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Annual Energy Consumption Analysis Report for Richland Middle School

B. Liu

December 2003

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Report Issued: December 17, 2003

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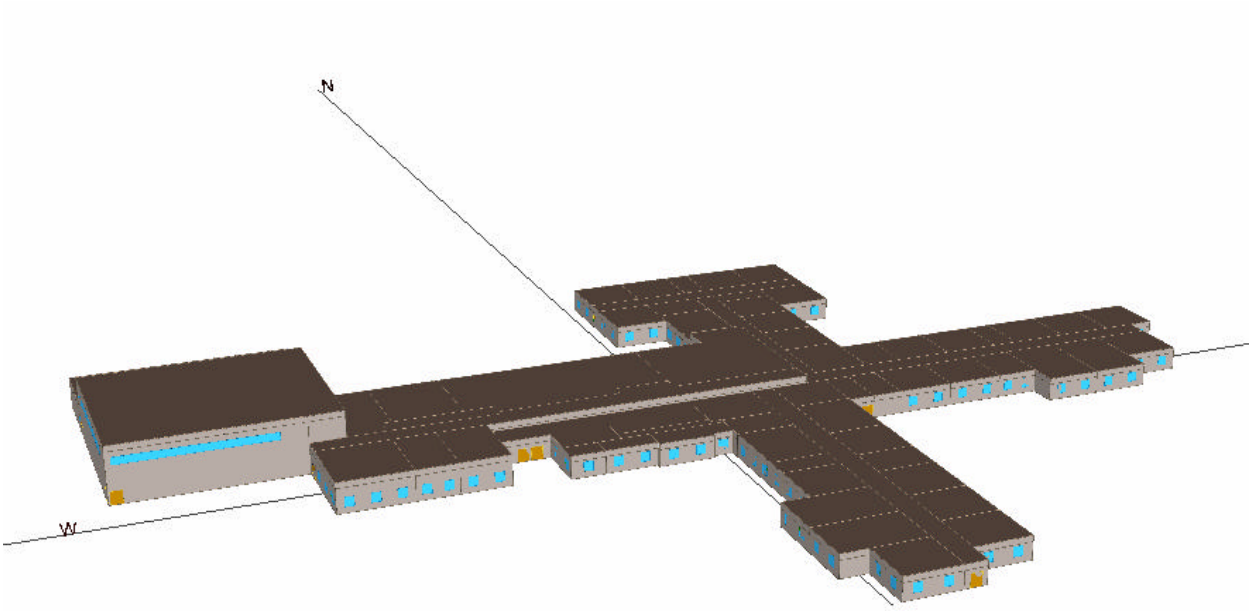


Richland Middle School 3-D Model

Richland Middle School is a single story, 90,000 square feet new school to be located in Richland, WA. The design team proposed four HVAC system options to serve the building. The proposed HVAC systems are listed as following:

- 4-pipe fan coil units served by electrical chiller and gas-fired boilers,
- Ground-source closed water loop heat pumps
- Water loop heat pumps with boiler and cooling tower,
- VAV system served by electrical air-cooled chiller and gas-fired boiler.

This analysis estimates the annual energy consumptions and costs of each system option, in order to provide the design team with a reasonable basis for determining which system is most life-cycle cost effective. eQuest (version 3.37), a computer-based energy simulation program that uses the DOE-2 simulation engine, was used to estimate the annual energy costs.

The eQuest model represents the preliminary building design in accordance with the Nov 20th, 2003 design configuration. The model includes envelope construction, glass sizing and properties, architectural shading, occupancy schedules, lighting power, anticipated plug loads, preliminary HVAC equipment selection, design airflow and domestic hot water.

Assumptions of envelope construction, internal loads and mechanical equipment applied in the energy modeling are listed in Table 1. Table 3 lists the annual energy use and costs predicted by the energy simulation. It was assumed that when the school is closed for summer and winter break, HVAC systems will cycle on to maintain room setup/setback temperature during unoccupied periods.

The following utility tariffs were used for the model:

Electric Utility Rate:	Schedule 10 by Benton Rural Electric Association	
Monthly Charge:	$13.0 plus 0.15 times the highest monthly demand during the past twelve (12) months, over 50 kW.	
Energy Charge:	First 20,000 kWh per month	$0.0648 per kWh
	Over 20,000 kWh per month	$0.0393 per kWh
Demand Charge:	First 50 kW per month – no charge	
	All over 50 kW per month:	
	$0.66 per kW during "off peak" periods	
	$4.41 per kW during "on peak" periods	
Natural Gas Rate:	Cascade Natural Gas	
Monthly Charge:	$7.0	
Energy Charge:	First 50 therms per month	$0.91686 per therm
	Next 450 therms per month	$0.91086 per therm
	Next 3500 therms per month	$0.86276 per therm
	Over 3500 therms per month	$0.82285 per therm

Table 1 Building Modeling Assumptions

Description	Richland Middle School
General	
Location	Richland, WA
Weather file	TMY2\YAKIMAWA.bin
Modeled Floor Area, ft²	87,000
Modeled Volume, ft³	1,351,300
School Season (9-month)	Summer break: second week of June – third week of August Winter break: last two weeks of December
Architectural Features	
Configuration/Shape	
Number of Floors	1
Window to Wall Ratio (WWR)	25%
Floor-to-Ceiling Height	- 9 feet in classrooms, - 13 feet in library/common/music rooms - 27 feet in gymnasium
Floor-to-Floor Height	- 13 feet in typical classrooms - 16 feet in library/common/music rooms - 30 feet in gymnasium
Infiltration Rate	0.35 air change per hour for entire building
Infiltration Schedule	See Table 2 School Operating Schedule
Exterior Walls	
Structure	2x4 steel stud at 16 in. O.C., 8" Split Face CMU exterior finish
Insulation	R-13 cavity insulation with R-3.8 rigid insulation
U-Factor, Btu/hr-ft²-F	U = 0.077
Roof	
Structure	Pre-engineered trusses with plywood deck
Insulation	R-38 batt insulation
U-Factor, Btu/hr-ft²-F	U = 0.026
Slab-On-Grade Floor	
Type	6 in. HW Concrete
Insulation	R-10 24 in. vertical insulation
F-Factor, Btu/hr-ft-F	F = 0.54
Fenestration/Windows	
Structure	Double-pane, low-e, tint (DOE-2 Code: 2636)
U-Value, Btu/hr-ft²-F	U = 0.43
SHGC	SHGC = 0.39 (SC = 0.45)
Window Shading/Overhangs	No
Opaque Doors	
Total U-Factor	U = 0.60

Table 1 Building Modeling Assumptions (continued)

Internal Loads	
Occupancy	250 students
Occupancy density	- 30 ft² /person in classrooms - 100 ft² /person in offices/teachers rooms
Occupancy Schedule	See Table 2 School Operating Schedule
People Load	- 250 Btu/h-person Sensible Heat Gain - 200 Btu/h-person Latent Heat Gain
Lighting	
Peak Lighting Power Density, w/sf	- 1.25 w/sf in classrooms - 1.20 w/sf in offices/teachers rooms - 0.80 w/sf in corridors/entries/restrooms /storages - 1.50 w/sf in kitchen/commons/library - 1.00 w/sf in gymnasium
Lighting Schedule	See Table 2 School Operating Schedule
Office Equipment	
Peak Plug Load, w/sf	- 0.50 w/sf in classrooms - 1.00 w/sf in offices/teachers rooms - 1.50 w/sf in library with computer lab
Equipment Schedule	See Table 2 School Operating Schedule
HVAC System	
System Type	- Option 1: 4-pipe FCU system - Option 2: Ground-source Heat Pump (GSHP) system - Option 3: Water-loop Heat Pump (WLHP) system - Option 4: VAV system
Number of Thermal Zones	71
Space T-stat Set Point	75°F cooling / 70°F heating
Space T-stat Setup/Setback	82° F setup / 64° F setback
Outside Air Flow	- 15 cfm/person in classrooms 20 cfm/person in offices/teachers rooms
Design Supply Air	Minimum 0.5 cfm/sf
Fan Total Static Pressure	- 1.00 in. in 4-pipe FCU system - 1.25 in. in GSHP or WLHP system - 3.00 in. in VAV system
Fan Schedule	See Table 2 School Operating Schedule
Economizer	Only in VAV system
HVAC Equipment Efficiency	- 4-pipe FCU system o Chiller COP = 2.9 (EIR = 0.3413) o Boiler Thermal Efficiency = 80% (HIR = 1.25) - Ground-Source Heat Pump o EER = 13.4 (EIR = 0.2235) o COP = 3.2 (HIR = 0.30) - Water-Loop Heat Pump o EER = 12.0 (EIR = 0.2489) o COP = 3.8 (HIR = 0.2432) - VAV system o Chiller COP = 2.9 (EIR = 0.3413) o Boiler Thermal Efficiency = 80% (HIR = 1.25)

Table 1 Building Modeling Assumptions (continued)

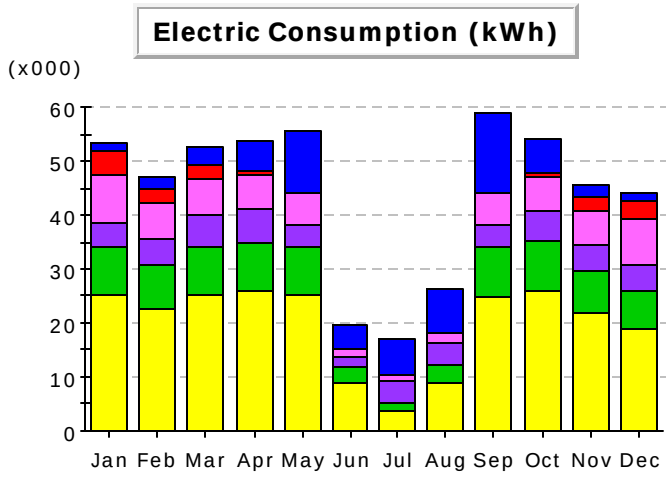
Service Water Heating	
Water Heater Type	- 4-pipe FCU system: gas storage water heater - GSHP system: heat pump water heater - WLHP system: gas storage water heater - VAV system: gas storage water heater
Supply Temperature	120° F
SWH Efficiency	- 80 % thermal efficiency (HIR = 1.25) for gas storage water heater - COP = 2.7 (HIR = 0.37) for heat pump water heater
SWH Schedule	See Table 2 School Operating Schedule

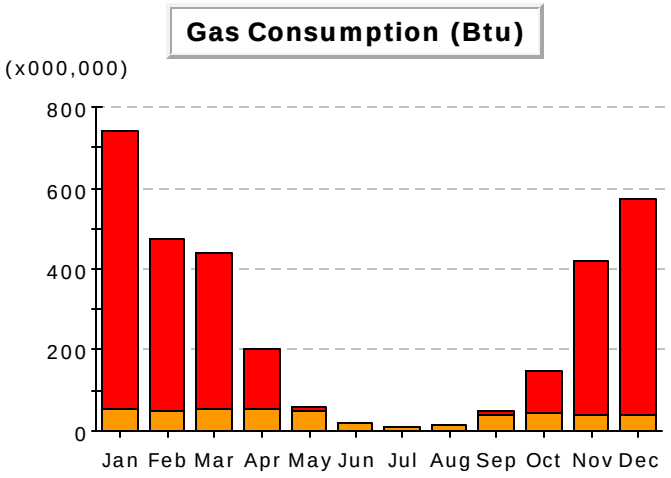
Table 2 School Operating Schedule

	1a	2a	3a	4a	5a	6a	7a	8a	9a	10a	11a	12	1p	2p	3p	4p	5p	6p	7p	8p	9p	10p	11p	12
Occupants																								
Mon - Fri	0	0	0	0	0	0	0	0.1	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.5	0.2	0.1	0.3	0.3	0.3	0.1	0	0
Sat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lighting																								
Mon - Fri	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.3	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.5	0.5	0.7	0.7	0.7	0.3	0.05	0.05
Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Sun	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Receptacle																								
Mon - Fri	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.3	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.5	0.5	0.7	0.7	0.7	0.3	0.05	0.05
Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Sun	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Fans																								
Mon - Fri	Off	Off	Off	Off	Off	Off	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	Off	Off
Sat	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off
Sun	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off
Cooling																								
Mon - Fri	82	82	82	82	82	82	79	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	82	82
Sat	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
Sun	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
Heating																								
Mon - Fri	64	64	64	64	64	64	67	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	64	64
Sat	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64
Sun	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64
Hot Water																								
Mon - Fri	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.5	0.5	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.3	0.5	0.5	0.5	0.3	0.05	0.05	0.05
Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Sun	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05

Table 3 Annual Energy Consumption & Cost – Richland Middle School

	Option 1 4-Pipe FCUs	Option 2 GSHP	Option 3 WLHP	Option 4 VAVs
Annual Energy Consumption				
Electric (kWh)	527,864	996,319	683,419	536,115
Gas (therm)	31,383	0	13,763	42,379
Total Energy (kBtu/yr)	4,939,929	3,400,436	3,708,835	6,067,689
Energy Use Index (kBtu/sf-yr)	**56.7**	**39.1**	**42.6**	**69.7**
Annual Bill				
Electric Cost ($)	33,852	58,838	42,973	34,326
Gas Cost ($)	27,144	0	12,193	36,524
Total Cost ($)	60,996	58,838	55,166	70,850
Unit Energy Cost ($/sf-yr)	**0.70**	**0.68**	**0.63**	**0.81**





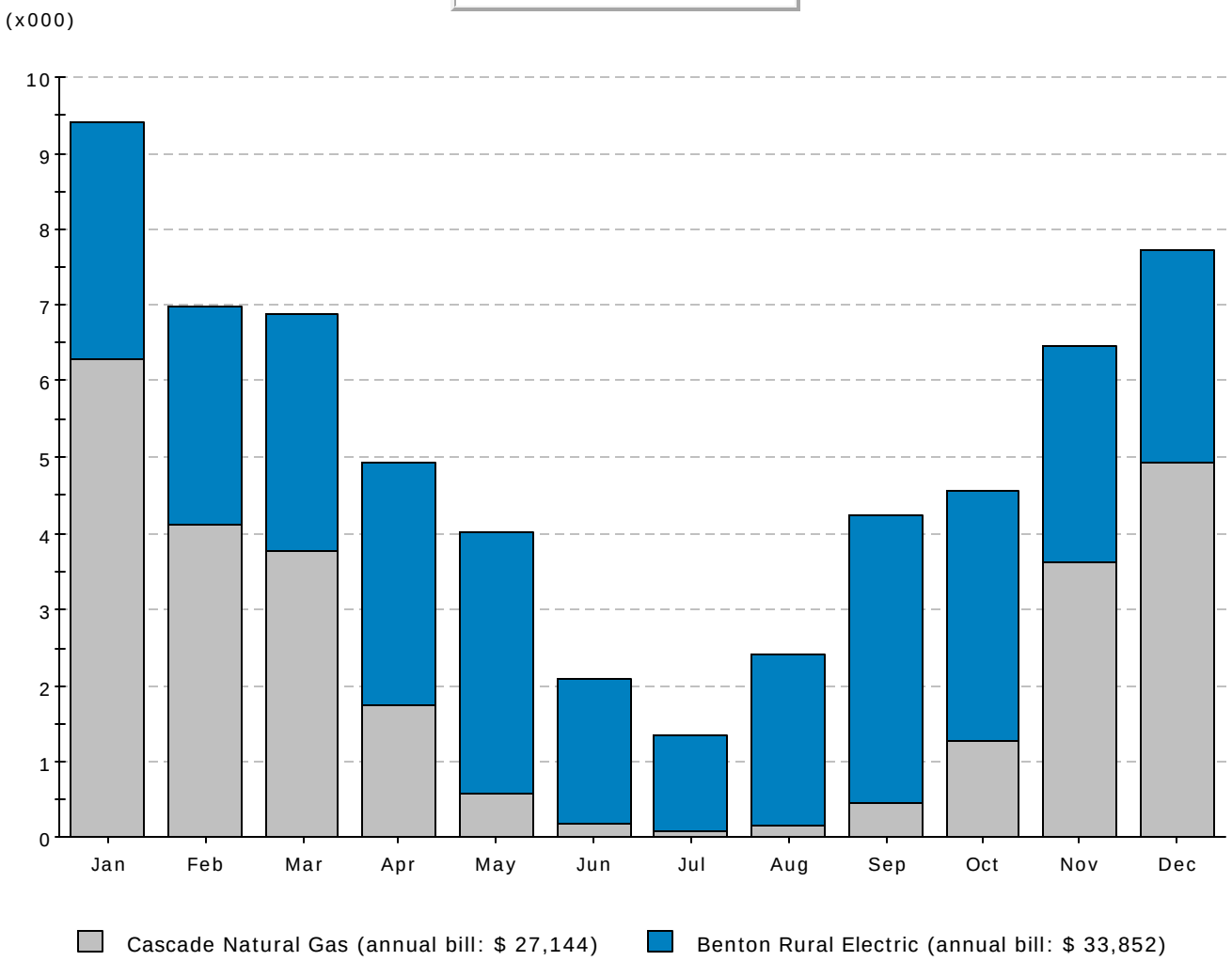
Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	1.49	2.12	3.30	5.22	11.43	4.24	6.67	7.86	14.47	6.50	2.55	1.67	67.52
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	4.35	2.74	2.44	0.93	0.07	-	-	-	0.06	0.66	2.42	3.44	17.11
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	8.86	6.65	6.79	6.26	5.80	1.43	1.20	1.93	5.80	6.22	6.13	8.59	65.68
Pumps & Aux.	4.74	4.91	6.18	6.07	4.45	1.90	4.07	4.22	4.66	5.63	5.08	4.94	56.85
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	8.97	8.12	8.97	9.29	8.97	3.13	1.36	3.17	8.93	9.34	7.84	6.80	84.89
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	24.93	22.55	24.93	25.82	24.93	8.68	3.77	8.81	24.81	25.94	21.78	18.88	235.82
Total	53.35	47.09	52.61	53.58	55.65	19.37	17.07	26.00	58.74	54.28	45.80	44.33	527.86

Gas Consumption (Btu x000,000)

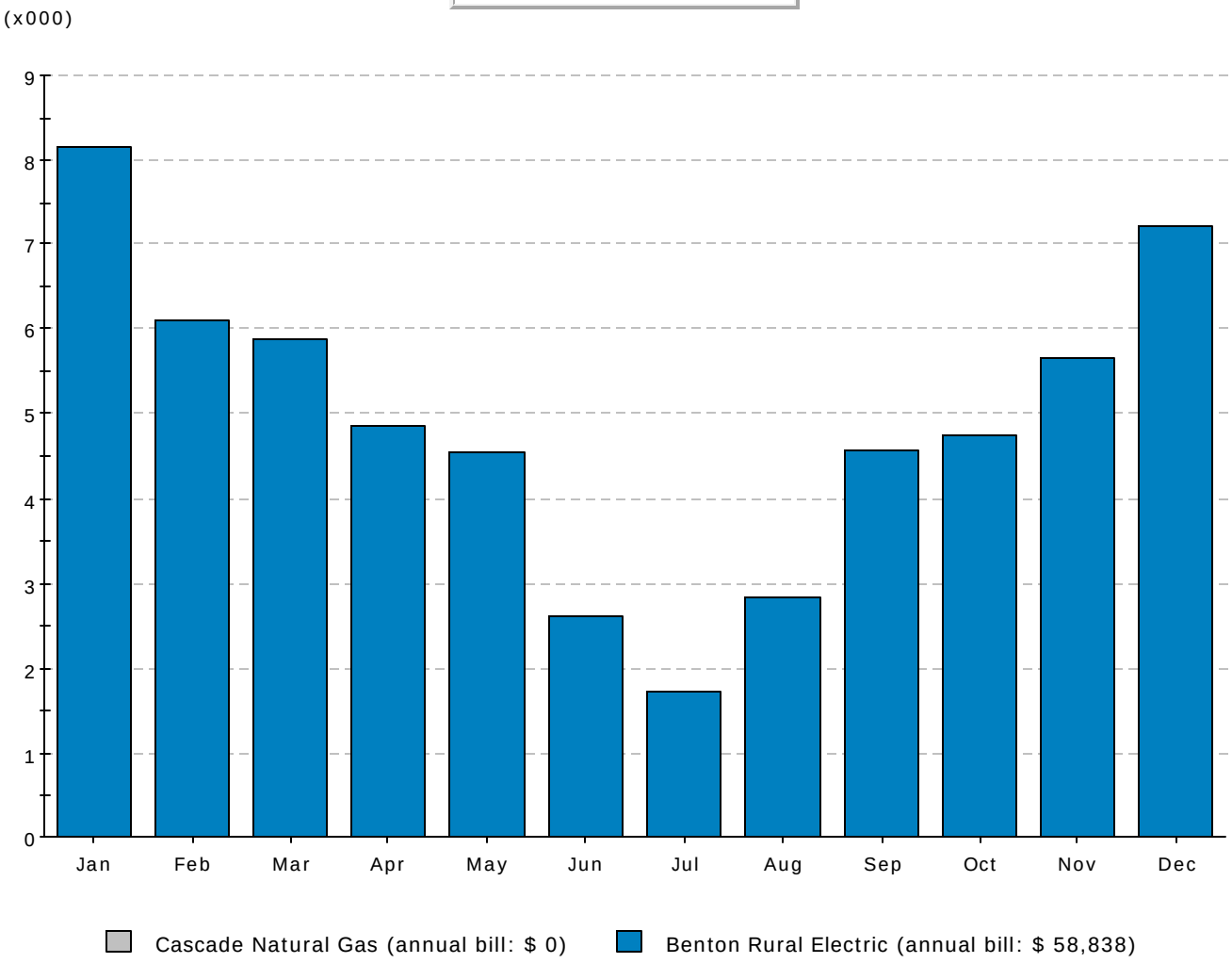
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	685.4	425.8	379.2	143.9	11.2	-	-	-	9.5	102.2	376.9	535.7	2,669.9
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	53.5	50.3	55.8	56.3	50.1	17.6	8.4	15.5	39.3	43.2	40.0	38.5	468.4
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	738.9	476.1	435.0	200.2	61.3	17.6	8.4	15.5	48.8	145.4	416.9	574.1	3,138.3

Monthly Utility Bills ($)



Total Annual Bill Across All Rates: $ 60,996

Monthly Utility Bills ($)



Total Annual Bill Across All Rates: $ 58,838