SF
6	Closet/Storage	Closet/Storage	13,347 SF
4	Corridor/Vestibule/Stair/Commons	Common Areas/Hallways	65,179 SF
12	Computer Lab/Technology Center	Computer Lab	9,491 SF
9	Gymnasium	Gymnasium	30,415 SF
8	Weights/Lockers/Fitness/Training	Gymnasium	11,139 SF
	Gymnasium Subtotal		41,554 SF
5	Kitchen/Food Service	Kitchen/Food Service	11,916 SF
11	Library/Resource Center	Library/Resource Center	18,147 SF
2	Mech/Elec/Data Room	Mech/Elec/Data Room	12,623 SF
3	Restrooms/Showers	Restrooms/Showers	7,894 SF
18	Theater Seating	Theater	4,604 SF
19	Theater - Black Box	Theater	1,412 SF
20	Theater Stage	Theater	3,168 SF
21	Theater Misc.	Theater	4,690 SF
	Theater Subtotal		13,874 SF

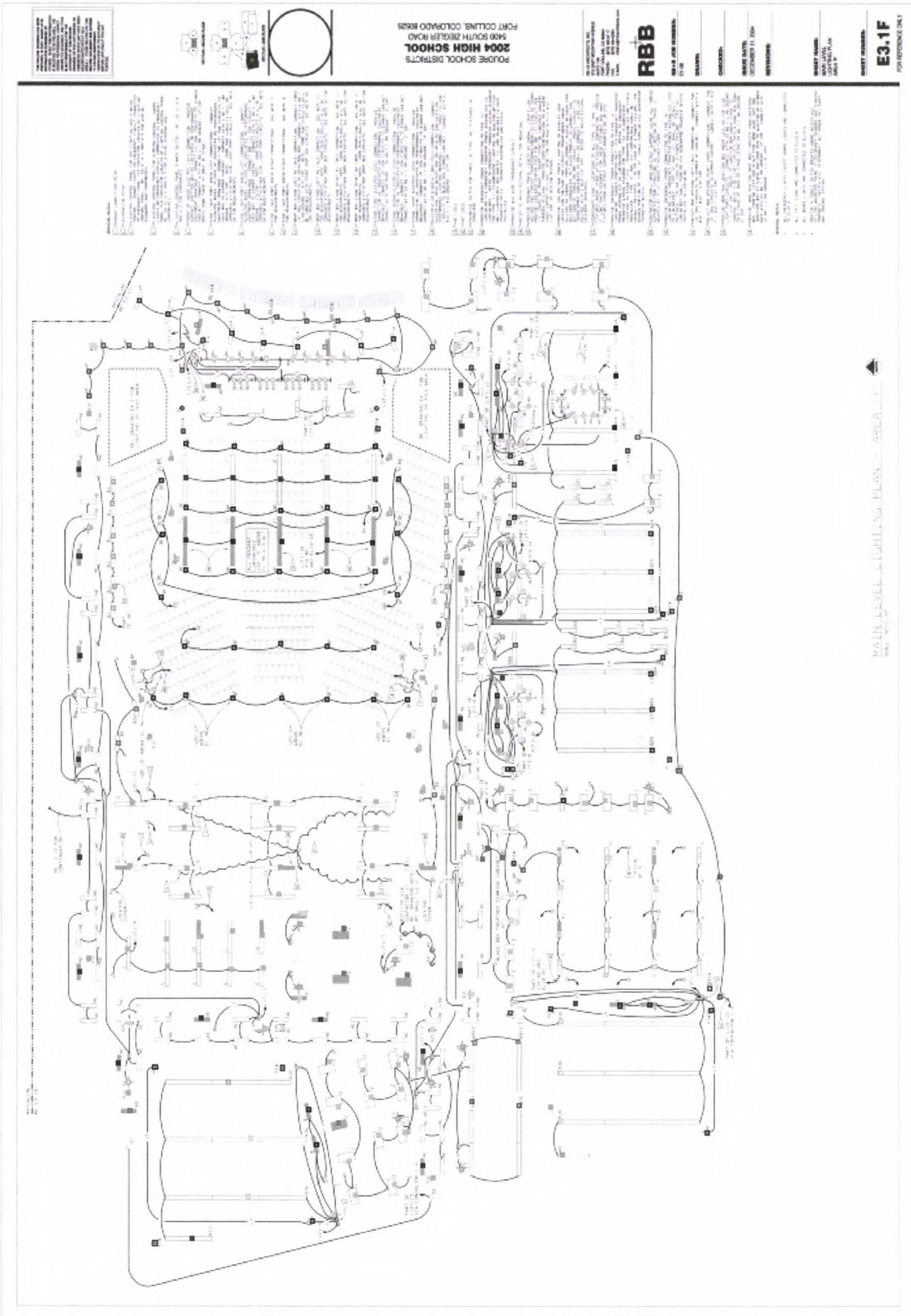
Appendix B

On-Screen Takeoff Lighting Screenshots and Quantity Tables

Example 1 – FRHS First Floor Wing A



Example 2 – FRHS First Floor Wing F



FRHS Lighting Quantity Table from On-Screen Takeoff

Takeoff Tab

Fossil Ridge Lighting

Bid No. 10

No.	Name	Height	Area	Quantity1	UOM1	Quantity2	UOM2	Quantity3	UOM3
Exterior									
27	Building Exterior Light - SG	0"	(unassigned)	9	EA	0		0	
4	Building Exterior Light - SF	0"	(unassigned)	57	EA	0		0	
133	Building Exterior Light - SI	0"	(unassigned)	2	EA	0		0	
Classroom									
26	BB	0"	(unassigned)	2	EA	0		0	
25	A32 Light	0"	(unassigned)	16	EA	0		0	
23	A28 Light	0"	(unassigned)	8	EA	0		0	
20	A20 Light	0"	(unassigned)	29	EA	0		0	
19	H light	0"	(unassigned)	30	EA	0		0	
14	B Egress	0"	(unassigned)	141	EA	0		0	
13	AD Egress	0"	(unassigned)	5	EA	0		0	
12	AD	0"	(unassigned)	13	EA	0		0	
10	A24 Light	0"	(unassigned)	110	EA	0		0	
48	A28 Light Egress	0"	(unassigned)	2	EA	0		0	
49	AB8	0"	(unassigned)	20	EA	0		0	
50	A12 Light	0"	(unassigned)	16	EA	0		0	
51	V	0"	(unassigned)	2	EA	0		0	
52	V Egress	0"	(unassigned)	6	EA	0		0	
53	AB20E Light	0"	(unassigned)	3	EA	0		0	
54	Z	0"	(unassigned)	81	EA	0		0	
55	Z Egress	0"	(unassigned)	12	EA	0		0	
56	Q Egress	0"	(unassigned)	15	EA	0		0	
57	BC	0"	(unassigned)	64	EA	0		0	
58	BC Egress	0"	(unassigned)	28	EA	0		0	
59	Y	0"	(unassigned)	5	EA	0		0	
60	A16 Light	0"	(unassigned)	28	EA	0		0	
65	M	0"	(unassigned)	41	EA	0		0	
66	M Egress	0"	(unassigned)	5	EA	0		0	
67	AK	0"	(unassigned)	32	EA	0		0	
68	AK Egress	0"	(unassigned)	8	EA	0		0	
69	AP	0"	(unassigned)	27	EA	0		0	
70	Q	0"	(unassigned)	6	EA	0		0	
71	BM8	0"	(unassigned)	2	EA	0		0	
72	BM24E	0"	(unassigned)	1	EA	0		0	
73	BM20E	0"	(unassigned)	1	EA	0		0	
74	BM36	0"	(unassigned)	1	EA	0		0	
76	A8 Light	0"	(unassigned)	7	EA	0		0	
78	J	0"	(unassigned)	8	EA	0		0	
79	AM	0"	(unassigned)	4	EA	0		0	
80	AN	0"	(unassigned)	1	EA	0		0	
81	AB12	0"	(unassigned)	21	EA	0		0	
83	AG	0"	(unassigned)	18	EA	0		0	

FRHS Lighting Quantity Table from On-Screen Takeoff (Cont)

Takeoff Tab

Fossil Ridge Lighting

Bid No. 10

No.	Name	Height	Area	Quantity1	UOM1	Quantity2	UOM2	Quantity3	UOM3
84	AH	0"	(unassigned)	4	EA	0		0	
85	AG Egress	0"	(unassigned)	3	EA	0		0	
86	AG1	0"	(unassigned)	3	EA	0		0	
87	AJ	0"	(unassigned)	2	EA	0		0	
88	BD	0"	(unassigned)	12	EA	0		0	
89	AI	0"	(unassigned)	5	EA	0		0	
94	AL4	0"	(unassigned)	2	EA	0		0	
96	BH24	0"	(unassigned)	10	EA	0		0	
97	BH24E	0"	(unassigned)	6	EA	0		0	
98	AL12 Light	0"	(unassigned)	6	EA	0		0	
99	AL12 Light Egress	0"	(unassigned)	1	EA	0		0	
100	AL8 Light	0"	(unassigned)	3	EA	0		0	
101	AL4 Egress	0"	(unassigned)	1	EA	0		0	
102	AL8 Light Egress	0"	(unassigned)	1	EA	0		0	
103	AL20 Light	0"	(unassigned)	1	EA	0		0	
104	AB16E	0"	(unassigned)	1	EA	0		0	
105	AR	0"	(unassigned)	5	EA	0		0	
106	B1 Egress	0"	(unassigned)	2	EA	0		0	
107	AP Egress	0"	(unassigned)	7	EA	0		0	
108	AS	0"	(unassigned)	7	EA	0		0	
109	AS1	0"	(unassigned)	9	EA	0		0	
111	A40 Light	0"	(unassigned)	1	EA	0		0	
118	BF	0"	(unassigned)	33	EA	0		0	
119	BP	0"	(unassigned)	12	EA	0		0	
120	BJ	0"	(unassigned)	12	EA	0		0	
121	F	0"	(unassigned)	5	EA	0		0	
122	F1	0"	(unassigned)	5	EA	0		0	
123	A36 Light	0"	(unassigned)	5	EA	0		0	
124	AV	0"	(unassigned)	4	EA	0		0	
125	B2 Egress	0"	(unassigned)	6	EA	0		0	
126	BU	0"	(unassigned)	15	EA	0		0	
127	AU	0"	(unassigned)	22	EA	0		0	
128	AB8	0"	(unassigned)	25	EA	0		0	
129	BG	0"	(unassigned)	1	EA	0		0	
130	H1 Egress	0"	(unassigned)	4	EA	0		0	
132	AB16	0"	(unassigned)	2	EA	0		0	
142	AZ	0"	(unassigned)	2	EA	0		0	
143	A8 Light Egress	0"	(unassigned)	1	EA	0		0	
144	AB12 Egress	0"	(unassigned)	1	EA	0		0	
145	BE Egress	0"	(unassigned)	7	EA	0		0	
146	R	0"	(unassigned)	38	EA	0		0	
147	R1 Egress	0"	(unassigned)	6	EA	0		0	
148	D	0"	(unassigned)	115	EA	0		0	

FRHS Lighting Quantity Table from On-Screen Takeoff (Cont)

Takeoff Tab

Fossil Ridge Lighting

Bid No. 10

No.	Name	Height	Area	Quantity1 UOM1	Quantity2UOM2	Quantity3 UOM3
84	AH	0"	(unassigned)	4 EA	0	0
85	AG Egress	0"	(unassigned)	3 EA	0	0
86	AG1	0"	(unassigned)	3 EA	0	0
87	AJ	0"	(unassigned)	2 EA	0	0
88	BD	0"	(unassigned)	12 EA	0	0
89	AI	0"	(unassigned)	5 EA	0	0
94	AL4	0"	(unassigned)	2 EA	0	0
96	BH24	0"	(unassigned)	10 EA	0	0
97	BH24E	0"	(unassigned)	6 EA	0	0
98	AL12 Light	0"	(unassigned)	6 EA	0	0
99	AL12 Light Egress	0"	(unassigned)	1 EA	0	0
100	AL8 Light	0"	(unassigned)	3 EA	0	0
101	AL4 Egress	0"	(unassigned)	1 EA	0	0
102	AL8 Light Egress	0"	(unassigned)	1 EA	0	0
103	AL20 Light	0"	(unassigned)	1 EA	0	0
104	AB16E	0"	(unassigned)	1 EA	0	0
105	AR	0"	(unassigned)	5 EA	0	0
106	B1 Egress	0"	(unassigned)	2 EA	0	0
107	AP Egress	0"	(unassigned)	7 EA	0	0
108	AS	0"	(unassigned)	7 EA	0	0
109	AS1	0"	(unassigned)	9 EA	0	0
111	A40 Light	0"	(unassigned)	1 EA	0	0
118	BF	0"	(unassigned)	33 EA	0	0
119	BP	0"	(unassigned)	12 EA	0	0
120	BJ	0"	(unassigned)	12 EA	0	0
121	F	0"	(unassigned)	5 EA	0	0
122	F1	0"	(unassigned)	5 EA	0	0
123	A36 Light	0"	(unassigned)	5 EA	0	0
124	AV	0"	(unassigned)	4 EA	0	0
125	B2 Egress	0"	(unassigned)	6 EA	0	0
126	BU	0"	(unassigned)	15 EA	0	0
127	AU	0"	(unassigned)	22 EA	0	0
128	AB8	0"	(unassigned)	25 EA	0	0
129	BG	0"	(unassigned)	1 EA	0	0
130	H1 Egress	0"	(unassigned)	4 EA	0	0
132	AB16	0"	(unassigned)	2 EA	0	0
142	AZ	0"	(unassigned)	2 EA	0	0
143	A8 Light Egress	0"	(unassigned)	1 EA	0	0
144	AB12 Egress	0"	(unassigned)	1 EA	0	0
145	BE Egress	0"	(unassigned)	7 EA	0	0
146	R	0"	(unassigned)	38 EA	0	0
147	R1 Egress	0"	(unassigned)	6 EA	0	0
148	D	0"	(unassigned)	115 EA	0	0

FRHS Lighting Quantity Table from On-Screen Takeoff (Cont)

Takeoff Tab

Fossil Ridge Lighting

Bid No. 10

No.	Name	Height	Area	Quantity1	UOM1	Quantity2	UOM2	Quantity3	UOM3
149	D Egress	0"	(unassigned)	21	EA	0		0	
151	AB8E	0"	(unassigned)	2	EA	0		0	
152	A20E Light	0"	(unassigned)	2	EA	0		0	
Corridor A									
24	Occupany Sensor Type 2 Corridor/Vest	0"	(unassigned)	11	EA	0		0	
9	Corridor Light BD Egress	0"	(unassigned)	6	EA	0		0	
8	Corridor Light BD	0"	(unassigned)	29	EA	0		0	
35	Corridor Light AE	0"	(unassigned)	414	EA	0		0	
36	Corridor Light AE Egress	0"	(unassigned)	109	EA	0		0	
41	Corridor Light AW	0"	(unassigned)	8	EA	0		0	
42	Corridor Light AP	0"	(unassigned)	27	EA	0		0	
43	Corridor Light V	0"	(unassigned)	78	EA	0		0	
44	Corridor Light V Egress	0"	(unassigned)	14	EA	0		0	
45	Corridor Light L	0"	(unassigned)	14	EA	0		0	
46	Corridor Light AB36	0"	(unassigned)	2	EA	0		0	
47	Corridor Light W Egress	0"	(unassigned)	10	EA	0		0	
63	Corridor Light BN	0"	(unassigned)	22	EA	0		0	
82	Corridor Light H	0"	(unassigned)	1	EA	0		0	
90	Corridor Light U16E	0"	(unassigned)	4	EA	0		0	
91	Corridor Light BQ	0"	(unassigned)	48	EA	0		0	
92	Corridor Light AL24	0"	(unassigned)	9	EA	0		0	
93	Corridor Light AL24E	0"	(unassigned)	6	EA	0		0	
115	Corridor Light U4	0"	(unassigned)	7	EA	0		0	
116	Corridor Light U4E	0"	(unassigned)	2	EA	0		0	
117	Corridor Light BT	0"	(unassigned)	2	EA	0		0	
131	Corridor Light BP	0"	(unassigned)	1	EA	0		0	
134	Corridor Light U	0"	(unassigned)	13	EA	0		0	
135	Corridor Light BR	0"	(unassigned)	2	EA	0		0	
136	Corridor Light BS	0"	(unassigned)	9	EA	0		0	
137	Corridor Light BS Egress	0"	(unassigned)	1	EA	0		0	
138	Corridor Light AX	0"	(unassigned)	3	EA	0		0	
140	Corridor Light BL Egress	0"	(unassigned)	2	EA	0		0	
141	Corridor Light U Egress	0"	(unassigned)	7	EA	0		0	
150	Corridor Light W	0"	(unassigned)	2	EA	0		0	
MMech/Elec									
22	H Mech/Elec Egress	0"	(unassigned)	8	EA	0		0	
21	H Mech/Elec	0"	(unassigned)	52	EA	0		0	
40	G1 Elec/Mech. Egree	0"	(unassigned)	11	EA	0		0	
75	G	0"	(unassigned)	36	EA	0		0	
77	G Egress	0"	(unassigned)	6	EA	0		0	
110	Y	0"	(unassigned)	1	EA	0		0	
Occupancy									

FRHS Lighting Quantity Table from On-Screen Takeoff (Cont)

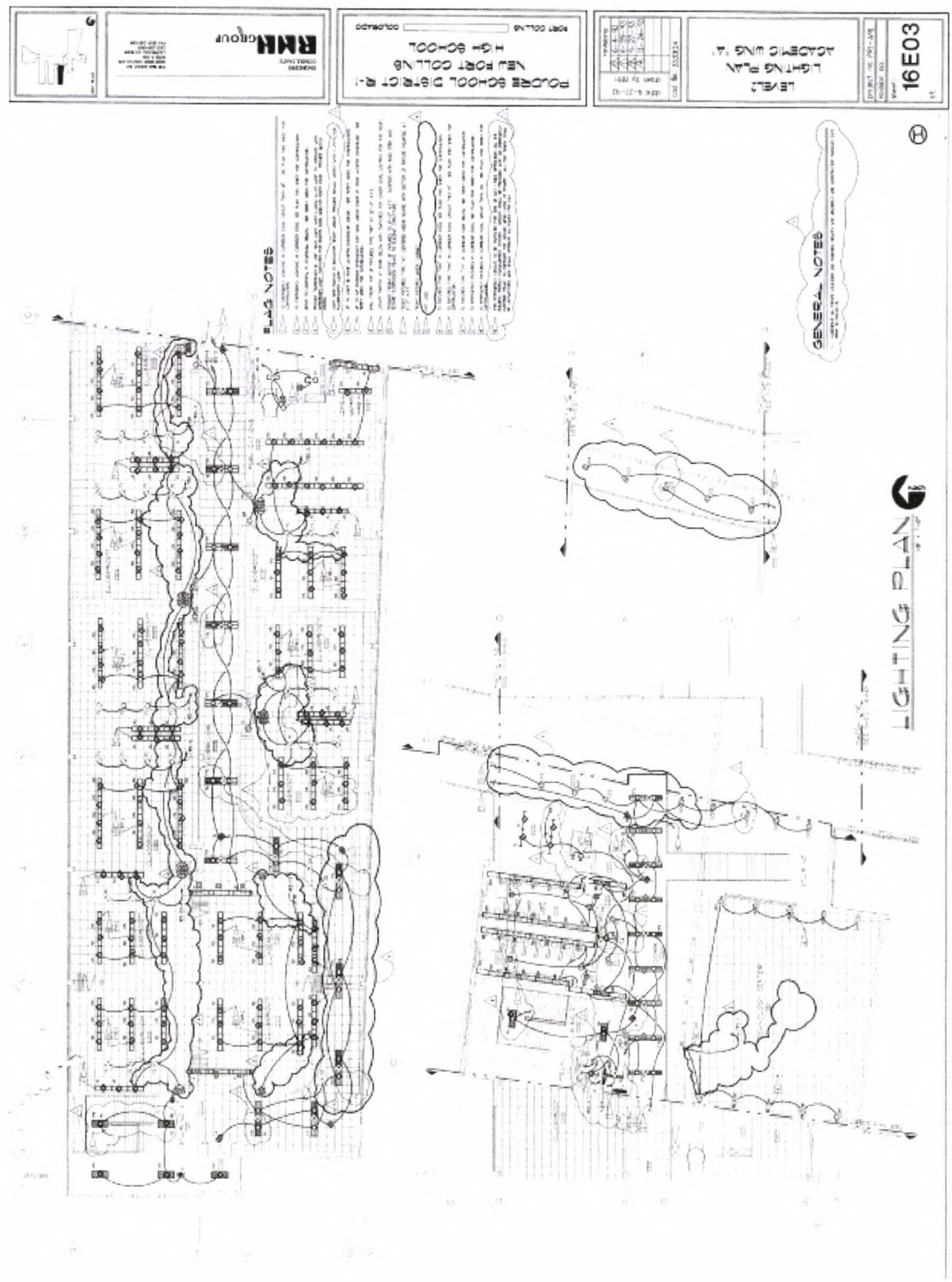
Takeoff Tab

Fossil Ridge Lighting

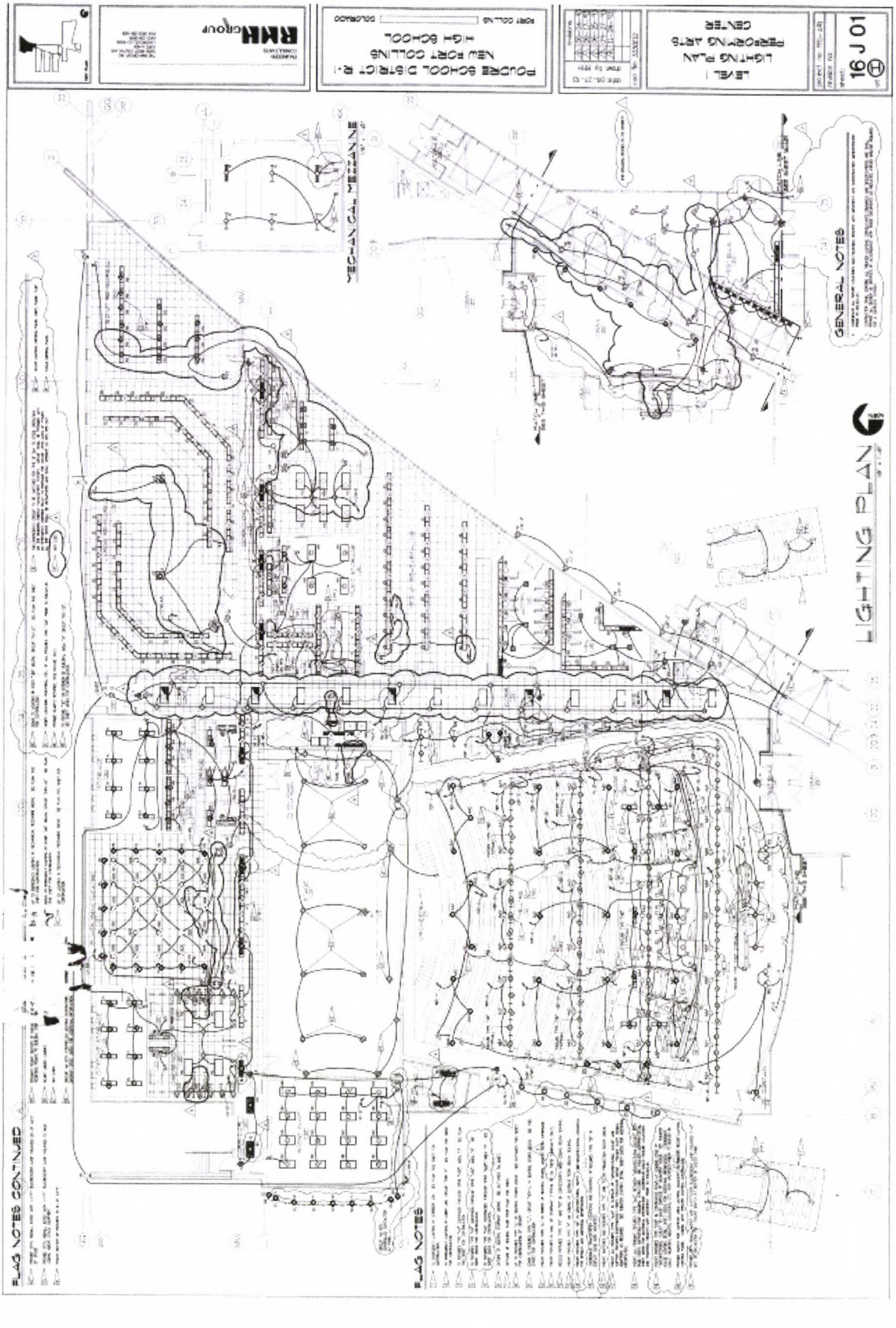
Bid No. 10

No.	Name	Height	Area	Quantity1 UOM1	Quantity2UOM2	Quantity3 UOM3
18	Occupancy Sensor Type 5	0"	(unassigned)	37 EA	0	0
17	Occupancy Sensor Type 4	0"	(unassigned)	25 EA	0	0
16	Occupancy Sensor Type 3	0"	(unassigned)	129 EA	0	0
15	Occupancy Sensor Type 2	0"	(unassigned)	65 EA	0	0
11	Occupancy Sensor Type 1	0"	(unassigned)	109 EA	0	0
Exit						
5	Exit Light - X1W	0"	(unassigned)	64 EA	0	0
33	Exit Light - X2C	0"	(unassigned)	39 EA	0	0
34	Exit Light - X1C	0"	(unassigned)	77 EA	0	0
62	Exit Light - X1E	0"	(unassigned)	4 EA	0	0
139	Exit Light - X2E	0"	(unassigned)	1 EA	0	0
Parking						
3	Parking Lot Light - SC	0"	(unassigned)	26 EA	0	0
2	Parking Lot Light - SB	0"	(unassigned)	23 EA	0	0
1	Parking Lot Light - SA	0"	(unassigned)	33 EA	0	0
Plugged Devices						
28	Projectors	0"	(unassigned)	62 EA	0	0
29	TVs	0"	(unassigned)	69 EA	0	0
30	Printers	0"	(unassigned)	10 EA	0	0
31	Computer Classroom	0"	(unassigned)	300 EA	0	0
32	Computer Business	0"	(unassigned)	98 EA	0	0
61	Computer Admin	0"	(unassigned)	67 EA	0	0
95	Computer Library	0"	(unassigned)	37 EA	0	0
112	Ranges	0"	(unassigned)	6 EA	0	0
113	Washers	0"	(unassigned)	2 EA	0	0
114	Dryers	0"	(unassigned)	2 EA	0	0
Restroom						
37	AA	0"	(unassigned)	45 EA	0	0
38	AA1	0"	(unassigned)	20 EA	0	0
39	BC - Egress	0"	(unassigned)	2 EA	0	0
64	BC	0"	(unassigned)	9 EA	0	0

Example 3 – FCHS First Floor Wing E



Example 4 – FCHS First Floor Wing J



FCHS Lighting Quantity Table from On-Screen Takeoff

Fort Collins Lighting

Bid No. 20

No.	Name	Height	Area	Quantity1	UOM1	Quantity2	UOM2	Quantity3	UOM:
(unassigned)									
102	DD2	0"	(unassigned)	3	EA	0		0	
101	DD1	0"	(unassigned)	5	EA	0		0	
100	B1	0"	(unassigned)	4	EA	0		0	
99	LL	0"	(unassigned)	63	EA	0		0	
98	AA2	0"	(unassigned)	24	EA	0		0	
97	G Egress	0"	(unassigned)	2	EA	0		0	
96	227V @ stage	0"	(unassigned)	18	EA	0		0	
95	CC1	0"	(unassigned)	16	EA	0		0	
94	R1 Egress	0"	(unassigned)	15	EA	0		0	
93	QQ1	0"	(unassigned)	25	EA	0		0	
92	JJ1	0"	(unassigned)	2	EA	0		0	
91	E	0"	(unassigned)	5	EA	0		0	
90	M2	0"	(unassigned)	6	EA	0		0	
89	Z1	0"	(unassigned)	81	EA	0		0	
88	H Egress	0"	(unassigned)	8	EA	0		0	
87	R	0"	(unassigned)	2	EA	0		0	
86	ZZ1	0"	(unassigned)	6	EA	0		0	
85	AA3	0"	(unassigned)	40	EA	0		0	
84	H1B	0"	(unassigned)	77	EA	0		0	
83	QQ	0"	(unassigned)	2	EA	0		0	
82	J2	0"	(unassigned)	3	EA	0		0	
81	R2 Egress	0"	(unassigned)	6	EA	0		0	
78	UU1	0"	(unassigned)	5	EA	0		0	
77	EM1	0"	(unassigned)	22	EA	0		0	
76	U1	0"	(unassigned)	14	EA	0		0	
75	M1	0"	(unassigned)	30	EA	0		0	
74	TT3	0"	(unassigned)	12	EA	0		0	
73	*TRACK LIGHTING*	0"	(unassigned)	17	EA	0		0	
72	G1 Egress	0"	(unassigned)	6	EA	0		0	
71	V1 Egress	0"	(unassigned)	4	EA	0		0	
70	V1	0"	(unassigned)	53	EA	0		0	
69	T2	0"	(unassigned)	24	EA	0		0	
68	Y	0"	(unassigned)	2	EA	0		0	
67	NN1	0"	(unassigned)	23	EA	0		0	
66	F2 Egress	0"	(unassigned)	21	EA	0		0	
65	G2 Egress	0"	(unassigned)	4	EA	0		0	
64	GGA	0"	(unassigned)	28	EA	0		0	
63	F1 Egress	0"	(unassigned)	18	EA	0		0	
62	NN	0"	(unassigned)	30	EA	0		0	
61	A2	0"	(unassigned)	14	EA	0		0	
60	GG	0"	(unassigned)	63	EA	0		0	
59	T Egress	0"	(unassigned)	1	EA	0		0	

FCHS Lighting Quantity Table from On-Screen Takeoff (Cont)

Takeoff Tab

Fort Collins Lighting

Bid No. 20

No.	Name	Height	Area	Quantity1 UOM1	Quantity2UOM2	Quantity3 UOM3
58	H	0"	(unassigned)	59 EA	0	0
57	C1	0"	(unassigned)	7 EA	0	0
56	HH	0"	(unassigned)	43 EA	0	0
55	CC2 Egress	0"	(unassigned)	9 EA	0	0
54	CC2	0"	(unassigned)	32 EA	0	0
53	KK	0"	(unassigned)	729 EA	0	0
52	F1	0"	(unassigned)	151 EA	0	0
51	G2	0"	(unassigned)	23 EA	0	0
50	F Egress	0"	(unassigned)	3 EA	0	0
49	G1	0"	(unassigned)	73 EA	0	0
48	TT1 Egress	0"	(unassigned)	110 EA	0	0
47	TT1	0"	(unassigned)	26 EA	0	0
46	NN Egress	0"	(unassigned)	37 EA	0	0
45	BBA Egress	0"	(unassigned)	2 EA	0	0
44	EE Egress	0"	(unassigned)	2 EA	0	0
43	BBA	0"	(unassigned)	43 EA	0	0
42	CC	0"	(unassigned)	19 EA	0	0
41	A1	0"	(unassigned)	213 EA	0	0
40	V	0"	(unassigned)	22 EA	0	0
39	J	0"	(unassigned)	88 EA	0	0
37	BB Egress	0"	(unassigned)	16 EA	0	0
36	BB	0"	(unassigned)	238 EA	0	0
35	AA1	0"	(unassigned)	11 EA	0	0
34	AA	0"	(unassigned)	30 EA	0	0
33	F	0"	(unassigned)	92 EA	0	0
32	Z	0"	(unassigned)	76 EA	0	0
31	T1 Egress	0"	(unassigned)	75 EA	0	0
30	T1	0"	(unassigned)	182 EA	0	0
29	N Egress	0"	(unassigned)	12 EA	0	0
28	N	0"	(unassigned)	172 EA	0	0
27	T	0"	(unassigned)	7 EA	0	0
26	ZZ	0"	(unassigned)	76 EA	0	0
23	TT2	0"	(unassigned)	10 EA	0	0
22	FF	0"	(unassigned)	11 EA	0	0
21	W	0"	(unassigned)	35 EA	0	0
20	UU Egress	0"	(unassigned)	4 EA	0	0
19	UU	0"	(unassigned)	261 EA	0	0
17	EE	0"	(unassigned)	29 EA	0	0
16	G	0"	(unassigned)	6 EA	0	0
15	YY Egress	0"	(unassigned)	19 EA	0	0
14	YY	0"	(unassigned)	75 EA	0	0
13	PP Egress	0"	(unassigned)	1 EA	0	0
12	PP	0"	(unassigned)	11 EA	0	0

FCHS Lighting Quantity Table from On-Screen Takeoff (Cont)

Takeoff Tab

Fort Collins Lighting

Bid No. 20

No.	Name	Height	Area	Quantity1 UOM1	Quantity2UOM2	Quantity3 UOM3
11	RR1	0"	(unassigned)	6 EA	0	0
10	RR	0"	(unassigned)	2 EA	0	0
9	M	0"	(unassigned)	7 EA	0	0
8	H1 Egress	0"	(unassigned)	15 EA	0	0
7	H1	0"	(unassigned)	100 EA	0	0
3	T3	0"	(unassigned)	4 EA	0	0
2	H2	0"	(unassigned)	13 EA	0	0
1	H1A	0"	(unassigned)	121 EA	0	0
103	TT Egress	0"	(unassigned)	10 EA	0	0
104	Track Lights (Bulbs Shown)	0"	(unassigned)	78 EA	0	0
Exterior						
80	H2	0"	(unassigned)	9 EA	0	0
79	ZZ1	0"	(unassigned)	6 EA	0	0
38	Q	0"	(unassigned)	2 EA	0	0
25	SQ	0"	(unassigned)	4 EA	0	0
24	SC	0"	(unassigned)	15 EA	0	0
18	SK	0"	(unassigned)	55 EA	0	0
6	SE	0"	(unassigned)	31 EA	0	0
5	SC1	0"	(unassigned)	14 EA	0	0
105	SG	0"	(unassigned)	34 EA	0	0
106	SH	0"	(unassigned)	20 EA	0	0
107	SD	0"	(unassigned)	24 EA	0	0
108	SF	0"	(unassigned)	5 EA	0	0
109	SJ	0"	(unassigned)	3 EA	0	0
Exit						
4	X	0"	(unassigned)	122 EA	0	0

Appendix C

Lighting Wattage Quantification Example

Fort Collins High School - Lighting Quantity Sheet Sample for Appendix

									Egress				Egress	1/2 Egress L	
					Fixture Type per Schedule	A1	A2	AA	AA1	AA3	B1	BB	BB	BBC	E
					Number of Lamps	1	2	1	1	1	1	1	1	2	
					Watts/lamp	32	60	250	400	500	15	32	32	32	
Room Number	Floor	Wing	Designation	Room Name/Location	Total Watts/Fixture	32	120	250	400	500	15	32	32	64	
n/a			Exterior	Parking Lot		4	3								
n/a	1st	A	Exterior	Exterior		2	7								
Corridor	1st	A	Wing A - Corridor	Corridor					3	11					
A25	1st	A	Corridor/Commons	Dinning & Commons					5	13					
A24	1st	A	Corridor/Commons	Student Store					6	12					
A26	1st	A	Food Service	Faculty Dinning				15							
n/a	1st	B	Exterior	Exterior		5	2								
Corridor	1st	B	Wing B - Corridor	Corridor					4	10					
B05,06	1st	B	Mech/Elec.	Central Mech.										10	
B02	1st	B	Wing B - Admin	Lounge										2	
B03	1st	B	Closet/Storage	Storage/Work Room										2	
B01	1st	B	Closet/Storage	Receiving/Storage										2	
n/a	1st	C	Exterior	Exterior		8	7								
Corridor	1st	C	Wing C - Corridor	Corridor					3	10					
C01	1st	C	Weights/Fitness/Training	Weights & Fitness				24	3	14					
C05	1st	C	Restrooms	Women's								10	1		
C06	1st	C	Restrooms	Men's								10	1		
n/a	1st	D	Exterior	Exterior		13	8								
Corridor	1st	D	Wing D - Corridor	Corridor					3	11					
D40	1st	D	Closet/Storage	Storage							2				
D39	1st	D	Closet/Storage	Storage							2				
D34	1st	D	Weights/Fitness/Training	Training					2						
D36	1st	D	Weights/Fitness/Training	Men's locker area					4	14					
D35	1st	D	Closet/Storage	Closet							3				
D33	1st	D	Weights/Fitness/Training	Shower								2			
D32	1st	D	Weights/Fitness/Training	Shower								2			
D30	1st	D	Restrooms	Restroom					2			5			
D29	1st	D	Restroom	Restroom					2			5			
D27	1st	D	Restrooms	Restroom					2			8			
D28	1st	D	Restroom	Restroom					2			8			
D26	1st	D	Closet/Storage	Storage/Vest.							2				
D22	1st	D	Closet/Storage	Closet							2				
D23	1st	D	Closet/Storage	Closet							2				
					Total Fixture Quantity:	32	27	39	41	95	13	50	2	16	
					Total Fixture Wattage:	1024	3240	9750	16400	47500	195	1600	64	1024	4
					School Day Runtime (hrs):	12	12	9	24	9	9	9	24	9	
					School Day kWh:	12.3	38.9	87.8	393.6	427.5	1.8	14.4	1.5	9.2	1
					Total Fixture Wattage:	1024	3240	9750	16400	47500	195	1600	64	1024	4
					Weekend Runtime (hrs):	0	0	0	24	0	0	0	24	0	
					Weekend Day kWh:	0	0.0	0.0	393.6	0.0	0.0	0.0	1.5	0.0	1

Total kWh Per School Day:	997.7
Total kWh Per Weekend Day:	405.9

Appendix D

Plug Load Equipment Quantification Table

FCHS Plug Load Distribution by Workspace Designation

Equipment/Appliance Type	Designation	Quantity	On Watts	Hours On	Stand-by Watts	Hours Standby	kWh per day	Days	Monthly kWH
Administrative									
Computers	Administrative	431	120	7	12	3	377.56	21.667	8,180.51
Monitors	Administrative	431	150	7	6.5	3	460.95	21.667	9,987.50
Printers	Administrative	80	400	2	16.8	22	93.57	21.667	2,027.34
Telephones	Administrative	431	2.1	24	0	0	21.72	30	651.67
Refrigerator (assume 16 CF)	Administrative	16	725	4	0	0	46.40	30	1,392.00
Coffee Pots	Administrative	6	1050	3	1.1	21	19.04	21.667	412.51
Space Heaters	Administrative	7	425	4	0	20	11.90	21.667	257.84
Microwaves	Administrative	11	925	2	2.8	20	20.97	21.667	454.27
Toaters	Administrative	1	1100	2	0	0	2.20	21.667	47.67
								Subtotal:	23,411.30
Classrooms									
Computers	Classroom	68	120	3	12	7	30.19	21.667	654.17
Monitors	Classroom	68	150	3	6.5	7	33.69	21.667	730.05
Printers	Classroom	14	400	1	16.8	23	11.01	21.667	238.55
TVs (assume 36")	Classroom	68	133	1	3	23	13.74	21.667	297.62
VCR/DVD Avergae 17/25	Classroom	68	21	1	5.4	23	9.87	21.667	213.93
Projecter	Classroom	68	300	1	10	23	36.04	21.667	780.88
Telephones	Classroom	80	2.1	24	0	0	4.03	21.667	87.36
									3,002.55
Computer Labs									
Computers	Computer Lab	100	120	7	12	3	87.60	21.667	1,898.03
Monitors	Computer Lab	100	150	7	6.5	3	106.95	21.667	2,317.29
Printers	Computer Lab	13.6	400	2	16.8	22	15.91	21.667	344.65
									4,559.96
Computer Labs									
Clothes Washer	Gymnasium/Lockers	2	425	4	0	20	3.40	21.667	73.67
Clothes Dryer	Gymnasium/Lockers	2	3050	4	0	20	24.40	21.667	528.67
									602.34
Computer Labs									
Computers	Library	33	120	7	12	3	28.91	21.667	626.35
Monitors	Library	33	150	7	6.5	3	35.29	21.667	764.70
Printers	Library	7	400	2	16.8	22	8.19	21.667	177.39
									1,568.45
Computer Labs									
Refrigerator (assume 16 CF)	Trades Classroom	8	725	4	0	0	23.20	30	696.00
Ranges	Trades Classroom	8	2100	2	1.3	22	33.83	21.667	732.97
Microwaves	Trades Classroom	8	925	2	1.1	22	14.99	21.667	324.87
Clothes Washer	Trades Classroom	2	425	4	0	20	3.40	21.667	73.67
Clothes Dryer	Trades Classroom	2	3050	4	0	20	24.40	21.667	528.67
									2,356.18

Monthly Total kWh	35,500.78
Annual Factor	10.554

Estimated Annual Plug Load Electric Consumption: 374,675

FCHS Plug Load Distribution by Equipment Type

Equipment/Appliance Type	Designation	Quantity	On Watts	Hours On	Stand-by Watts	Hours Standby	kWh per day	Days	Monthly kWH
Clothes Dryer	Gymnasium/Lockers	2	3050	4	0	20	24.40	21.667	528.67
Clothes Dryer	Trades Classroom	2	3050	4	0	20	24.40	21.667	528.67
									1,057.35
Clothes Washer	Gymnasium/Lockers	2	425	4	0	20	3.40	21.667	73.67
Clothes Washer	Trades Classroom	2	425	4	0	20	3.40	21.667	73.67
									147.34
Coffee Pots	Administrative	6	1050	3	1.1	21	19.04	21.667	412.51
									412.51
Computers	Administrative	431	120	7	12	3	377.56	21.667	8,180.51
Computers	Classroom	68	120	3	12	7	30.19	21.667	654.17
Computers	Computer Lab	100	120	7	12	3	87.60	21.667	1,898.03
Computers	Library	33	120	7	12	3	28.91	21.667	626.35
									11,359.05
Microwaves	Administrative	11	925	2	2.8	20	20.97	21.667	454.27
Microwaves	Trades Classroom	8	925	2	1.1	22	14.99	21.667	324.87
									779.14
Monitors	Administrative	431	150	7	6.5	3	460.95	21.667	9,987.50
Monitors	Classroom	68	150	3	6.5	7	33.69	21.667	730.05
Monitors	Computer Lab	100	150	7	6.5	3	106.95	21.667	2,317.29
Monitors	Library	33	150	7	6.5	3	35.29	21.667	764.70
									13,799.54
Printers	Administrative	80	400	2	16.8	22	93.57	21.667	2,027.34
Printers	Classroom	14	400	1	16.8	23	11.01	21.667	238.55
Printers	Computer Lab	13.6	400	2	16.8	22	15.91	21.667	344.65
Printers	Library	7	400	2	16.8	22	8.19	21.667	177.39
									2,787.92
Projecter	Classroom	68	300	1	10	23	36.04	21.667	780.88
									780.88
Ranges	Trades Classroom	8	2100	2	1.3	22	33.83	21.667	732.97
									732.97
Refrigerator (assume 16 CF)	Administrative	16	725	4	0	0	46.40	30	1,392.00
Refrigerator (assume 16 CF)	Trades Classroom	8	725	4	0	0	23.20	30	696.00
									2,088.00
Space Heaters	Administrative	7	425	4	0	20	11.90	21.667	257.84
									257.84
Telephones	Administrative	431	2.1	24	0	0	21.72	30	651.67
Telephones	Classroom	80	2.1	24	0	0	4.03	21.667	87.36
									739.03
Toaters	Administrative	1	1100	2	0	0	2.20	21.667	47.67
									47.67
TVs (assume 36")	Classroom	68	133	1	3	23	13.74	21.667	297.62
									297.62
VCR/DVD Avergae 17/25	Classroom	68	21	1	5.4	23	9.87	21.667	213.93
									213.93

Monthly Total kWh	35,500.78
Annual Factor	10.554

Estimated Annual Plug Load Electric Consumption: 374,675

FRHS Plug Load Distribution by Workspace Designation

Equipment/Appliance Type	Designation	Quantity	On Watts	Hours On	Stand-by Watts	Hours Standby	kWh per day	Days	Monthly kWH
Computers	Administrative	514	120	7	12	3	450.26	21	9,455.54
Monitors	Administrative	514	150	7	6.5	3	549.72	21	11,544.18
Printers	Administrative	102.8	400	2	16.8	22	120.23	21	2,524.93
Telephones	Administrative	7	2.1	24	0	0	0.35	31	10.94
Refrigerator (assume 16 CF)	Administrative	18	725	4	0	0	52.20	31	1,618.20
Microwaves	Administrative	8	925	2	2.8	20	15.25	21	320.21
Coffee Pots	Administrative	16	1050	3	1.1	21	50.77	21	1,066.16
Space Heaters	Administrative	10	425	4	0	20	17.00	21	357.00
Toaters	Administrative	4	1100	2	0	23	8.80	21	184.80
									27,081.97
Computers	Classroom	92	120	3	12	7	40.85	21	857.81
Monitors	Classroom	92	150	3	6.5	7	45.59	21	957.31
Printers	Classroom	19	400	1	16.8	23	14.94	21	313.77
TVs (assume 36")	Classroom	69	133	1	3	23	13.94	21	292.70
VCR/DVD Avergae 17/25	Classroom	69	21	1	5.4	23	10.02	21	210.39
Projecter	Classroom	69	300	1	10	23	36.57	21	767.97
Telephones	Classroom	69	2.1	24	0	0	3.48	21	73.03
									3,472.98
Computers	Commons	86	120	7	12	3	75.34	21	1,582.06
Monitors	Commons	86	150	7	6.5	3	91.98	21	1,931.52
Printers	Commons	17	400	2	16.8	22	19.88	21	417.55
									3,931.12
Computers	Computer Lab	175	120	6	12	3	132.30	21	2,778.30
Monitors	Computer Lab	150	150	6	6.5	3	137.93	21	2,896.43
Printers	Computer Lab	30	400	2	16.8	22	35.09	21	736.85
									6,411.57
Clothes Washer	Gymnasium/Lockers	2	425	4	0	20	3.40	21	71.40
Clothes Dryer	Gymnasium/Lockers	2	3050	4	0	20	24.40	21	512.40
									583.80
Computers	Library	42	120	7	12	3	36.79	21	772.63
Monitors	Library	42	150	7	6.5	3	44.92	21	943.30
Printers	Library	17.2	400	2	16.8	22	20.12	21	422.46
									2,138.39
Refrigerator (assume 16 CF)	Trades Classroom	8	725	4	0	0	23.20	31	719.20
Ranges	Trades Classroom	8	2100	2	1.3	22	33.83	21	710.40
Microwaves	Trades Classroom	8	925	2	2.8	22	15.29	21	321.15
Clothes Washer	Trades Classroom	2	1125	4	0	20	9.00	21	189.00
Clothes Dryer	Trades Classroom	2	3050	4	0	20	24.40	21	512.40
									2,452.15

Monthly Total kWh	46,071.98
Annual Factor:	10.2253

Estimated Annual Plug Load Electric Consumption: 471,099.85

FRHS Plug Load Distribution by Equipment Type

Equipment/Appliance Type	Designation	Quantity	On Watts	Hours On	Stand-by Watts	Hours Standby	kWh per day	Days	Monthly kWH
Clothes Dryer	Gymnasium/Lockers	2	3050	4	0	20	24.40	21	512.40
Clothes Dryer	Trades Classroom	2	3050	4	0	20	24.40	21	512.40
									1,024.80
Clothes Washer	Gymnasium/Lockers	2	425	4	0	20	3.40	21	71.40
Clothes Washer	Trades Classroom	2	1125	4	0	20	9.00	21	189.00
									260.40
Coffee Pots	Administrative	16	1050	3	1.1	21	50.77	21	1,066.16
									1,066.16
Computers	Administrative	514	120	7	12	3	450.26	21	9,455.54
Computers	Classroom	92	120	3	12	7	40.85	21	857.81
Computers	Commons	86	120	7	12	3	75.34	21	1,582.06
Computers	Computer Lab	175	120	6	12	3	132.30	21	2,778.30
Computers	Library	42	120	7	12	3	36.79	21	772.63
									15,446.34
Microwaves	Administrative	8	925	2	2.8	20	15.25	21	320.21
Microwaves	Trades Classroom	8	925	2	2.8	22	15.29	21	321.15
									641.36
Monitors	Administrative	514	150	7	6.5	3	549.72	21	11,544.18
Monitors	Classroom	92	150	3	6.5	7	45.59	21	957.31
Monitors	Commons	86	150	7	6.5	3	91.98	21	1,931.52
Monitors	Computer Lab	150	150	6	6.5	3	137.93	21	2,896.43
Monitors	Library	42	150	7	6.5	3	44.92	21	943.30
									18,272.73
Printers	Administrative	102.8	400	2	16.8	22	120.23	21	2,524.93
Printers	Classroom	19	400	1	16.8	23	14.94	21	313.77
Printers	Commons	17	400	2	16.8	22	19.88	21	417.55
Printers	Computer Lab	30	400	2	16.8	22	35.09	21	736.85
Printers	Library	17.2	400	2	16.8	22	20.12	21	422.46
									4,415.56
Projecter	Classroom	69	300	1	10	23	36.57	21	767.97
									767.97
Ranges	Trades Classroom	8	2100	2	1.3	22	33.83	21	710.40
									710.40
Refrigerator (assume 16 CF)	Administrative	18	725	4	0	0	52.20	31	1,618.20
Refrigerator (assume 16 CF)	Trades Classroom	8	725	4	0	0	23.20	31	719.20
									2,337.40
Space Heaters	Administrative	10	425	4	0	20	17.00	21	357.00
									357.00
Telephones	Administrative	7	2.1	24	0	0	0.35	31	10.94
Telephones	Classroom	69	2.1	24	0	0	3.48	21	73.03
									83.97
Toaters	Administrative	4	1100	2	0	23	8.80	21	184.80
									184.80
TVs (assume 36")	Classroom	69	133	1	3	23	13.94	21	292.70
									292.70
VCR/DVD Avergae 17/25	Classroom	69	21	1	5.4	23	10.02	21	210.39
									210.39

Monthly Total kWh	46,071.98
Annual Factor:	10.2253

Estimated Annual Plug Load Electric Consumption: 471,099.85

Appendix E

Food Service Equipment Quantification Tables

FRHS Food Service Equipment

Note Designation	Use	Quantity	Description	Hours/Day	Amps	Volts	Phase	Calculated kW	kWh/Day	School Day (JAN)	Weekend Days (Jan)	kWh/Month
91	Dish Washing	1	Disposer	0.75	60	208	3	21.62	16.21	21	0	340.45
97	Dish Washing	1	Booster heater	0.75	36	480	3	29.93	22.45	21	0	471.39
100	Dish Washing	1	Dish Machine	3	45.1	480	3	28.12	84.36	21	0	1,771.66
33	Preparation	1	Prep. Table	4	20	120	1	2.40	9.60	21	0	201.60
35	Preparation	1	Food Processor	1	2.8	208	3	1.01	1.01	21	0	21.18
36	Preparation	1	20qt mixer	1	8.2	120	1	0.98	0.98	21	0	20.66
41	Preparation	2	Prep. Table	4	20	120	1	4.80	19.20	21	0	403.20
51	Preparation	1	Prep. Table	4	20	120	1	2.40	9.60	21	0	201.60
53	Preparation	1	60qt. Mixer	1	10.9	208	1	2.27	2.27	21	0	47.61
57	Preparation	1	Mobile Proofing Cabinet	3	19.1	120	1	2.29	6.88	21	0	144.40
61	Preparation	2	Convection Oven	4	6	120	1	1.44	5.76	21	0	120.96
62	Preparation	1	Fryer System	1	6	208	1	1.25	1.25	21	0	26.21
62	Preparation	1	Fryer System Warmer	1	4.2	120	1	0.50	0.50	21	0	10.58
65	Preparation	1	Exhaust Hood	4	20	120	1	2.40	9.60	21	0	201.60
66	Preparation	1	Fire Suppression System	0	20	120	1	2.40	0.00	21	0	-
67	Preparation	1	Exhaust Hood	4	20	120	1	2.40	9.60	21	0	201.60
68	Preparation	1	Fire Suppression System	0	20	120	1	2.40	0.00	21	0	-
73	Preparation	1	40 gal. kettle	1	10	120	1	1.20	1.20	21	0	25.20
74	Preparation	1	Tilting kettle	1	3	120	1	0.36	0.36	21	0	7.56
76	Preparation	1	Combo oven	4	15	120	1	1.80	7.20	21	0	151.20
77	Preparation	2	Prep. Table	4	20	120	1	4.80	19.20	21	0	403.20
90	Preparation	1	Sink Agitator	1	5.6	120	1	0.67	0.67	21	0	14.11
104	Preparation	1	Disposer	1	6	208	3	2.16	2.16	21	0	45.39
112	Preparation	1	Hot Water Dispenser	7	11.3	120	1	1.36	9.49	21	0	199.33
115	Preparation	2	Microwave	1	15	120	1	3.60	3.60	21	0	75.60
143	Preparation	1	Back counter	4	20	120	1	2.40	9.60	21	0	201.60
152	Preparation	1	Conveyer Oven	4	7	120	1	0.84	3.36	21	0	70.56
153	Preparation	1	Exhaust Hood	4	20	120	1	2.40	9.60	21	0	201.60
154	Preparation	1	Fire Suppression System	0	20	120	1	2.40	0.00	21	0	-
155	Preparation	1	Refrigerated Pizza Prep.	1	9	120	1	1.08	1.08	21	0	22.68
13	Refrigeration	2	Evaporator Coil	8	16.1	208	1	3.35	26.79	21	8	776.92
25	Refrigeration	1	Compressor Rack	8	37.2	208	3	6.70	53.61	21	8	1,554.62
11	Refrigeration	1	Holding Freezer	8	20	120	1	1.20	9.60	21	8	278.40
15	Refrigeration	1	Holding Cooler	8	20	120	1	1.20	9.60	21	8	278.40
17	Refrigeration	1	Evaporator Coil	8	4.3	120	1	0.26	2.06	21	8	59.86
23	Refrigeration	1	Evaporator Coil	8	4.3	120	1	0.26	2.06	21	8	59.86
48	Refrigeration	0	Reach-in refrigerator	8	8.5	120	1	0.00	0.00	21	8	-
52	Refrigeration	1	Reach-in refrigerator	8	8.5	120	1	0.51	4.08	21	8	118.32
58	Refrigeration	1	Reach-in refrigerator	8	8.5	120	1	0.51	4.08	21	8	118.32
107	Refrigeration	3	Ice maker	8	11.2	120	1	2.02	16.13	21	8	467.71
107	Refrigeration	3	Ice maker	8	0.3	120	1	0.05	0.43	21	8	12.53
1	Service	1	Furniture/Equipment	7	20	12	1	0.24	1.68	21	0	35.28
4	Service	2	Beverage System	8	15	120	1	1.80	14.40	21	8	417.60
43	Service	2	Ice maker	8	12.6	120	1	1.51	12.10	21	8	350.78
43	Service	2	Ice maker	8	0.3	120	1	0.04	0.29	21	8	8.35
71	Service	1	Hot Food Cabinet	4	16.6	120	1	1.99	7.97	21	0	167.33
116	Service	1	Cappuccino Machine	1	20	120	1	2.40	2.40	21	0	50.40
122	Service	3	P.O.S Machine (cash register)	7	20	120	1	3.60	25.20	21	0	529.20
124	Service	3	Ice Cube Unit	8	5	120	1	1.80	14.40	21	8	417.60
125	Service	3	Heated Display Cabinet	3	18	120	1	6.48	19.44	21	0	408.24
126	Service	2	Hot Food Server	3	23.3	120	1	5.59	16.78	21	0	352.30
127	Service	3	Refrigerated Server Unit	3	7	120	1	2.52	7.56	21	0	158.76
128	Service	2	Refrigerated Server Unit	3	7	120	1	1.68	5.04	21	0	105.84
131	Service	0	Salad Bar Unit	3	15	120	1	0.00	0.00	21	0	-
142	Service	1	Reach-in refrig	8	10.4	120	1	0.62	4.99	21	8	144.77
144	Service	1	Pizza Display Unit	3	12.3	120	1	1.48	4.43	21	0	92.99
145	Service	1	Hot Holding Cabinet	3	16.6	120	1	1.99	5.98	21	0	125.50
147	Service	1	Sneeze Guard Lights	3	1	120	1	0.12	0.36	21	0	7.56
148	Service	1	Hot Food Well Unit	3	14.2	120	1	1.70	5.11	21	0	107.35
149	Service	1	Hot Cold Food Well	3	16.7	120	1	2.00	6.01	21	0	126.25
150	Service	1	P.O.S Machine (cash register)	7	20	120	1	1.20	8.40	21	0	176.40

Total kWh:	13,110.18
Annual Factor:	10.225

Estimated Annual kWh:	134,055.55

FCHS Food Service Equipment

Note Designation	Use	Quantity	Description	Hours/Day	Amps	Volts	Phase	Calculated kW	kWh/Day	School Day (JAN)	Weekend Days (Jan)	kWh/Month
91	Dish Washing	1	Disposer	0.75	60	208	3	21.62	16.21	21	0	340.45
97	Dish Washing	1	Booster heater	0.75	36	480	3	29.93	22.45	21	0	471.39
100	Dish Washing	1	Dish Machine	3	45.1	480	3	28.12	84.36	21	0	1,771.66
33	Preparation	1	Prep. Table	4	20	120	1	2.40	9.60	21	0	201.60
35	Preparation	1	Food Processor	1	2.8	208	3	1.01	1.01	21	0	21.18
36	Preparation	1	20qt mixer	1	8.2	120	1	0.98	0.98	21	0	20.66
41	Preparation	2	Prep. Table	4	20	120	1	4.80	19.20	21	0	403.20
51	Preparation	1	Prep. Table	4	20	120	1	2.40	9.60	21	0	201.60
53	Preparation	1	60qt. Mixer	1	10.9	208	1	2.27	2.27	21	0	47.61
57	Preparation	1	Mobile Proofing Cabinet	3	19.1	120	1	2.29	6.88	21	0	144.40
61	Preparation	2	Convection Oven	4	6	120	1	1.44	5.76	21	0	120.96
62	Preparation	1	Fryer System	1	6	208	1	1.25	1.25	21	0	26.21
62	Preparation	1	Fryer System Warmer	1	4.2	120	1	0.50	0.50	21	0	10.58
65	Preparation	1	Exhaust Hood	4	20	120	1	2.40	9.60	21	0	201.60
66	Preparation	1	Fire Suppression System	0	20	120	1	2.40	0.00	21	0	-
67	Preparation	1	Exhaust Hood	4	20	120	1	2.40	9.60	21	0	201.60
68	Preparation	1	Fire Suppression System	0	20	120	1	2.40	0.00	21	0	-
73	Preparation	1	40 gal. kettle	1	10	120	1	1.20	1.20	21	0	25.20
74	Preparation	1	Tilting kettle	1	3	120	1	0.36	0.36	21	0	7.56
76	Preparation	1	Combo oven	4	15	120	1	1.80	7.20	21	0	151.20
77	Preparation	2	Prep. Table	4	20	120	1	4.80	19.20	21	0	403.20
90	Preparation	1	Sink Agitator	1	5.6	120	1	0.67	0.67	21	0	14.11
104	Preparation	1	Disposer	1	6	208	3	2.16	2.16	21	0	45.39
112	Preparation	1	Hot Water Dispenser	7	11.3	120	1	1.36	9.49	21	0	199.33
115	Preparation	2	Microwave	1	15	120	1	3.60	3.60	21	0	75.60
143	Preparation	1	Back counter	4	20	120	1	2.40	9.60	21	0	201.60
152	Preparation	1	Conveyer Oven	4	7	120	1	0.84	3.36	21	0	70.56
153	Preparation	1	Exhaust Hood	4	20	120	1	2.40	9.60	21	0	201.60
154	Preparation	1	Fire Suppression System	0	20	120	1	2.40	0.00	21	0	-
155	Preparation	1	Refrigerated Pizza Prep.	1	9	120	1	1.08	1.08	21	0	22.68
13	Refrigeration	2	Evaporator Coil	8	16.1	208	1	3.35	26.79	21	8	776.92
25	Refrigeration	1	Compressor Rack	8	37.2	208	3	6.70	53.61	21	8	1,554.62
11	Refrigeration	1	Holding Freezer	8	20	120	1	1.20	9.60	21	8	278.40
15	Refrigeration	1	Holding Cooler	8	20	120	1	1.20	9.60	21	8	278.40
17	Refrigeration	1	Evaporator Coil	8	4.3	120	1	0.26	2.06	21	8	59.86
23	Refrigeration	1	Evaporator Coil	8	4.3	120	1	0.26	2.06	21	8	59.86
48	Refrigeration	0	Reach-in refrigerator	8	8.5	120	1	0.00	0.00	21	8	-
52	Refrigeration	1	Reach-in refrigerator	8	8.5	120	1	0.51	4.08	21	8	118.32
58	Refrigeration	1	Reach-in refrigerator	8	8.5	120	1	0.51	4.08	21	8	118.32
107	Refrigeration	3	Ice maker	8	11.2	120	1	2.02	16.13	21	8	467.71
107	Refrigeration	3	Ice maker	8	0.3	120	1	0.05	0.43	21	8	12.53
1	Service	1	Furniture/Equipment	7	20	12	1	0.24	1.68	21	0	35.28
4	Service	2	Beverage System	8	15	120	1	1.80	14.40	21	8	417.60
43	Service	2	Ice maker	8	12.6	120	1	1.51	12.10	21	8	350.78
43	Service	2	Ice maker	8	0.3	120	1	0.04	0.29	21	8	8.35
71	Service	1	Hot Food Cabinet	4	16.6	120	1	1.99	7.97	21	0	167.33
116	Service	1	Cappuccino Machine	1	20	120	1	2.40	2.40	21	0	50.40
122	Service	3	P.O.S Machine (cash register)	7	20	120	1	3.60	25.20	21	0	529.20
124	Service	3	Ice Cube Unit	8	5	120	1	1.80	14.40	21	8	417.60
125	Service	3	Heated Display Cabinet	3	18	120	1	6.48	19.44	21	0	408.24
126	Service	2	Hot Food Server	3	23.3	120	1	5.59	16.78	21	0	352.30
127	Service	3	Refrigerated Server Unit	3	7	120	1	2.52	7.56	21	0	158.76
128	Service	2	Refrigerated Server Unit	3	7	120	1	1.68	5.04	21	0	105.84
131	Service	0	Salad Bar Unit	3	15	120	1	0.00	0.00	21	0	-
142	Service	1	Reach-in refrig	8	10.4	120	1	0.62	4.99	21	8	144.77
144	Service	1	Pizza Display Unit	3	12.3	120	1	1.48	4.43	21	0	92.99
145	Service	1	Hot Holding Cabinet	3	16.6	120	1	1.99	5.98	21	0	125.50
147	Service	1	Sneeze Guard Lights	3	1	120	1	0.12	0.36	21	0	7.56
148	Service	1	Hot Food Well Unit	3	14.2	120	1	1.70	5.11	21	0	107.35
149	Service	1	Hot Cold Food Well	3	16.7	120	1	2.00	6.01	21	0	126.25
150	Service	1	P.O.S Machine (cash register)	7	20	120	1	1.20	8.40	21	0	176.40

Total kWh:	13,110.18
Annual Factor:	10.554

Estimated Annual kWh:	138,364.87

Appendix F

HVAC Equipment Quantification Tables

FRHS Mechanical Equipment

FRHS - HVAC Pump and Fan Schedule

Air handling Unit table

Unti #		Supply Fan HP	Return Fan HP	Evap. Cooling Pump HP	Energy Wheels HP	kW	Notes
AHU-	1	15.000	15.000	0.250	0.000	16.972	VFD on Both Fans/Not on Pump
AHU-	2	7.500	7.500	0.250	0.000	8.579	VFD on Both Fans/Not on Pump
AHU-	3	7.500	7.500	0.250	0.000	8.579	VFD on Both Fans/Not on Pump
AHU-	4	2.000	2.000	0.250	0.000	2.425	VFD on Both Fans/Not on Pump
AHU-	5	3.000	3.000	0.250	0.000	3.544	VFD on Both Fans/Not on Pump
AHU-	6	5.000	5.000	0.250	0.000	5.782	VFD on Both Fans/Not on Pump
AHU-	7	5.000	5.000	0.250	0.000	5.782	VFD on Both Fans/Not on Pump
AHU-	8	15.000	10.000	0.000	0.063	14.034	VFD on Both Fans/Not on Pump
AHU-	9	10.000	7.500	0.000	0.063	9.838	VFD on Both Fans/Not on Pump
AHU-	10	15.000	7.500	0.000	0.063	12.635	VFD on Both Fans/Not on Pump
AHU-	11	10.000	7.500	0.000	0.250	9.978	VFD on Both Fans/Not on Pump
AHU-	12	7.500	7.500	0.000	0.063	8.439	VFD on Both Fans/Not on Pump
AHU-	13	7.500	7.500	0.000	0.063	8.439	VFD on Both Fans/Not on Pump
AHU-	14	3.000	3.000	0.000	0.063	3.404	VFD on Both Fans/Not on Pump
AHU-	15	15.000	10.000	0.000	0.063	14.034	VFD on Both Fans/Not on Pump
						132.462	

Make-up Air Unit Schedule

		Supply Fan HP	Evap. Cooling Pump HP	kW	Notes
MUA-	1	20.000	0.020	11.205	VFD on Supply Van
MUA-	2	20.000	0.020	11.205	VFD on Supply Van
MUA-	3	20.000	0.020	11.205	VFD on Supply Van
				33.615	

Blower Coil Schedule:

	Supply Fan HP	Chilled Water Coil MBh	Heater Coil MBh	(Fan Only - Central Pump) kW
A- 1	0.330	20.900	36.600	0.246
A- 2	0.330	16.800	23.000	0.246
A- 3	0.330	18.400	24.900	0.246
A- 4	0.250	12.500	28.200	0.187
A- 5	0.330	14.100	29.700	0.246
A- 6	0.750	18.600	36.300	0.560
A- 7	0.500	15.800	33.500	0.373
A- 8	0.333	18.400	24.900	0.248
A- 9	0.500	17.500	35.200	0.373
A- 10	0.500	17.300	32.900	0.373
A- 11	0.250	12.500	28.200	0.187
A- 12	0.330	11.800	18.200	0.246
A- 13	0.330	14.900	30.500	0.246
A- 14	0.330	13.100	18.300	0.246
A- 15	0.250	9.940	15.800	0.187
A- 16	0.250	10.600	16.400	0.187
A- 17	0.250	11.800	17.400	0.187
A- 18	0.333	18.200	24.200	0.248
A- 19	0.250	10.800	11.600	0.187
A- 20	0.250	7.600	11.600	0.187
A- 21	0.333	25.000	32.600	0.248
A- 22	0.333	8.810	13.800	0.248
A- 23	0.250	6.740	12.300	0.187
A- 24	0.250	7.910	13.200	0.187
A- 25	0.250	7.160	11.200	0.187
A- 26	1.000	33.900	54.100	0.746
A- 27	0.250	10.800	16.400	0.187
A- 28	0.333	25.000	32.600	0.248
A- 29	0.250	12.800	18.700	0.187
A- 30	0.500	19.000	25.200	0.373
A- 31	0.330	12.600	18.500	0.246
A- 32	0.250	10.500	15.400	0.187
B- 1	0.250	11.000	16.400	0.187
B- 2	0.500	18.100	23.400	0.373
B- 3	0.333	8.500	13.800	0.248
B- 4	0.250	13.800	19.200	0.187
B- 5	0.250	11.300	16.700	0.187
B- 6	0.250	11.300	16.700	0.187
B- 7	0.250	14.200	19.600	0.187
B- 8	0.250	14.200	19.600	0.187
B- 9	0.250	11.300	16.700	0.187
B- 10	0.250	14.000	20.000	0.187
B- 11	0.250	14.200	19.600	0.187
B- 12	0.250	14.600	20.300	0.187
B- 13	0.500	24.300	37.600	0.373
B- 14	0.500	28.000	38.800	0.373
B- 15	0.333	12.400	17.700	0.248
B- 16	1.000	35.000	50.800	0.746
B- 17	0.750	20.300	28.600	0.560
B- 18	0.250	7.950	11.800	0.187
B- 19	0.500	23.300	34.500	0.373
B- 20	0.250	9.600	15.100	0.187
B- 21	0.250	10.700	16.010	0.187
B- 22	0.500	18.500	26.200	0.373
B- 23	0.250	10.800	17.500	0.187

Blower Coil Schedule:

	Supply Fan HP	Chilled Water Coil MBh	Heater Coil MBh	(Fan Only - Central Pump) kW
B- 24	0.500	17.200	27.000	0.373
C- 1	0.250	11.000	16.400	0.187
C- 2	0.500	18.100	23.400	0.373
C- 3	0.333	8.500	13.800	0.248
C- 4	0.250	13.800	19.000	0.187
C- 5	0.250	11.300	16.500	0.187
C- 6	0.250	11.300	16.500	0.187
C- 7	0.250	14.200	19.300	0.187
C- 8	0.250	14.200	19.300	0.187
C- 9	0.250	11.300	16.500	0.187
C- 10	0.250	13.900	19.700	0.187
C- 11	0.250	14.200	19.300	0.187
C- 12	0.250	14.600	20.100	0.187
C- 13	0.500	24.200	37.000	0.373
C- 14	0.500	28.000	38.300	0.373
C- 15	0.333	12.400	17.500	0.248
C- 16	1.000	31.900	47.100	0.746
C- 17	0.500	20.300	26.300	0.373
C- 18	0.250	7.950	11.600	0.187
C- 19	0.333	22.700	32.100	0.248
C- 20	0.250	13.500	21.000	0.187
C- 21	0.250	10.700	15.600	0.187
C- 22	0.250	15.500	21.800	0.187
C- 23	0.250	10.800	17.200	0.187
C- 24	0.500	17.200	26.500	0.373
D- 1	0.250	6.690	11.000	0.187
D- 2	0.333	17.300	23.000	0.248
D- 3	0.250	9.680	12.600	0.187
D- 4	1.000	29.700	60.000	0.746
D- 5	0.500	26.000	27.200	0.373
D- 6	0.250	7.510	11.500	0.187
D- 7	0.500	18.100	24.700	0.373
E- 1	0.250	6.690	11.000	0.187
E- 2	0.333	17.300	23.000	0.248
E- 3	0.250	9.680	12.600	0.187
E- 4	1.000	29.700	60.000	0.746
E- 5	0.500	26.000	27.200	0.373
E- 6	0.250	7.510	11.500	0.187
E- 7	0.500	18.100	24.700	0.373
E- 8	0.750	33.600	42.800	0.560
F- 1	0.250	11.600	19.000	0.187
F- 2	0.750	29.300	43.900	0.560
F- 3	0.330	13.300	20.200	0.246
F- 4	0.500	18.900	29.200	0.373
F- 5	0.500	17.200	30.900	0.373
F- 6	0.750	29.500	41.000	0.560
F- 7	0.500	22.200	31.800	0.373
F- 8	0.750	30.900	42.300	0.560
F- 9	0.500	16.700	20.000	0.373
G- 1	0.750	13.000	35.200	0.560
G- 2	0.750	23.900	34.100	0.560
H- 1	0.250	9.980	28.600	0.187
H- 2	0.500	9.270	22.400	0.373
H- 3	0.500	11.100	31.800	0.373
H- 4	1.000	29.400	48.600	0.746
H- 5	0.250	9.980	28.600	0.187
H- 6	0.500	14.500	28.600	0.373
H- 7	1.000	22.500	59.800	0.746
				34.104

Exhaust Fans

	HP	kWh
EF- A1	0.040	0.030
EF- A2	0.167	0.124
EF- A3	0.040	0.030
EF- A4	0.040	0.030
EF- A5	0.167	0.124
EF- A6	0.040	0.030
EF- A7	0.125	0.093
EF- A8	0.167	0.124
EF- A9	0.167	0.124
EF- A10	0.750	0.560
EF- A11	0.500	0.373
EF- B1	0.333	0.248
EF- B2	0.167	0.124
EF- B3	0.040	0.030
EF- B4	0.040	0.030
EF- B5	0.166	0.124
EF- B6	0.333	0.248
EF- B7	0.040	0.030
EF- B8	0.040	0.030
EF- B9	0.125	0.093
EF- C1	0.330	0.246
EF- C2	0.167	0.125
EF- C3	0.040	0.030
EF- C4	0.040	0.030
EF- C5	0.167	0.125
EF- C6	0.333	0.248

Exhaust Fans

	HP	kWh
EF- C7	0.040	0.030
EF- C8	0.040	0.030
EF- C9	0.125	0.093
EF- D1	0.125	0.093
EF- D2	0.040	0.030
EF- D3	0.040	0.030
EF- D4	0.040	0.030
EF- D5	0.750	0.560
EF- D6	3.000	2.238
EF- D7	1.000	0.746
EF- D8	0.040	0.030
EF- E1	0.125	0.093
EF- E2	0.040	0.030
EF- E3	0.040	0.030
EF- E4	0.333	0.248
EF- E5	0.167	0.125
EF- E6	0.167	0.125
EF- E7	0.125	0.093
EF- F1	0.040	0.030
EF- F2	0.040	0.030
EF- F3	0.040	0.030
EF- F4	0.040	0.030
EF- F5	0.167	0.125
EF- F6	1.500	1.119
EF- F7	0.333	0.248
EF- F8	0.250	0.187
EF- G1	0.125	0.093
EF- G2	0.040	0.030
EF- G3	0.125	0.093
EF- G4	0.040	0.030
EF- G5	0.040	0.030
EF- G6	0.040	0.030
EF- H1	0.125	0.093
EF- H2	0.125	0.093
EF- H3	0.040	0.030
EF- H4	0.167	0.125
EF- H5	0.040	0.030
EF- K1	5.000	3.730
EF- K2	5.000	3.730
EF- K3	0.167	0.125
EF- K4	0.750	0.560
EF- 1	0.500	0.373
EF- 2	0.167	0.125
		19.1725

Unit Heaters

	Pump HP	MBh	kW
UH- A1	0.125	10.000	0.093
UH- A2	0.125	20.000	0.093
UH- D1	0.125	20.000	0.093
CH- A1	0.125	16.800	0.093
CH- A2	0.125	16.800	0.093
CH- B1	0.083	9.500	0.062
CH- C1	0.083	13.600	0.062
CH- D1	0.125	9.500	0.093
CH- E1	0.125	9.500	0.093
CH- F1	0.083	7.200	0.062
CH- F2	0.083	7.200	0.062
CH- H1	0.083	6.100	0.062
CH- H2	0.083	8.500	0.062
EUH-			20.000
			21.026

Air Compressor

	HP	kW
AC-1	25.000	**18.650**

Air Dryer

	HP	kW
AD-1	1.000	**0.746**

Computer Room Air Conditioner

	Volts	Amps (FLA)	Phase	Watts	kW	
CRAC 1	460	1.6	3	1274.789	1.275	Used FLA Full Load Amps
CRAC 2	460	1.6	3	1274.789	1.275	Used FLA Full Load Amps
CRAC 3	460	1.3	3	1035.766	1.036	Used FLA Full Load Amps
CRAC 4	460	1.3	3	1035.766	1.036	Used FLA Full Load Amps
					4.621	

Condensing Unit

	Motor HP	kW
COND 1	1.500	1.119
COND 2	1.500	1.119
COND 3	1.000	0.746
COND 4	1.000	0.746
		3.730

Air Cooled Chiller

			Volts	phase	RLA or FLA	Watts	kW
CH	-1	Compressor	460	3	212	168909.595	168.910
		Fan	460	3	3	2390.230	2.390
							171.300

Boiler Water Heaters (Blowers)

		Volts	Amps	Phase	kW
B	-1	460	15	3	11.951
B	-2	460	15	3	11.951
B	-3	460	15	3	11.951
WH	-1	120	20	1	2.400
WH	-2	120	20	1	2.400
					40.653

Pumps

		Pump (HP)	kW	
P	1	15.000	8.393	VFD
p	2	15.000	8.393	VFD
p	3	10.000	7.460	
P	4	10.000	7.460	
p	5	15.000	8.393	VFD
p	6	15.000	8.393	VFD
P	7	10.000	7.460	
RP	1	0.750	0.560	
RP	2	0.040	0.030	
			56.539	

		Running Hours	School Days January	Weekend Days January	Monthly kWh
All Pumps & Fans					
Total kW	536.62	11.00	21		123958.87
Total kW	536.62	6.00		10	32197.11
				Januaray Total kWh	156155.98
				Annaul Factor	10.2253
				Estimated Annual HVAC Electric Consumption:	1,596,741.70
				Load Factor:	35%
				Estimated Annual HVAC Electric Consumption:	558,860

FCHS Mechanical Equipment

FCHS - HVAC Pump and Fan Schedule

Air handling Unit table

Unti #		Fan HP	Calculated kW	
AHU-	1	7.500	5.595	
AHU-	2	10.000	5.595	VFD
AHU-	3	15.000	11.190	
AHU-	4	20.000	14.920	
AHU-	5	30.000	22.380	
AHU-	6	7.500	5.595	
AHU-	7	5.000	3.730	
AHU-	8	40.000	29.840	
AHU-	3	20.000	14.920	
AHU-	10	15.000	11.190	
AHU-	11	60.000	44.760	
AHU-	12	75.000	55.950	
AHU-	13	75.000	55.950	
AHU-	14	20.000	14.920	
AHU-	15	20.000	14.920	
AHU-	16	30.000	22.380	
AHU-	17	30.000	22.380	
AHU-	18	30.000	22.380	
			378.595	

Chiller	kW/Ton	Calculated kW
C-1	0.530	139.125

Cooling Tower

	Pump HP	Calculated kW	
CT-1	15.000	8.393	VFD

Boilers (natural gas, with electric blower)

	Blower/Fan HP	Calculated kW
B-1	7.500	5.595
B-2	7.500	5.595
B-3	7.500	5.595
		16.785

Exhaust & Supply Fans

		Fan HP	Calculated kW
SF-	1	0.125	0.093
SF-	2	0.375	0.280
SF-	3	not used	0.000
EF-	1	0.500	0.373
EF-	2	0.750	0.560
EF-	3	0.500	0.373
EF-	4	1.000	0.746
EF-	5	1.000	0.746
EF-	6	1.000	0.746
EF-	7	1.000	0.746
EF-	8	0.330	0.246
EF-	9	0.500	0.373
EF-	10	0.250	0.187
EF-	11	0.500	0.373
EF-	12	0.250	0.187
EF-	13	0.250	0.187
EF-	14	0.250	0.187
EF-	15	0.250	0.187
EF-	16	0.250	0.187
EF-	17	1.500	1.119
EF-	18	1.500	1.119
EF-	19	0.500	0.373
EF-	20	0.500	0.373
EF-	21	0.250	0.187
EF-	22	0.250	0.187
EF-	23	0.750	0.560
EF-	24	0.750	0.560
EF-	25	1.000	0.746
EF-	26	2.000	1.492

Exhaust & Supply Fans

		Fan HP	Calculated kW	
EF-	27	0.333	0.248	
EF-	28	0.500	0.373	
EF-	29	0.500	0.373	
EF-	30	1.500	1.119	
EF-	31	0.250	0.187	
EF-	32	0.750	0.560	
EF-	33	0.250	0.187	
EF-	34	0.250	0.187	
EF-	35	0.250	0.187	
EF-	36	0.250	0.187	
EF-	37	0.250	0.187	
EF-	38	0.040	0.030	
EF-	39	0.040	0.030	
EF-	40	0.040	0.030	
EF-	41	0.040	0.030	
EF-	42	0.750	0.420	VFD
EF-	43	0.750	0.560	
EF-	44	0.750	0.560	
EF-	45	0.250	0.187	
EF-	46	0.250	0.187	
EF-	47	0.250	0.187	
EF-	48	0.250	0.187	
EF-	49	0.250	0.187	
EF-	50	0.250	0.187	
EF-	51	0.500	0.373	
EF-	52	0.500	0.373	
EF-	53	0.500	0.373	
EF-	54	0.500	0.373	
EF-	55	0.500	0.373	
EF-	56	0.333	0.248	
EF-	57	0.500	0.373	
EF-	58	0.250	0.187	
EF-	59	0.500	0.373	
EF-	60	0.250	0.187	
EF-	61	0.750	0.560	
EF-	62	0.250	0.187	
EF-	63	0.250	0.187	
EF-	64	0.250	0.187	
EF-	65	0.250	0.187	
EF-	66	0.250	0.187	
EF-	67	0.500	0.373	
EF-	68	0.750	0.560	
EF-	69	0.250	0.187	
EF-	70	0.500	0.373	
EF-	71	0.750	0.560	
EF-	8	0.750	0.560	
EF-	73	0.500	0.373	
EF-	74	0.333	0.248	
			28.013	

Unit heaters:

	Pump HP	Pump kW
UH-1	0.063	0.047
UH-2	0.063	0.047
CUH-1		0.270
		0.363

Pumps:

		HP	Pump kW	
BP	-1	5.000	3.730	
BP	-2	5.000	3.730	
BP	-3	5.000	3.730	
CP	-1	15.000	11.190	
CWP	-1	10.000	7.460	
CWPT	-1	25.000	13.988	VFD
HPT	-1	25.000	13.988	VFD
HPT	-2	25.000	13.988	VFD
HPT	-3	25.000	13.988	VFD
HWCP	-1	1.000	0.746	
HWCP	-2	0.500	0.373	

Pumps:

		HP	Pump kW
P	-1	0.5000	0.3730
P	-2	0.5000	0.3730
P	-3	0.7500	0.5595
P	-4	0.5000	0.3730
P	-5	0.7500	0.5595
P	-6	0.5000	0.3730
P	-7	0.5000	0.3730
P	-8	0.7500	0.5595
P	-9	1.5000	1.1190
P	-10	0.7500	0.5595
P	-11	0.3330	0.2484
P	-12	0.5000	0.3730
P	-13	2.0000	1.4920
P	-14	3.0000	2.2380
P	-15	0.5000	0.3730
P	-16	1.5000	1.1190
P	-17	0.7500	0.5595
P	-18	0.5000	0.3730
P	-19	3.0000	2.2380
P	-20	0.7500	0.5595
P	-21	3.0000	2.2380
P	-22	0.5000	0.3730
P	-23	5.0000	3.7300
P	-24	0.5000	0.3730
P	-25	1.0000	0.7460
P	-26	0.3333	0.2486
P	-27	1.5000	1.1190
P	-28	0.7500	0.5595
P	-29	2.0000	1.4920
P	-30	1.5000	1.1190
P	-31	2.0000	1.4920
P	-32	0.5000	0.3730
P	-33	1.0000	0.7460
			116.3136

		Running Hours	School Days January	Weekend Days January	Monthly kWh
All Pumps & Fans					
Total kW	687.59	11.50	21.67		171350.30
Total kW	687.59	6.00		8.33	34365.63
				Januaray Total kWh	205715.93
				Annaul Factor	10.553
				Estimated Annual HVAC Electric Consumption:	2,170,920.26
				Load Factor:	35%
				Estimated Annual HVAC Electric Consumption:	759,822