

WISCONSIN DIVISION OF ENERGY
WISCONSIN ENERGY INITIATIVE-2 PROGRAM
AND THE
WISCONSIN DIVISION OF PUBLIC HEALTH
INDOOR AIR PROGRAM

WAUSAU WEST HIGH SCHOOL

ENVIRONMENTAL AND ENERGY TESTING
RESULTS

INTRODUCTION

This is a report of the indoor air quality parameters and energy usage data measured at Wausau West High School, Wausau, Wisconsin. Environmental testing at the school was conducted December 8, 1999 by staff of the Wisconsin Division of Public Health Indoor Air Program. Energy tracking was conducted by the Wisconsin Division of Energy and Public Benefits, Wisconsin Energy Initiative-2 Program in conjunction with Cooperative Educational Service Agency 10, and Wilinski and Associates, Incorporated.

BACKGROUND

There were air quality complaints associated with the areas that were sampled. Marathon County Public Health Department has responded to concerns about air quality at the Wausau West High School. Wausau West High School contains over 1700 students and is a 275,000 square foot building, built in 1968. The school has no classroom windows and no insulation in the walls. It had problems with mechanical system failures. There were complaints of hot and cold rooms, poor ventilation and poor air quality.

Mechanical equipment failure and air quality complaints prompted corrective action measures by Wausau West School Officials. All of the corrective action measures are not in place but the complaints about air quality have been reduced significantly. The objective of the corrective action was to improve air quality and reduce energy, increase the operating life of the building and lower maintenance costs. Dennis Wald, Facility Manager and Lentz and Associates (Engineering firm) used several methods to address the problem. The State of Wisconsin's Department of Administration provided an important tool in this process. An Energy Survey conducted by the State of Wisconsin Division of Energy, Wisconsin Energy Initiative-2 program, identified the condition the physical plant, evaluated the mechanical, electrical, control systems and provided insight to alternative energy saving processes.

A three-phase plan was made.

Phase 1 included repairs and upgrades:

- Improve class room ventilation,
- Evaluate mechanical electrical, and control systems,
- Research alternative processes for potential energy reduction

Phase 2 was to replace the problem mechanical systems.

Phase 3 was to install additional systems and to up grade the system for peak cooling conditions.

Monitoring the indoor environmental quality is part of the evaluation of the effect of these changes. The focus of the environmental monitoring was to monitor carbon dioxide levels within various areas of the building. Carbon dioxide levels serve as an indicator of inadequate ventilation. There were consistent concentrations of greater than 1000 parts per million found in several areas of the building when these areas were occupied. Prior testing performed by Legend Technical Services, September 16 and 22, 1998, showed elevated carbon dioxide concentrations when compared to ASHRAE Standard 62-1989 criteria. Legend recommended increasing the amount of fresh air and the number of air changes per hour supplied to the indoor space. Elevated carbon dioxide concentrations suggest a potential for, and increase in, other indoor contaminants. High carbon dioxide concentrations have been linked to more incidents of air quality complaints.

On December 8, 1999, a round of testing was done at the request of Dennis Wald of the Wausau School District and Terry Pease of the State of Wisconsin Division of Energy. As a part of a maintenance program and energy savings initiative, several procedures were employed by the Wausau West staff and their technical consultant Mark Lentz of Lentz Engineering and Associates. The battery of tests have evaluated the air quality in the building after the program improvements were put in place.

METHODS

- Environmental monitoring was performed within occupied spaces of the school during normal class hours.
- Areas that reported air quality problems in prior tests were sampled.
- Monitoring was performed with direct read out equipment and glass filter tubes with personal air sampling pumps.
- Additional sites were also sampled to give a complete picture of the indoor environment.

Substance monitored	Type of equipment	Range
Carbon dioxide	Gastech, RI411, infrared detector, portable monitor	20 /9950 parts per million
Biological Aerosols	Andersen N6, single stage viable impactor. Sampling time 2 minutes.	Placed on malt extract agar, incubated at 25°C for 5 to 7 days. Molds are identified to genus levels. <i>Aspergillus</i> <i>Stachybotrys chartarum</i> and <i>Aureobasidium pullans</i> are identified to species level Limit of detection: 18 colony forming units/cubic meter
Temperature and humidity	Testo term 6100 Thermohygrometer , single probe, digital read out, portable	2-98% relative humidity 10 to 140 ° Fahrenheit
Ozone (ion chromatography) Wisconsin Occupational Health Laboratory method	OSHA ID214, Air sample collected using a calibrated sampling pump and a two-piece polystyrene cassette containing two nitrite impregnated glass fiber filters.	Detection limit: 0.008 PPM
Carbon monoxide	Gastech, GX86, electrochemical sensor, 4 gas portable gas monitor	
Oxygen	Gastech, GX86, electrochemical sensor, 4 gas portable gas monitor	
Particulates	Haz-Dust 10µm Particulate Monitor, infrared detector (Environmental Devices Corporation)	0.01-9.99mg/m3 (most sensitive range) measures 10µm and smaller particles.

FINDINGS

AIR QUALITY HAS IMPROVED. CHANGES IN THE AIR HANDLING SYSTEMS AND OTHER OPERATIONAL METHODS DID NOT ADVERSELY AFFECT INDOOR AIR QUALITY COMFORT PARAMETERS.

Sampling results taken September 16 to September 22, 1998 indicated that the Wausau West School had inadequate ventilation in several areas of the building. Carbon dioxide levels, in areas where the only known source of carbon dioxide is exhaled breath, were elevated when the spaces were occupied. The carbon dioxide levels ranged between 1000 and 2000 parts per million. Sampling results taken December 8, 1999 in the same areas under similar conditions indicate that the carbon dioxide levels in these areas have improved.

- Carbon dioxide levels ranged between 400 and 1300 parts per million when they were occupied. *Standard/Guideline ASHRAE Standard 62-1989 recommends 1000ppm as the upper limit for comfort(odor)reasons.*
- Other indicators of acceptable air quality and comfort such as temperature and humidity were within acceptable ranges. *Standard/Guideline- no standards exist for general indoor air application Ashrae recommends a relative humidity between 30 and 60 per cent to help control conditions that promote mold growth.*
- Biological substances, environmental mold and fungus were within acceptable limits. A comparison of indoor and outdoor levels of fungal organisms shows indoor mold levels lower than outdoor levels. Biological material including bacteria, virus, fungi, mold spores, pollens, skin flakes and insect parts are ubiquitous in the indoor environments. These particulates range from less than one to several microns in size. Airborne biological materials are usually attached to dust particles. Adequate ventilation, general good housekeeping and maintenance of heating and air conditioning equipment, are important factors to reduce pollutants. *Standard/Guideline- No standards exist for general indoor air applications.*
- Ozone *Standard /Guideline EPA Ambient Air Quality Standard is a maximum 8 hour average outdoor concentration of 0.08 PPM.*
- Nuisance Dust *Standard/Guideline-The EPA Ambient Air Quality standard for particles less than 10 microns in diameter is 150µg/m³ for a 24 hour average.*

Potential problem sources such as ozone generation and general dust were acceptable. However carpeted surfaces in the building can be a source of dust and other particles of irritation. Test results indicate that some of the carpeted areas had a significant increase in airborne particles during moderate activity, such as mass movement of students to their classrooms. Particulate levels did not remain elevated enough to approach any standard or guideline. However, common dust can be a factor in aggravating existing health conditions such as asthma, a major health concern for children and adults.

DISCUSSION

Indoor air quality in schools is an important public health issue. In recent years comparative risk studies performed by the United States Environmental Protection Agency and its science advisory board have ranked indoor air pollution among the top five environmental risks to public health. Children may be especially susceptible to air pollution. Furthermore, failure to manage air quality problems can affect the school in the following ways.

Health:

- Increasing long and short-term health problems such as cough eye irritation, headache asthma episodes.
- Promoting the spread of airborne infectious disease.

Cost of Operation:

- Accelerated deterioration and efficiency of physical plant and equipment.

Educational Problems:

- Producing an unfavorable learning and working environment for students and staff..

Exposure to indoor air pollutants has increased due to construction of tightly sealed buildings, reduced ventilation rates to save energy, the use of synthetic building material and furnishings, personal care products, pesticides and housekeeping supplies. School administrators and other officials are faced with complicated problems to address such issues in an area of tight school budgets.

One type of solution to such problems has been “common sense guidance programs” designed to solve most indoor air problems with minimal cost and involvement. The “Tools for Schools” Program is designed to raise awareness and provide some methods to address indoor air problems. While it is largely a United States Environmental Protection Agency Program, other organizations such as American Federation of Teachers, Association of School Business Officials, Council of American Private Education, National Education Association, National Parent Teachers Association and The American Lung Association endorse it. It can be used with other programs such as the EPA’s Energy Star® program or other facility improvement programs such as the Wisconsin Energy Initiative 2 (WEI-2). A program that is ushering in a new era of energy efficiency and innovative financing for schools and local governments in Wisconsin. The WEI-2 solves the problems of time and money by facilitating energy saving improvements for both existing and new construction projects. With the "paid from savings" approach, financing payments come from the energy savings themselves. Programs of this type look to achieve energy savings while providing good indoor air quality.

Comparison of carbon dioxide concentrations taken by Legend Environmental Services (Sept 98) and Wisconsin Division of Public Health Indoor Air Program (Dec 99)

Room location	Carbon dioxide concentrations	Carbon dioxide concentrations
	Legend Environmental Services	WI Division of Health
	September 98	December 99
348	1380 PPM max	1300 PPM max
	1047 PPM min	700 PPM min
208	1440 PPM max	850 PPM max
	1190 PPM min	350 PPM min
135	2000 PPM max	850 PPM max
	1541 PPM min	400 PPM min

Environmental Monitoring MMHS
 Location Room 166
 Date 12/8/99

Time	Carbon monoxide	Temperature	Humidity	Oxygen	CARBON DIOXIDE	PARTICULATES
						µg/m ³
8:30AM occupied	0	70	35.5	20.1	850	60
12:00PM occupied		71	34		500	
2:50PM unoccupied		72	32.5		400	

Carpeted room
 Room Dimensions 39 ft x 22 x 8

Occupied at 8:30AM
 Unoccupied at 12:00PM
 Unoccupied at 2:50PM

Environmental Monitoring MMHS
 Location Auto Shop
 Date 12/8/99

Time	Carbon monoxide	Temperature	Humidity	Oxygen	CARBON DIOXIDE	PARTICULATES
						μ/m^3
8:35AM occupied	0	68	37	20.2	700	90
11:45AM unoccupied		65	36.7		850	
unoccupied						

Environmental Monitoring MMHS
 Location Commons (Old System)
 Date 12/8/99

Time	Carbon monoxide	Temperature	Humidity	Oxygen	CARBON DIOXIDE	PARTICULATES
						$\mu g/m^3$
8:25AM occupied	0	69	37	20.7	800	30
		68	41	20.3	750	
		68	37	20.1	650	

Environmental Monitoring MMHS
 Location 135
 Date 12/8/99

Time	Carbon monoxide	Temperature	Humidity	Oxygen	CARBON DIOXIDE	PARTICULATES
						ug/m3
8:05AM occupied	0	71	37	20.3	600	150
9:20AM occupied		71	32.7	20.3	850	
12:05PM occupied		71	33	20.3	400	
2:30PM occupied		74	33.6		600	

Environmental Monitoring MMHS
 Location 326
 Date 12/8/99

8:00 AM Hallway carbon dioxide 650PPM small number of people in hallway

9:00 AM Hallway carbon dioxide 1300PPM class exchange

Time	Carbon monoxide	Temperature	Humidity	Oxygen	CARBON DIOXIDE	PARTICULATES
						μ/m3
8:00AM occupied	0	65	36.6	20.4	700	
9:00AM occupied		76	29	20.7	400	
unoccupied						

Environmental Monitoring MMHS
 Location 348
 Date 12/8/99

Time	Carbon monoxide	Temperature	Humidity	Oxygen	CARBON DIOXIDE	PARTICULATES
						$\mu\text{g}/\text{m}^3$
8:01Am occupied	0	71	35.6	20.4	1300	
11.05AM occupied		72	34	20.1	700	
unoccupied						

- Room open to 345
- *Room closed separated by dividers (11:05AM)

Environmental Monitoring MMHS
 Location IMC (Instructional Materials Center)
 Date 12/8/99

Time	Carbon monoxide	Temperature	Humidity	Oxygen	CARBON DIOXIDE	PARTICULATES
						$\mu\text{g}/\text{m}^3$
8:05AM occupied	0	71	30.3	20.4	700	
10:50AM occupied	0	73	30.4	20.2	400	
3:30PM unoccupied		70	31.3	20.2	350	

SURFACE WIPE SAMPLES

Location

Wwhs1 Surfaces **on roof near air handler**

Mold specie	Colony forming units
Alternaria	300
Aureobasidium pullans	900
Cladosporium	500
Phoma	300
Rhodotorula	240000
Yeast	2000

Wwhs2 **Surfaces in ozone treatment room**

Cladosporium	3200 cfu/sample
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Wshs3 **Carpet surfaces of IMC room**

None Detected	<100 cfu/sample
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Wwhs4 **Carpet surfaces West Hallway 2nd floor**

None Detected	<100 cfu/sample
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Wwhs5 **Surface South Hallway ledge 1st floor**

Cladosporium	100
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Wwhs6 **Surface Carpet Room 166 floor**

None Detected	<100 cfu/sample
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Air Samples

Ozone

Sample location

Wwhs1 **ambient air near ozone unit**

At or near limit of detection	< 3ug/sample
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Wwhs2 **ozone mix room**

At or near limit of detection	< 3ug/sample
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Wwhs3 **Supply air side**

	0.014 PPM
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Wwhs4 **field blank**

At or near limit of detection	< 3ug/sample
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BIOAEROSOL SAMPLING

Anderson N6 sampler

Sample location:

Wwhsas1 **Outside roof air handling unit North side of building**

Alternaria	35 cfu/m3
Cladosporium	214 cfu/m3
Phoma	18 cfu/m3
Aspergillus fumigatus	18 cfu/m3

Wwhsas2 **Ozone treatment room 2nd floor mechanical, east treatment room**

None Detected	< 18 cfu/m3
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Wwhsas3 **IMC 3rd floor**

Cladosporium	18 cfu/m3
Phoma	35 cfu/m3
Rhodoturla	18 cfu/m3

Wwhsas4 **West hallway 2nd floor near stairwell**

Alternaria	35 cfu/m3
Yeast	1770 cfu/m3

Wwhsas5 **South hallway by main entrance**

Non sporulating fungi	18 cfu/m3
Penicillium	18 cfu/m3

Wwhsas6 **Room 166**

Epicoccum	18 cfu/m3

Wisconsin Department of Administration

Wisconsin Energy Initiative-2 Program (WEI-2)

Energy Tracking Study of Wausau West High School

INTRODUCTION

Beginning in 1998, the heating, ventilation and air conditioning (HVAC) systems at Wausau West High School in Wausau, Wisconsin underwent renovations in an effort to increase indoor air quality, and decrease energy consumption. Traditionally, improvements in indoor air quality that rely on increased ventilation have come at the expense of energy efficiency. To determine if energy savings can be achieved while improving indoor air quality, two studies were undertaken by the State of Wisconsin. One study focused on measuring indoor air quality parameters, and the other tracked energy consumption. This section of the report will focus on results of energy tracking at Wausau West High.

BACKGROUND

The Wausau School District decided to embark on an HVAC system upgrade at Wausau West High school in the hopes of increasing energy efficiency and mechanical reliability while reducing complaints about comfort, indoor air quality and mechanical noise. The upgrades began in the summer of 1998, and were completed in the summer of 2000. To better understand the changes that took place at Wausau West, a general overview of the old and new systems is provided.

Table 1: General Overview of Changes to the Wausau West HVAC System

Old Systems	New Systems
Air Handling Units (AHU's): Systems used a combination of mechanical cooling and outside air economizers to cool, and steam coils for heat. <u>Classrooms:</u> Constant volume dual duct systems that mixed outside air and return air from the building. <u>Other areas:</u> Mix of single zone constant volume systems and constant volume reheat systems that mixed outside air and return air from the building. <u>Total Horsepower:</u> 600	Air Handling Units (AHU's): Systems use a combination of indirect and direct evaporative cooling, with some mechanical cooling for peak loads. <u>Classrooms:</u> Variable air volume dual duct systems that use 100% outside air with heat recovery / indirect and direct evaporative cooling. <u>Other areas:</u> Variable air volume systems that use 100% outside air with heat recovery / indirect evaporative cooling. <u>Total Horsepower:</u> 300
Heating Plant: Three large steam boilers.	Heating Plant: Seven modular hot water boilers.
Cooling Plant: 678 ton absorption chiller that operates using	Cooling Plant: Primary cooling from indirect and direct

steam from the boilers.	evaporative coolers (coupled to the air handlers), with a 50 ton ice storage chiller for peak cooling loads.
Controls: Primarily used as time-clock controls.	Controls: DDC with occupancy based ventilation control.

Some important dates for the HVAC improvements are as follows. The Absorption Chiller was removed from service in the spring of 1997. This profoundly affected natural gas use at the facility. Work on the building air handling units commenced in the summer of 1998. The upgrades were completed in early summer of 2000 when the ice storage chiller was installed.

METHODS

To track energy consumption at Wausau West, METRIX™¹ utility tracking software produced by SRC systems was used. Wilinski Associates Incorporated², a private engineering firm under contract with the State of Wisconsin’s Wisconsin Energy Initiative 2 program, performed the METRIX™ energy tracking. METRIX™ software statistically correlates past utility use with a variety of weather variables such as heating and cooling degree-days, as well as building use variables such as days of class in a billing period. Based on these correlations, a model of the building's energy use can be created. This model can be used to predict the energy consumption of a building if no significant facility modifications have taken place. The METRIX™ model for Wausau West High School was created using utility data before the summer of 1997 when the absorption air conditioner was still functioning.

PRELIMINARY FINDINGS

ENERGY CONSUMPTION AT WAUSAU WEST HIGH SCHOOL HAS DECREASED SIGNIFICANTLY FROM THE PRE-1997 BUILDING

The Graphs below show how energy use has decreased at Wausau West High School over the past 3 years when compared to the energy use predicted by METRIX™³. In the graphs the “Baseline” energy use, is the energy use predicted by METRIX™⁴, while the “Actual” use is from utility bills at Wausau West.

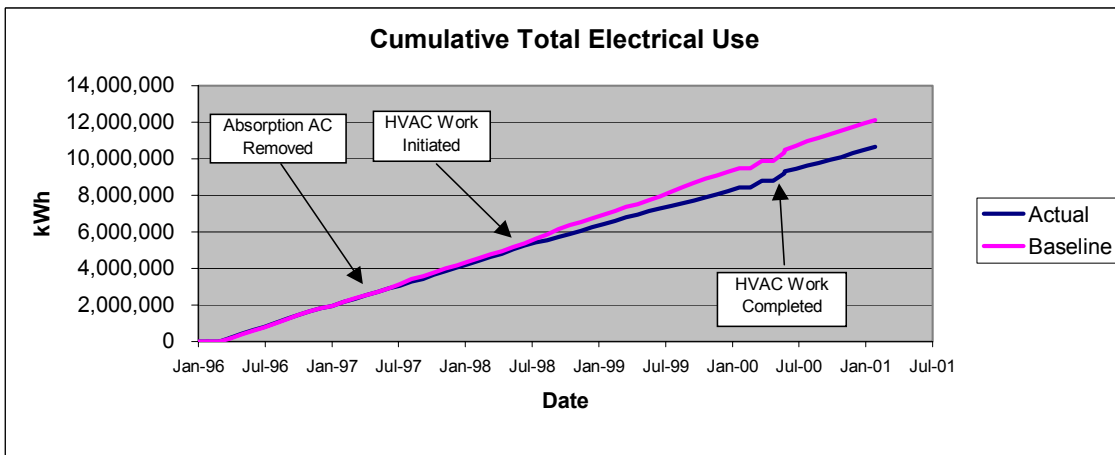
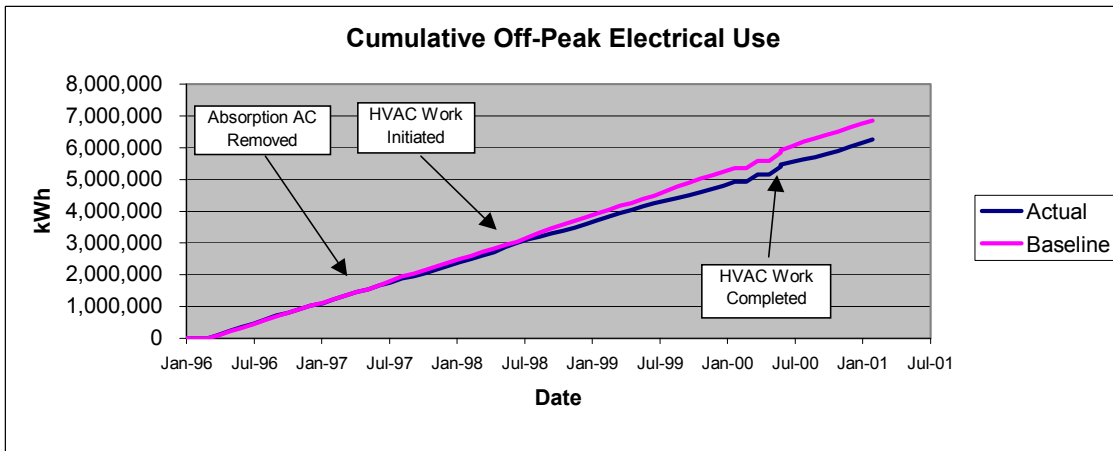
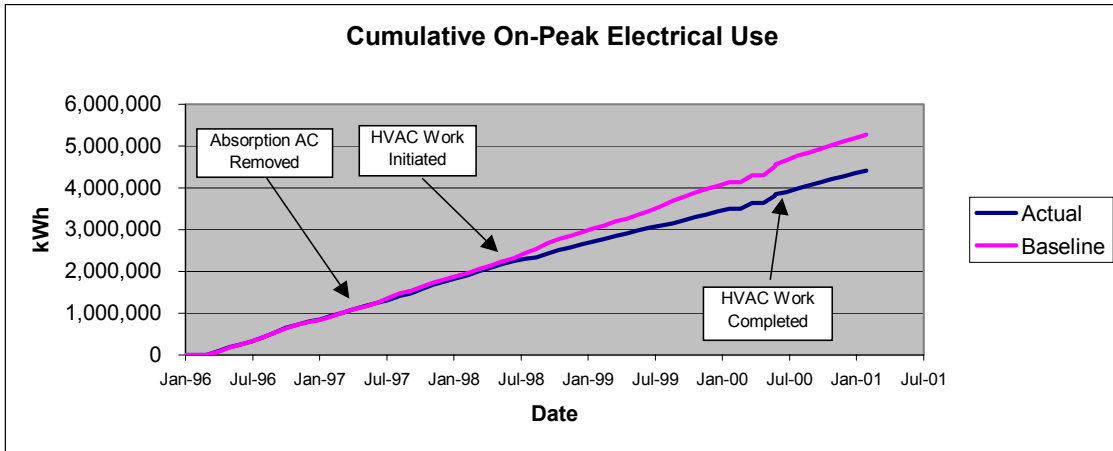
¹ METRIX Version 2.0; SRC Systems Inc., Berkeley, CA 94705

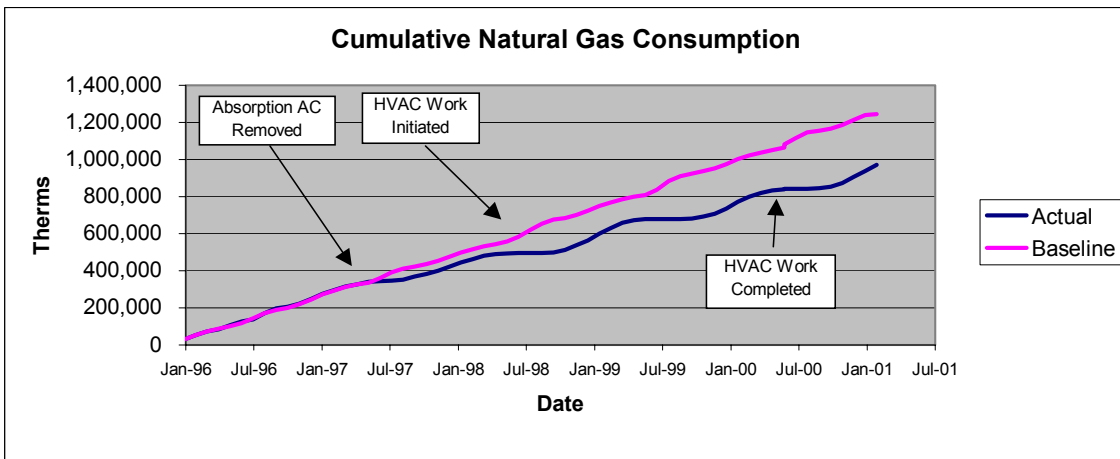
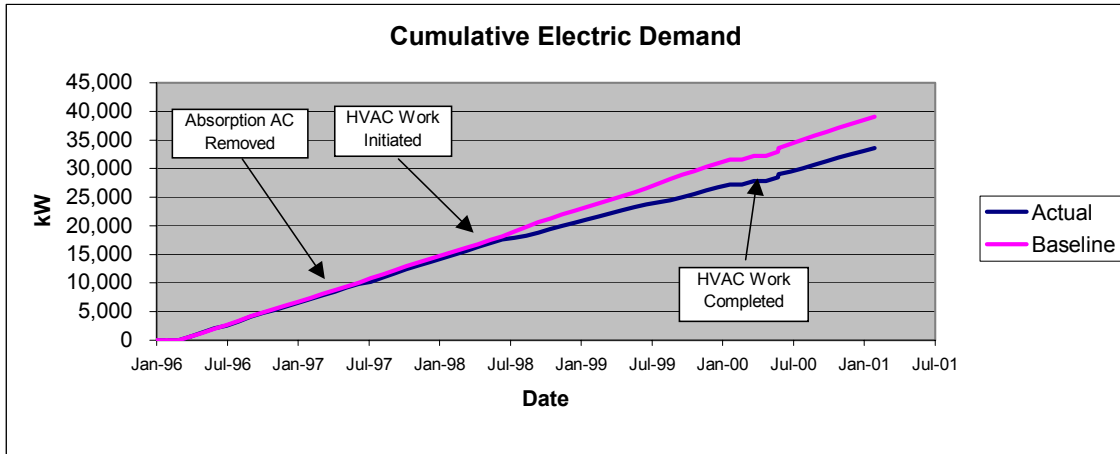
² Wilinski Associates Inc., Wauwatosa, WI

³ METRIX Version 2.0; SRC Systems Inc., Berkeley, CA 94705

⁴ METRIX Version 2.0; SRC Systems Inc., Berkeley, CA 94705

Energy Use at Wausau West High School January, 1996 through February 2001





Energy tracking results indicated that between March of 2000 and February of 2001 total energy use at the Wausau West facility has been reduced by approximately 21% when compared to Energy Use predicted by METRIX. A summary of the actual and predicted use is in the table below:

Table 3: Summary of Actual and Predicted Energy Use At Wausau West High
(March 2000 through February 2001)

	Actual Use	Baseline Use	Savings	% Savings
On Pk kWh	909,895	1,135,128	225,233	19.8%
Off Pk kWh	1,329,305	1,489,256	159,951	10.7%
Total kWh	2,239,200	2,624,384	385,184	14.7%
Demand kW	6,423	7,505	1,082	14.4%
Cust. Dmd kW	7,635	8,306	671	8.1%
Natural Gas (Therms)	171,338	222,411	51,073	23.0%
Totals (Mbtu)	24,776,190	31,198,123	6,421,933	20.6%

Note: Baseline use is based on the pre-summer of 1997 building.

It is important to note that new ice storage chiller was not operational for 3 months of the 12 months summarized in the table above. The inactive months were in the spring, making electric savings somewhat lower than predicted.

In 1998, a survey of energy use data was compiled for approximately 44% of public school buildings in Wisconsin. An interesting comparison between the baseline and actual per square foot energy use of Wausau West with that of other high schools without swimming pools is shown in Table 4.

Table 4: Comparison of Energy Use at Wausau West to Similar Schools

School	Electric Use (kWh/sq.ft./yr)	Fossil Fuel Use (Therms/sq.ft./yr)
Actual Use Wausau West	8.1	0.62
Baseline Use Wausau West	9.5	0.80
Average of HS's With AC	7.2	0.48
Average of HS's Without AC	5.7	0.57

A significant difference in energy consumption between the actual and baseline utility use at Wausau West is evident. The actual electric use for Wausau West is somewhat higher than the average for schools with air conditioning, while fossil fuel use is slightly above the statewide average. The upgrades have brought the energy use at Wausau West down from high levels, close to statewide averages. Since the renovated HVAC systems at Wausau West have not been completed and operating for a full year, it is uncertain whether energy use at the school will remain at average levels.

One item to note is that the 1998 survey data is not corrected for degree-days. Wausau is farther north than a majority of the schools in the state and experiences a greater number of heating degree-days through winter (8,354 versus 7,804 for the population weighted average of the state)⁵, and hence should have higher than state average fossil fuel use.

In conclusion, the retrofit work at Wausau West High School has significantly reduced energy consumption. Energy use at the facility has dropped from high levels, to levels close to state averages. Most of the energy savings have occurred in the summer months, due to the removal of the large absorption air conditioning unit. When comparing the current energy use at Wausau West to previous use, one should realize that the new ice storage chiller was installed in the early summer of 2000. So the facility was not fully air conditioned from 1997 through early summer of 2000. Continuance of energy monitoring will determine actual changes in usage as further upgrades take place.

Special recognition goes out to Patrick Bruckhart for his effort to compile and coordinate this study while working for CESA 10 and the Wisconsin Energy Initiative-2 program.

⁵ *Wisconsin Energy Statistics 1999*, pp126-127, Wisconsin Energy Bureau, Madison Wisconsin

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