

Overview of Energy Consumption and Conservation on Campus

Respectfully submitted to:
Buildings & Grounds Committee

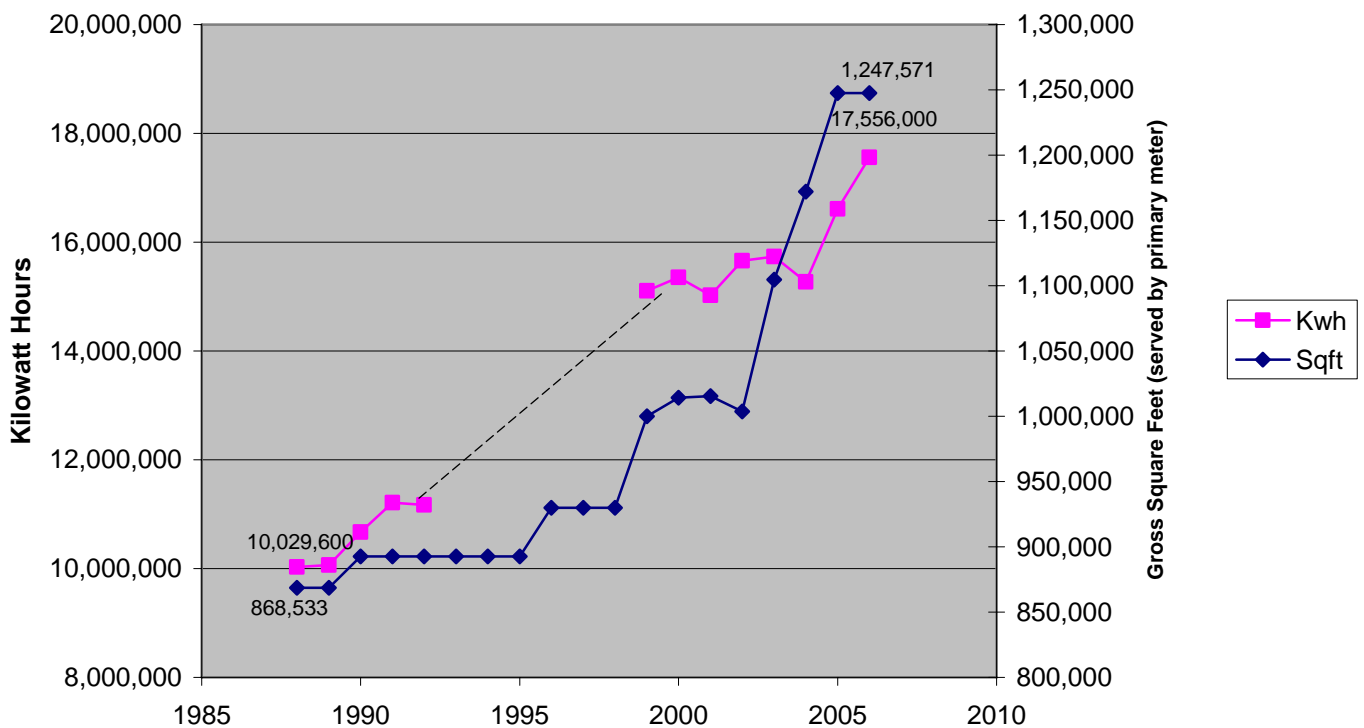
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This overview addresses trends of energy consumption by College buildings and lists energy conservation measures taken since 1995:

● *Electricity*

Figure 1. shows the relationship between the increase in electricity consumption over the last two decades and the increase in building square footage over that same time period. The power consumption data is from the primary electric meter supplying power to all “core” campus buildings. This accounts for approximately 90% of the total consumption from buildings owned by Grinnell College. Electricity data is lacking from 1993 to 1998, so a linear extrapolation is shown (dashed line).

Figure 1. Gross Square Footage and Kilowatt Hours



Since 1986, building square footage has increased by 44% while electricity consumption has increased by 75%. An appropriate measure of efficiency is electricity consumption per square foot of building space. Obviously, total energy consumption will increase with substantial increases in square footage. However, the trend data indicates that the types of buildings (Noyce Phase I and Bucksbaum) built in the 1990’s consume more energy per square foot than those built prior to or afterwards.

Figures 2 and 3 show electricity usage per square foot since 1986 and since 1999, respectively. For each year, the data has been adjusted for annual climate variations by applying a percentage difference from average heating and cooling seasons. From 1988 until 2002, the campus experienced a 35% increase in energy consumption per square foot. In 1988, the electricity usage per square foot was 11.5 kWh/sqft. This ratio increased steadily until 2002 when it reached 15.60 kWh/sqft. This increase can be attributed to several characteristics common to most of the newly constructed buildings, including:

- 1) higher ventilation rates, as dictated by building function and evolving building codes,
- 2) increased interior light levels and light-fixture densities,
- 3) increased exterior light levels and light-fixture densities and
- 4) increased temporary heating and cooling energy during the construction process.

In addition, with virtually all new buildings receiving air conditioning, the percentage of air conditioned building space has increased 10% over the last 18 years to 80%. In spite of these increases in ventilation and lighting demands, the trend has reversed itself with a 2006 ratio of 14.07 kWh/sqft. This is largely due to a plethora of energy conservation measures which have been implemented in both new construction and renovation/retrofit projects. A list of conservation measures is included in Appendix 1. A recent review by Sightlines shows that overall electrical usage is in-line with peer institutions and below their database average. See Appendix 2 for the FY 2006 Sightlines Energy Comparison. Electricity costs have been historically low in the south-central region of Iowa served by Alliant Energy. Grinnell's costs will align with the rest of the state as Alliant is mandated to "level" rates within their territory. Electricity unit costs for Grinnell are well below peer institutions and their database average, per Sightlines.

Figure 2. Climate Adjusted Kilowatt Hours Per Square Foot (Main Meter)

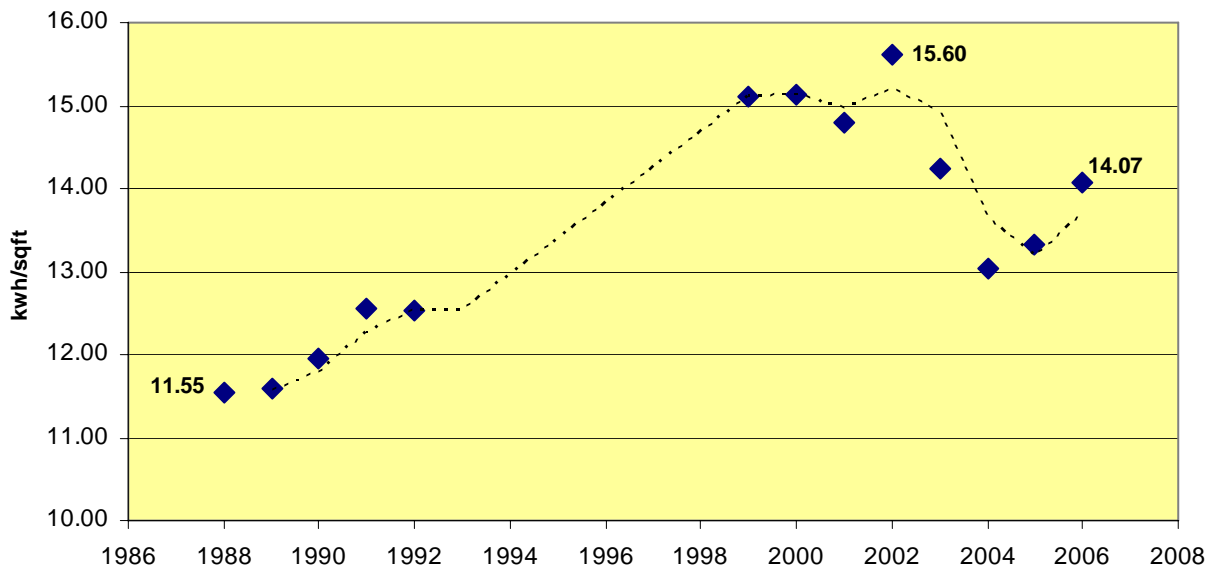
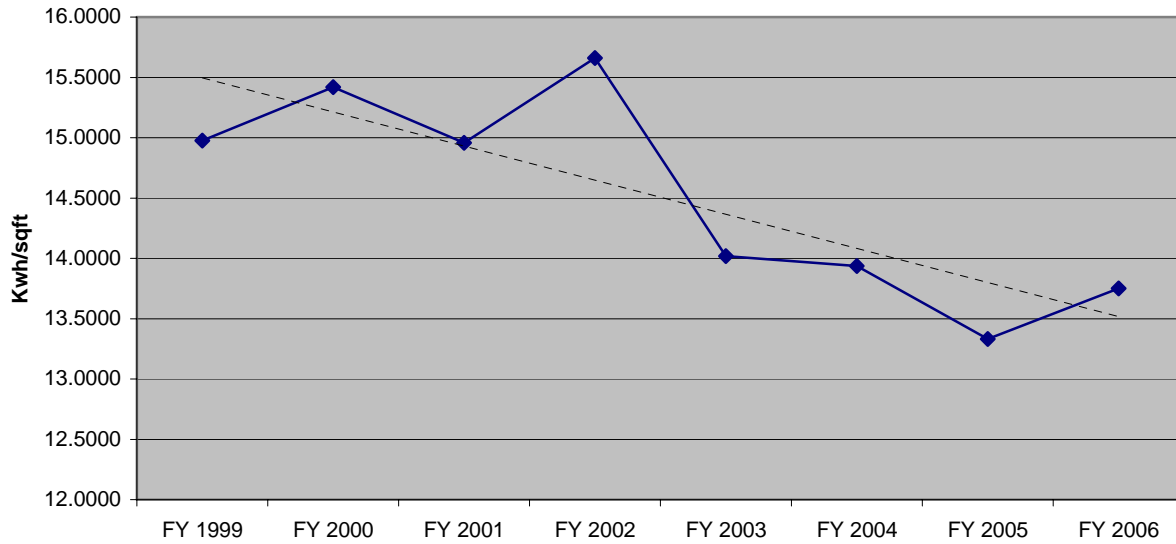


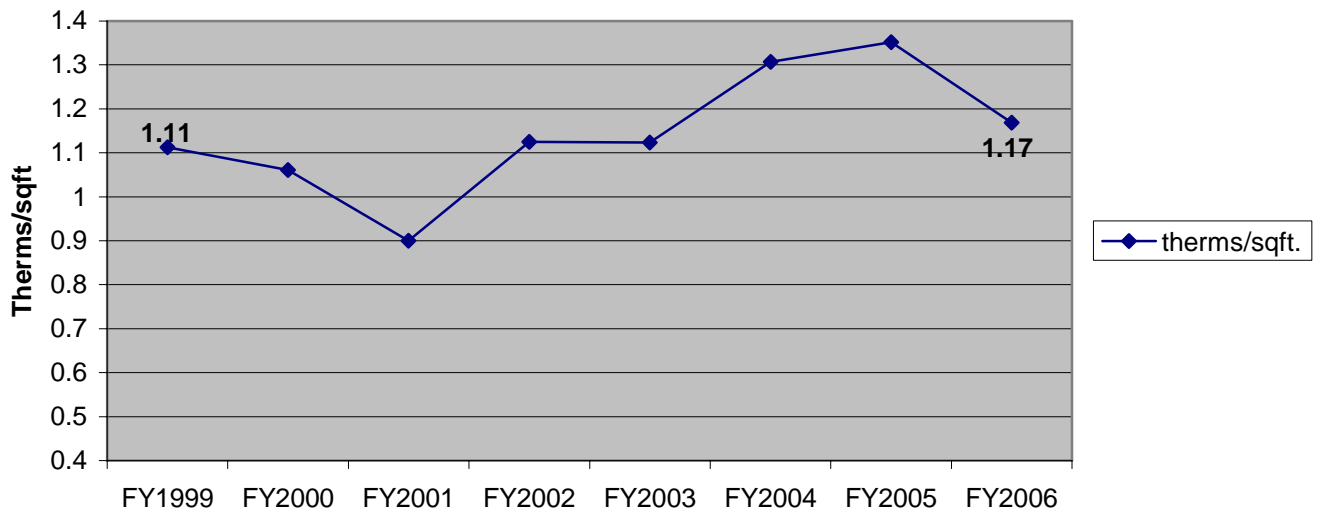
Figure 3. Climate Adjusted kwh/sqft (1999-2006)



● *Natural Gas*

There is less data available for analysis of historic natural gas usage. Figure 4 includes natural gas consumption by the heating plant for the last seven years. Although usage fluctuates, consumption in 2006 was only five percent greater than in 1999. The drop in 2001 was due to a switch from natural gas to diesel as the fuel used by the heating plant during January and February. A recent review by Sightlines shows that overall natural gas usage is in-line with peer institutions and below their database average. See Appendix 2 for the FY 2006 Sightlines Energy Comparison. Natural gas has experienced volatile swings in unit cost in recent history, making it difficult to estimate projections and budgets.

Figure 4. Climate Adjusted Therms (Natural Gas) per Square Foot



● *Conservation Measures*

Many conservation measures have been taken at Grinnell College over the last two decades. These measures have focused on:

- 1) Heat recovery
- 2) Lighting efficiency and control
- 3) Reflective Energy Star™ roofs
- 4) Heating and cooling plant improvements
- 5) Direct digital temperature control

Appendix 1 is a detailed list and description of measures. Facilities Management has an informal process of continually looking for ways to implement new conservation technologies, and budget for them annually. Recent conservation efforts have focused on new construction due to the unprecedented growth. As this growth tapers, efforts will be refocused on existing buildings. The measures described are the result of this continual investigation.

**Appendix 1. Timeline of energy-efficiency measures
at Grinnell College**

Appendix 1. Timeline of energy-efficiency measures at Grinnell College

<u>Year</u>	<u>Building</u>	<u>Project</u>	<u>Technology</u>
<1995	Various	lighting retrofits	Upgraded from T-12 to T-8 lamps and ballasts (electronic) for existing fluorescent fixtures
1995	Goodnow	renovation project	air-to-air heat exchangers (exhaust/intake)
1995	Rawson-Gates	renovation project	replace incandescent and older fluorescent light fixtures with compact fluorescent and T-8 fluorescent fixtures
1996	Darby	lighting project	replaced dual mercury vapor light fixtures with single metal-halide fixtures in gym, cutting fixture wattage in half
1996	Chiller Plant	new construction	two centrifugal chillers and underground chilled water distribution serving Science and eventually Fine Arts, Goodnow, Forum, Burling, Steiner, Herrick, Carnegie and ARH (replacing inefficient air-cooled chillers and direct-expansion A/C)
1996	Science	addition/renovation	variable-air-volume fume hood & exhaust system (Phoenix Controls)
			variable-frequency drives (VFD's) on air handler fans
			T-8 fluorescent light fixtures
1996	Loose	renovation project	replace incandescent and older fluorescent light fixtures with compact fluorescent and T-8 fluorescent fixtures
1997	Dibble	renovation project	replace incandescent and older fluorescent light fixtures with compact fluorescent and T-8 fluorescent fixtures
1998	Fine Arts	addition/renovation	energy-efficient windows
			direct-digital temperature control (DDC)
			variable-frequency drives (VFD's) on air handler fans & chilled-water pumps
			T-8 and compact-fluorescent light fixtures
1998	Cowles	renovation project	replace incandescent and older fluorescent light fixtures with compact fluorescent and T-8 fluorescent fixtures
1999	PEC	lighting project	replaced grid of older fluorescent fixtures above pool with metal-halide side-aimed fixtures, less wattage and higher light levels
1999	Burling	mechanical project	removed air-cooled chiller and tied building to higher-efficiency central chilled-water plant
1999	James	renovation project	replace incandescent and older fluorescent light fixtures with compact fluorescent and T-8 fluorescent fixtures
2000	Glove Factory	renovation project	energy-efficient windows
			reflective, energy-star roofing

			direct-digital temperature control (DDC)
			variable-frequency drives (VFD's) on air handler fans
2000	Haines	renovation project	replace incandescent and older fluorescent light fixtures with compact fluorescent and T-8 fluorescent fixtures
2000	Cleveland	control project	upgraded domestic water heating system to DDC control (formerly thermostatic control)
2000	Loose	control project	upgraded domestic water heating system to DDC control (formerly thermostatic control)
2001	Yunker	renovation project	replace incandescent and older fluorescent light fixtures with compact fluorescent and T-8 fluorescent fixtures
2001	Yunker	control project	upgraded domestic water heating system to DDC control (formerly thermostatic control); better insulated storage tanks
2001	Dibble	control project	upgraded domestic water heating system to DDC control (formerly thermostatic control); better insulated storage tanks
2001	ARH	mechanical project	removed air-cooled chiller and tied building to higher-efficiency central chilled-water plant
2001	Carnegie	mechanical project	removed air-cooled chiller and tied building to higher-efficiency central chilled-water plant
2002	Clark	renovation project	replace incandescent and older fluorescent light fixtures with compact fluorescent and T-8 fluorescent fixtures
2002	Harris	mechanical project	removed air-cooled chiller and tied building to higher-efficiency central chilled-water plant
2002	Cowles/Norris	mechanical project	removed air-cooled chiller and tied building to higher-efficiency central chilled-water plant
2003	ARH	control project	upgraded temperature control to DDC (formerly pneumatic)
2003	Chrystal Center	new construction	heat-recovery module on air handler (heat from exhaust transferred to intake air)
			energy-star TPO white membrane (reflective) roof
			direct-digital temperature control (DDC)
			variable-frequency drives (VFD's) on air handler fans & chilled-water pumps
2003	Energy Center	new construction	4-pass fire-tube boilers (more efficient than 3-pass models)
			advanced boiler combustion management system utilizing continuous exhaust gas analysis
			new steam and chilled-water underground distribution with improved insulation jacketing
			two new high-efficiency centrifugal chillers, one with VFD technology
			VFD's (and associated controls) installed on chilled water pumps throughout campus
2003	Steiner/Herrick	mechanical project	removed air-cooled chiller and tied building to higher-efficiency central chilled-water plant

2003	East Dorms	new construction	submitted for LEED certification, base level
			direct-digital temperature control (DDC) of fan-coil units with "open window" sensors to shut off heating/cooling
			energy-efficient windows
			compact fluorescent and T-8 light fixtures
			energy-star TPO white membrane (reflective) roof
			direct-digital temperature control (DDC)
			variable-frequency drives (VFD's) on air handler fans & chilled-water pumps
2003	Main	renovation project	replace incandescent and older fluorescent light fixtures with compact fluorescent and T-8 fluorescent fixtures
2003	Forum	roof replacement	Replaced roof with energy-star TPO white membrane (reflective)
2004	Norris	renovation project	replace incandescent and older fluorescent light fixtures with compact fluorescent and T-8 fluorescent fixtures
2004	Norris	roof replacement	Replaced roof with energy-star TPO white membrane (reflective)
2004	Chrystal Center	control project	DDC control (scheduling) of interior lighting
2004	Science	control project	DDC control (scheduling) of interior lighting
2004	Fine Arts	control project	DDC control (scheduling) of interior lighting
2004	Mears	renovation project	T-5 dimming fluorescent light fixtures in classrooms
2005	Athletics Ph I	new construction	DDC control (scheduling) of all lighting and daylighting control in fitness center, south and west lobby, motion sensor lighting control in various locations
			energy-star TPO white membrane (reflective) roof
			variable-frequency drives (VFD's) on air handler fans & chilled-water pumps
			heat-recovery module on three air handlers (heat from exhaust transferred to intake air)
			compact fluorescent and T-5 and T-8 light fixtures
			energy-efficient windows
			demand-based ventilation strategy using carbon-dioxide monitoring to limit air exchange rate (conditioning of outside air)
2005	CERA	new construction	certified LEED building, gold level

			geothermal heat-pump heating/cooling
			motion sensors for all lighting
			T-5 fluorescent light fixtures
			demand-based ventilation strategy using carbon-dioxide monitoring to limit air exchange rate (conditioning of outside air)
2005	Langan	renovation project	direct-digital temperature control (DDC) of fin-tube with "open window" sensors to shut off heating
			replace incandescent and older fluorescent light fixtures with compact fluorescent and T-8 fluorescent fixtures
2005	Boiler Plant	mechanical project	reverse-osmosis (RO) water filtration system installed for make-up water to boilers which increases cycles-of-concentration, saving fuel, water & chemicals
2005	Glove Factory	lighting project	upgraded lighting in open-plan office areas from indirect metal-halide to direct/indirect T-8 fluorescent
2005	Campus Buildings	preventive maintenance	initiated steam-trap inspection and maintenance program using ultrasonic technology to minimize wasted steam energy (ongoing)
2006	Cleveland	renovation project	direct-digital temperature control (DDC) of fin-tube with "open window" sensors to shut off heating
			replace incandescent and older fluorescent light fixtures with compact fluorescent and T-8 fluorescent fixtures
2006	Chrystal Center	control project	motion sensors for basement lighting
2006	East Dorms	control project	motion sensors for lighting in mechanical rooms and interconnecting tunnels
2006	Rosenfield Center	new construction	to be submitted for LEED certification, base level
			waste heat from refrigeration equipment recovered to pre-heat intake air and domestic hot water
			variable air volume cooking hood system which modulates air flow by temperature/particulate detected inside hoods
			DDC control (scheduling) of most lighting and daylighting control in 3rd floor office suite and "open" dining areas; motion sensor lighting control in various locations
			energy-star TPO white membrane (reflective) roof
			variable-frequency drives (VFD's) on air handler fans & chilled-water pumps
			heat-recovery module on air handler (heat from exhaust transferred to intake air)
			compact fluorescent and T-5 and T-8 light fixtures
			energy-efficient windows
			demand-based ventilation strategy using carbon-dioxide monitoring to limit air exchange rate (conditioning of outside air)

2006	Chiller Plant	mechanical project	installed efficient centrifugal chiller with VFD for Science Ph II cooling load
2006	CERA	lighting project	installed stand-alone solar (PV) lighting system for parking area
2006	Office Houses	control project	installed remote-programmable thermostats for tight setpoint control and setback capability
2006	Campus Buildings	control project/policy	where building automation enables, heating temperature setpoints lowered from 72 to 68 degf and cooling raised from 72 to 76 degf; installed temperature policy signage at "manual" thermostats
2007	CERA	energy project	installed 50kW wind turbine to offset nearly all (93% projected, 110,000 kWh) of new facility's energy needs
2007	Science Ph II	addition/renovation	to be submitted for LEED certification, silver level
			heat-recovery system on air handlers (heat from exhaust transferred to intake air)
			variable-air-volume fume hood & exhaust system (Phoenix Controls)
			partial DDC control (scheduling) of lighting and motion sensor lighting control in various locations
			energy-star TPO white membrane (reflective) roof
			variable-frequency drives (VFD's) on air handler fans & chilled-water pumps
			compact fluorescent, T-5 and T-8 light fixtures
			energy-efficient windows
			demand-based ventilation strategy using carbon-dioxide monitoring to limit air exchange rate (conditioning of outside air)
			motion sensors for fume hoods (decreases air flow when nobody is near)

Appendix 2. Sightlines Additional Energy Comparisons

Sightlines

Additional Energy Comparisons



GRINNELL COLLEGE

December 15, 2006



Comparison Institutions

Institution

Carleton College

Drake University

Hamline University

Iowa State University*

Macalester College

University of Evansville

University of Saint Thomas

Valparaiso University

Location

Northfield, MN

Des Moines, IA

St. Paul, MN

Ames, IA

St. Paul, MN

Evansville, IN

St. Paul, MN

Valparaiso, IN

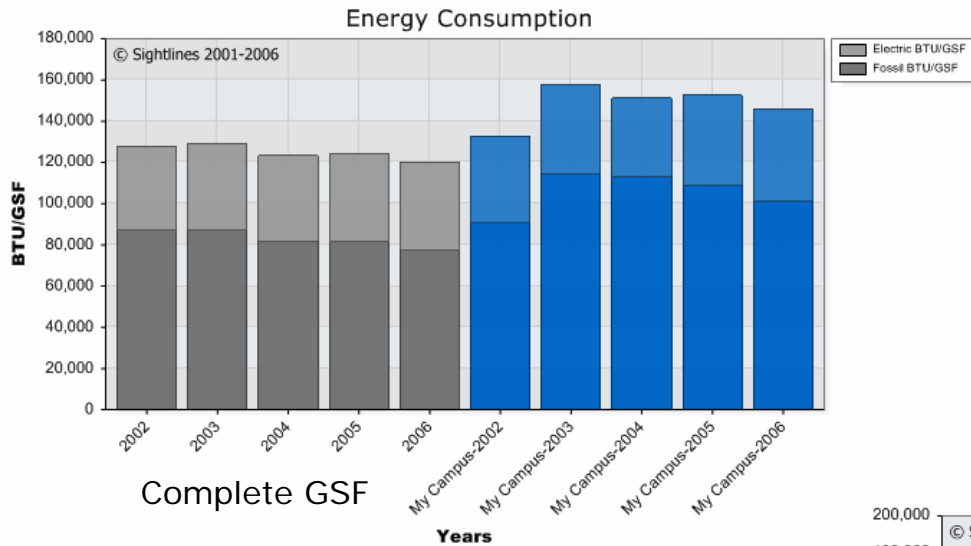


*Iowa State University is only included for consumption graphs. Since they use cogeneration, their unit costs are inconsistent with others in this peer group.

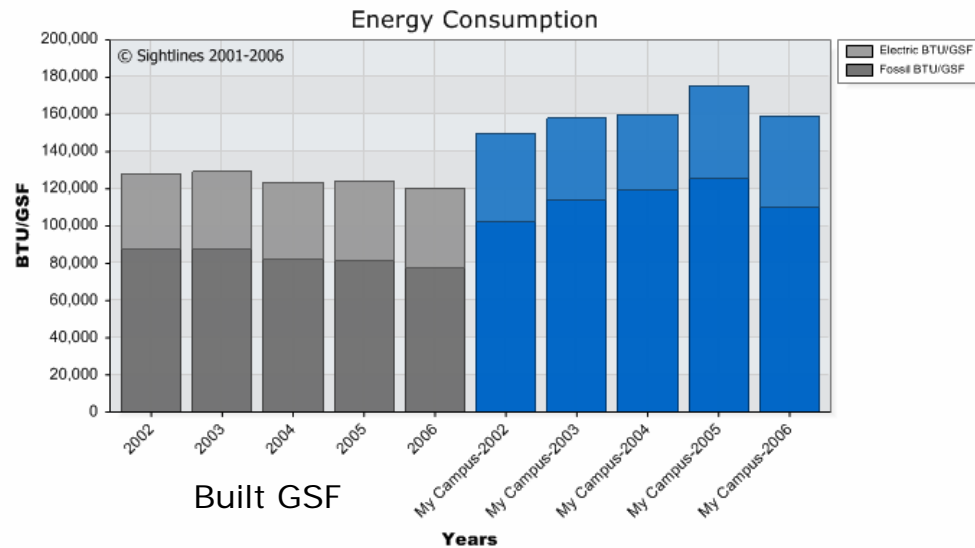


Energy Consumption

Sightlines Database Average: 158,883 BTU/GSF

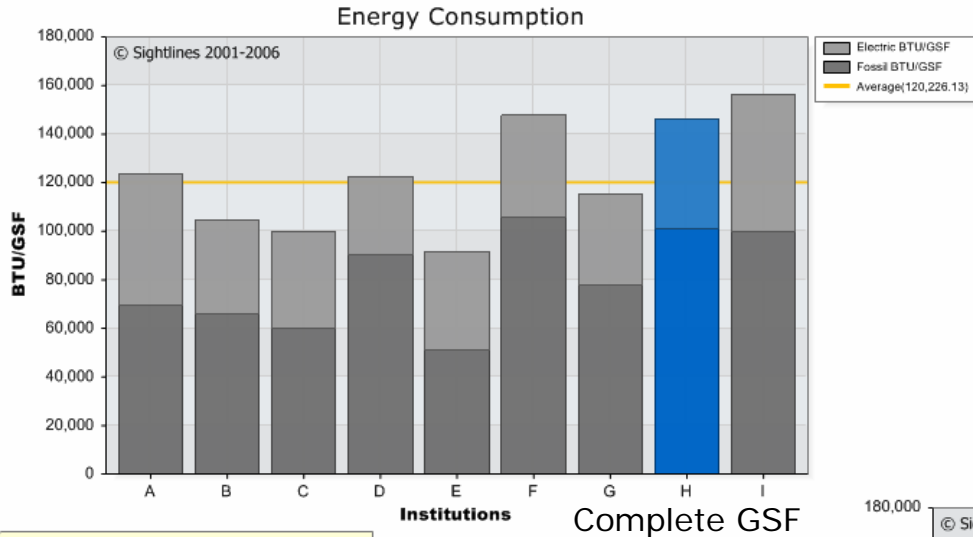


Grinnell's recent construction makes year-to-year benchmarking difficult. Since energy needs for a building under construction are vastly different from one that is complete, consumption graphs are provided for both complete (built and construction) GSF and built GSF. The truth is somewhere in between.



Energy Consumption

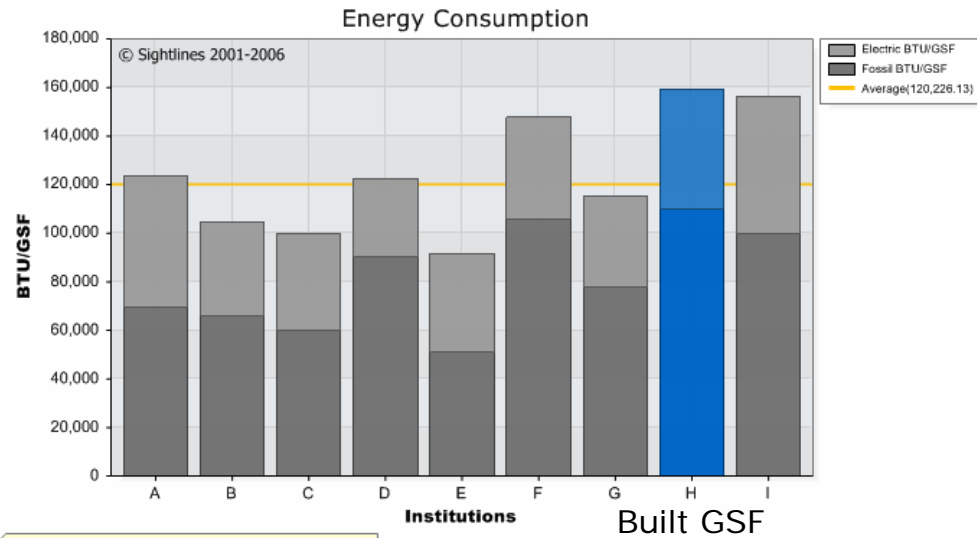
Sightlines Database Average: 158,883 BTU/GSF



Institutions shown in order of increasing TechRating

- Consumption is in line with overall Sightlines database average.
- Facilities Management has taken a variety of steps to reduce consumption on campus, and is doing an admirable job as campus needs vastly increase.

- Grinnell is incredibly technically complex for a small college; one of the most complex in the Sightlines database. Increased air conditioning and air handling needs raise consumption while providing superior service to campus users. Many of the newly constructed buildings are extraordinarily complex yet efficient, producing contradictory effects on energy consumption.

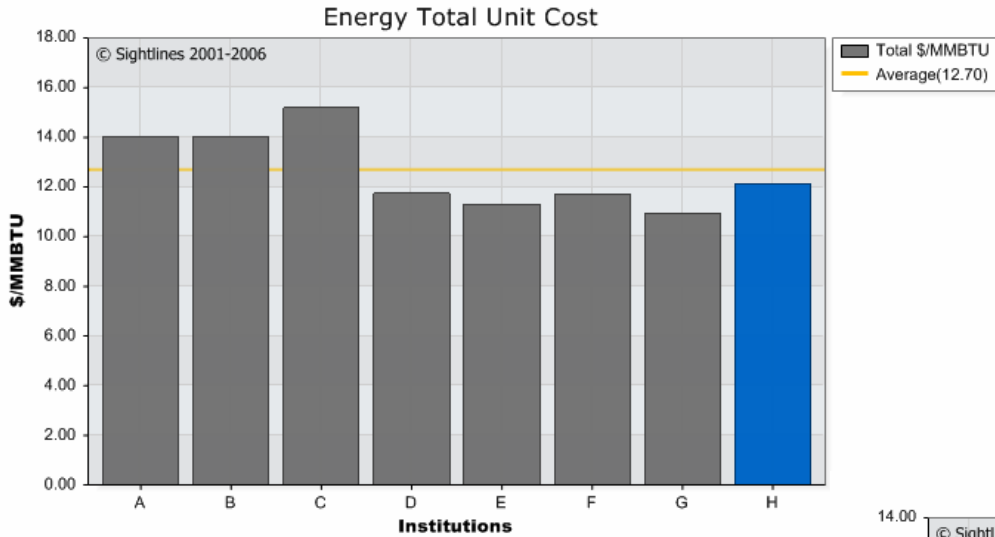


Institutions shown in order of increasing TechRating

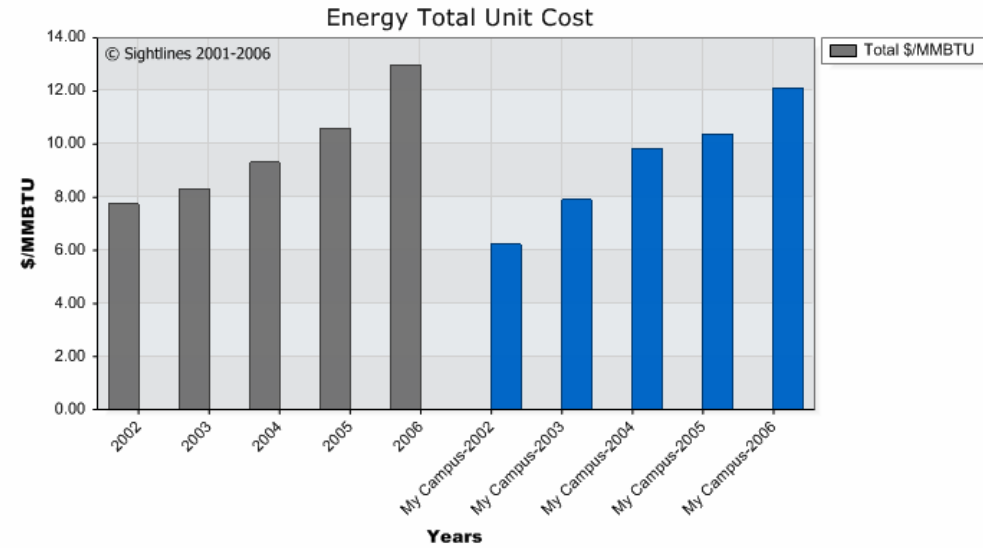


Rising Energy Costs

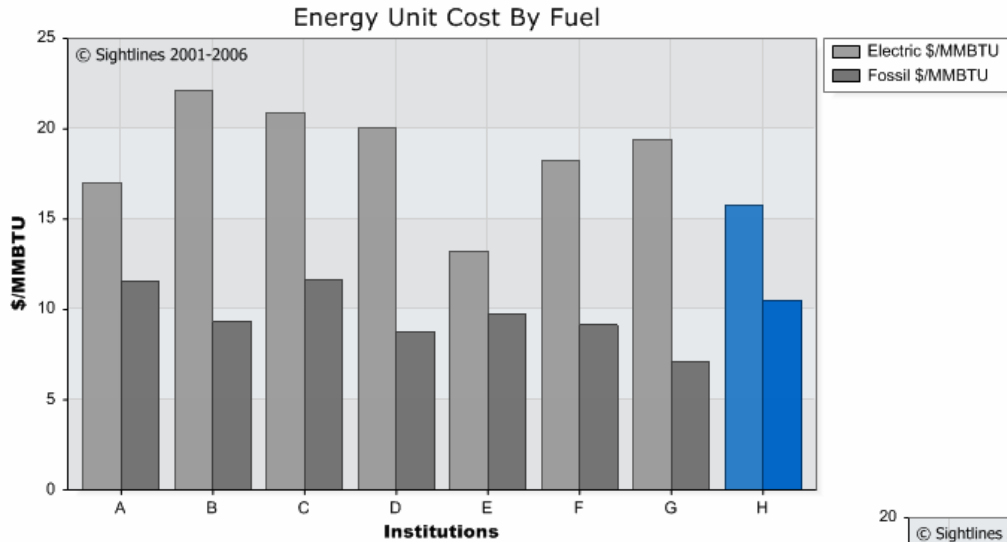
Sightlines Database Average: \$15.52/MMBTU



Institutions shown in order of increasing TechRating



Standard Split Between Fuel Unit Costs



Institutions shown in order of increasing TechRating

