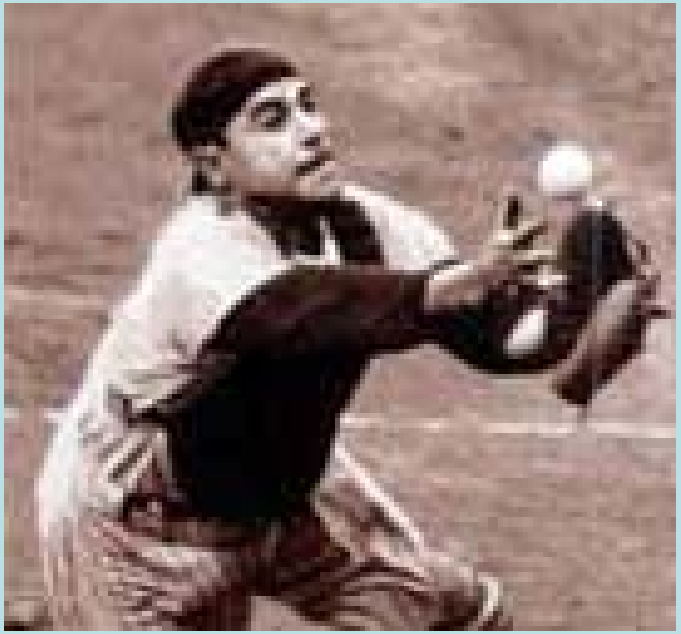
The Craft of Energy Auditing Illustrated: The Boulder Pottery Lab

Larry Kinney, Synertech Systems Corporation

Previews of coming attractions

- Fast look at a beautiful building
- Energy 102 applied to the pottery's windows and other energy systems
- Results of computer modeling of potential energy retrofit options
- How energy and demand rates affect options for limiting energy waste and saving money
- Discussion of how and where to accomplish recommended measures
- Feedback and further discussion

Sometimes you can see a lot just by looking

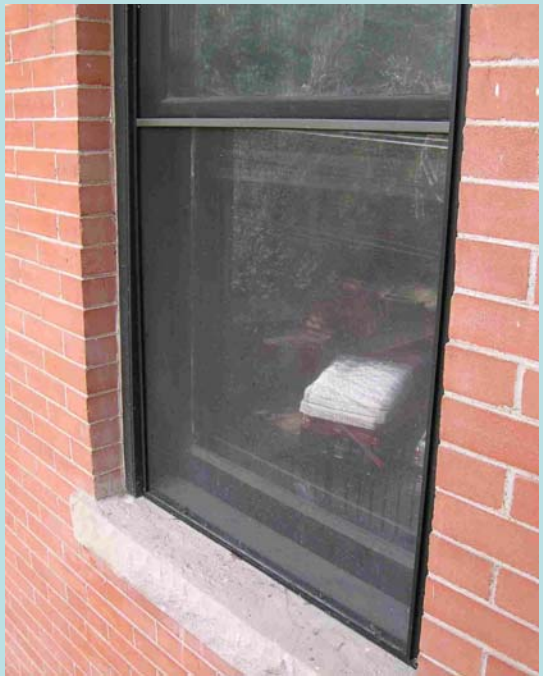


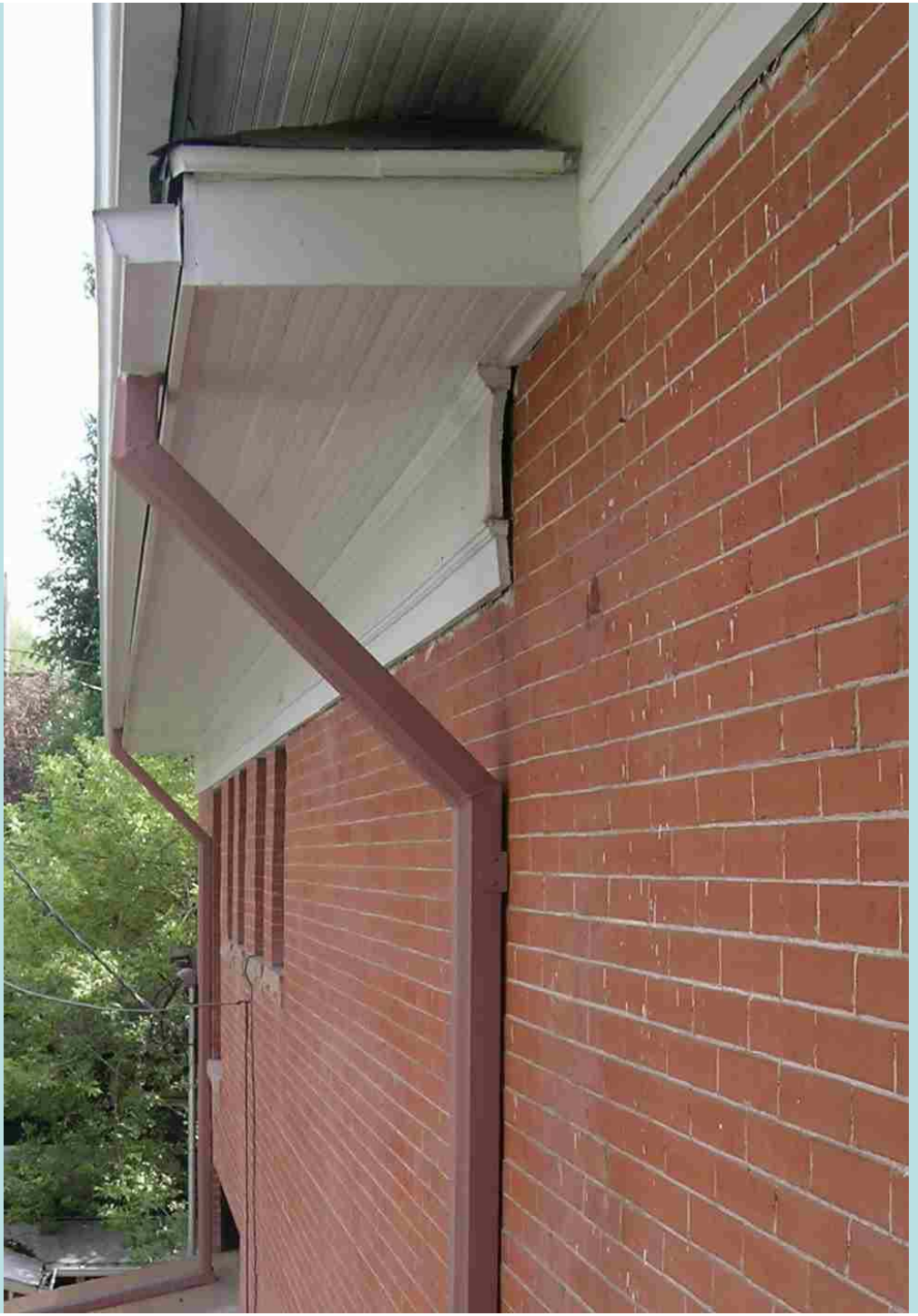
Yogi Berra

A beautiful building in a lovely neighborhood

NW and NE Elevations

Exterior in sound condition





Mechanisms for heat transfer

- Conductive
- Convective
- Radiative

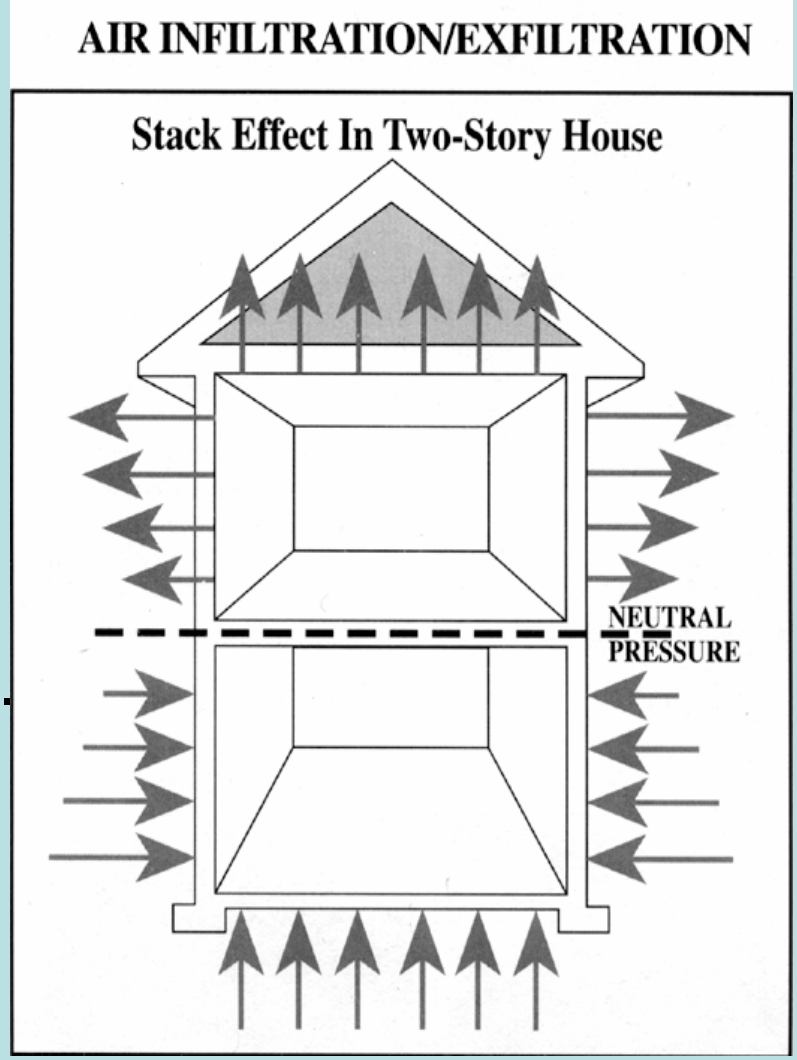
All play important roles at the pottery

Conductive heat transfer

- Heat transfer by surface contact
- Energy moves from warm to cold surface
- Conductivity is the inverse of resistivity (U = 1/R) where U is the coefficient of heat transfer in $Btu/hr/^{o}F/ft^{2}$
- Fiberglass and cellulose in walls; R ~ 4 per inch

Convective heat transfer

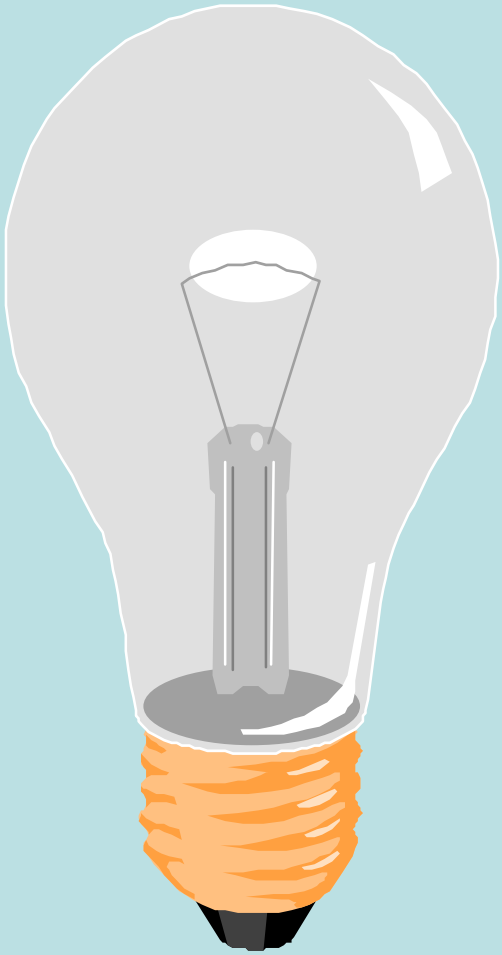
- Unwanted infiltration is a major problem in many buildings; stack effect is key.
- Warm air is more buoyant than cool, so rises, putting positive pressure on attic floor (exfiltration).
- Cool air drawn in at bottom of envelope (infiltration).
- Effect is a direct function of indoor/outdoor temp difference and the height of the conditioned envelope.
- Worst case on coldest day of the year when it's least welcome.
- Therefore it's essential to define the conditioned envelope at the attic floor and air seal carefully.

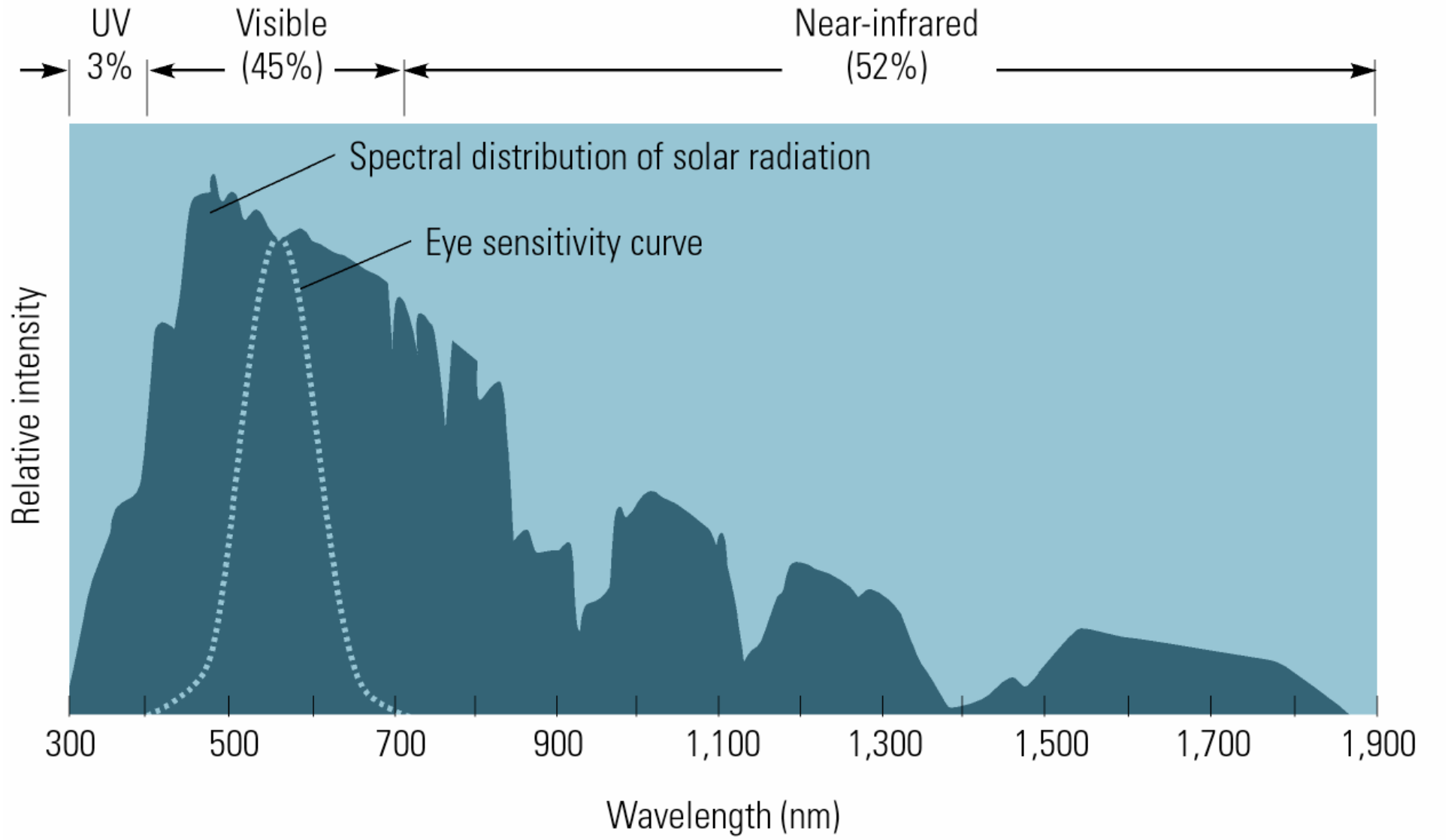


Blower door testing

- A blower door is a variable speed fan with mechanisms to allow it to fit tightly into an exterior door.
- Meters measure flow and inside/ outside pressure difference and flow.
- Allows for estimating the leakiness of a building and energy waste due to convection—and shows the location of most leaks.
- Test over porch of this home revealed a clear connection between overhang and the envelope.
- Later test with IR scanner showed similar problems with overhang of second floor on the south façade.
- Blowing cellulose to high density into cavities an appropriate solution

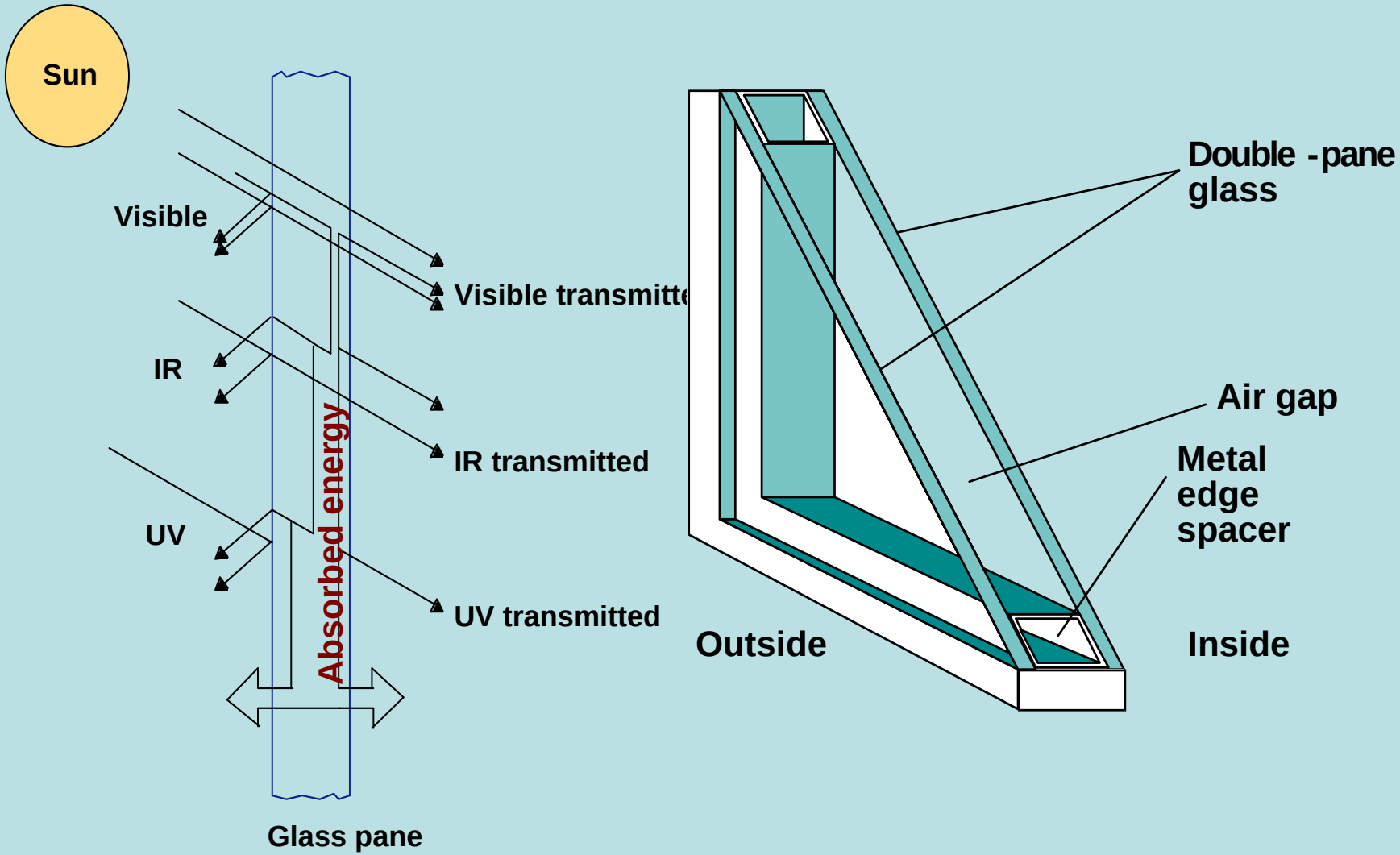
All bodies in the universe warmer than absolute zero radiate and absorb energy





Source: Kreith and Kreider

Windows illustrate all three types of heat transfer



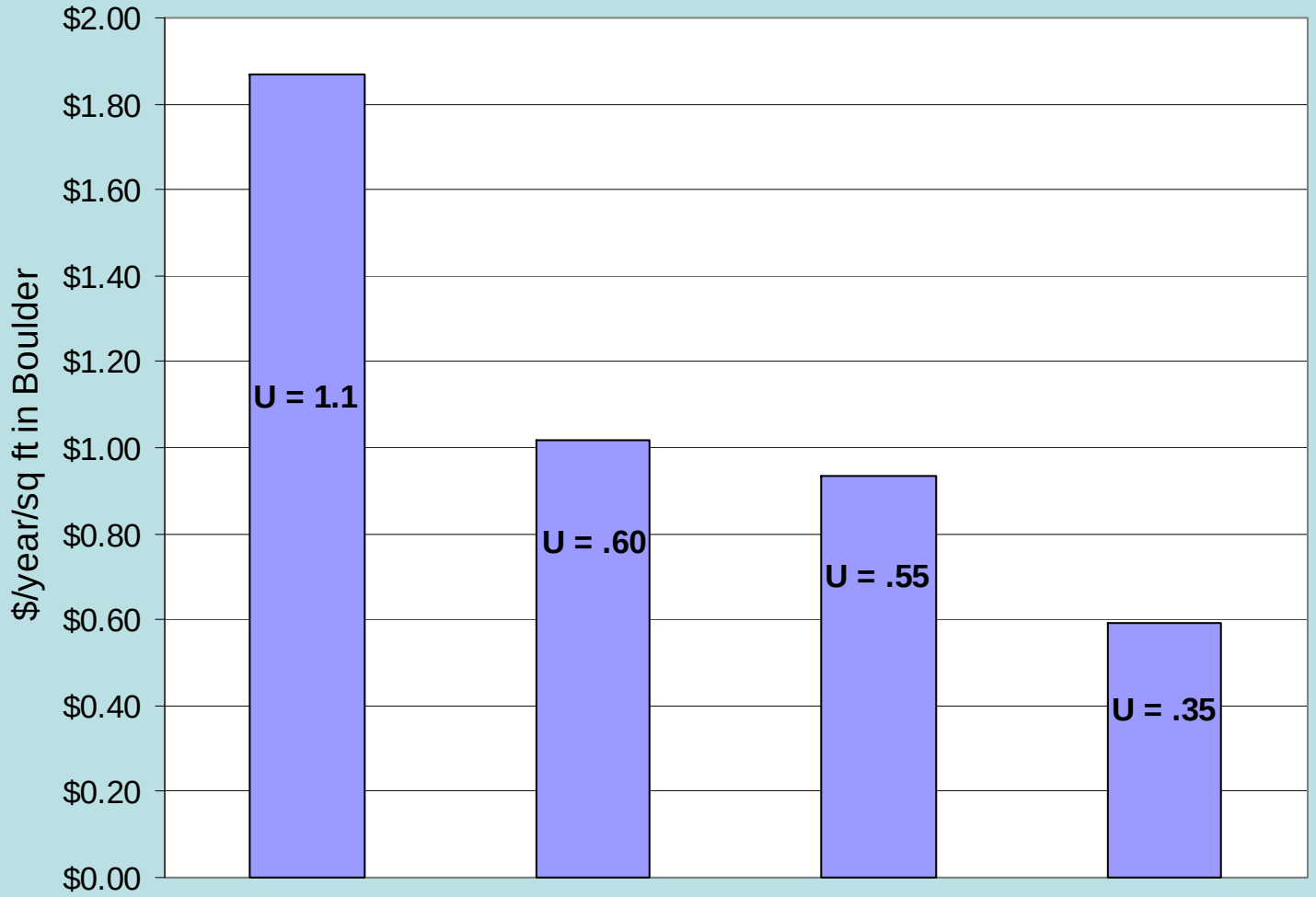
Pottery has a wide variety of window types

Most could use some attention, surely some air sealing

Window circumstances

- 112 sq ft single pane, U = 1.1
- 185 sq ft single pane with insider storms, U = 0.6
- 154 sq ft double pane, U = .55
- 450 sq ft total
- Assumed U of possible new windows = 0.35

Annual heating cost per square foot of window area by U value, Boulder weather, furnace system efficiency = 85%



The envelope

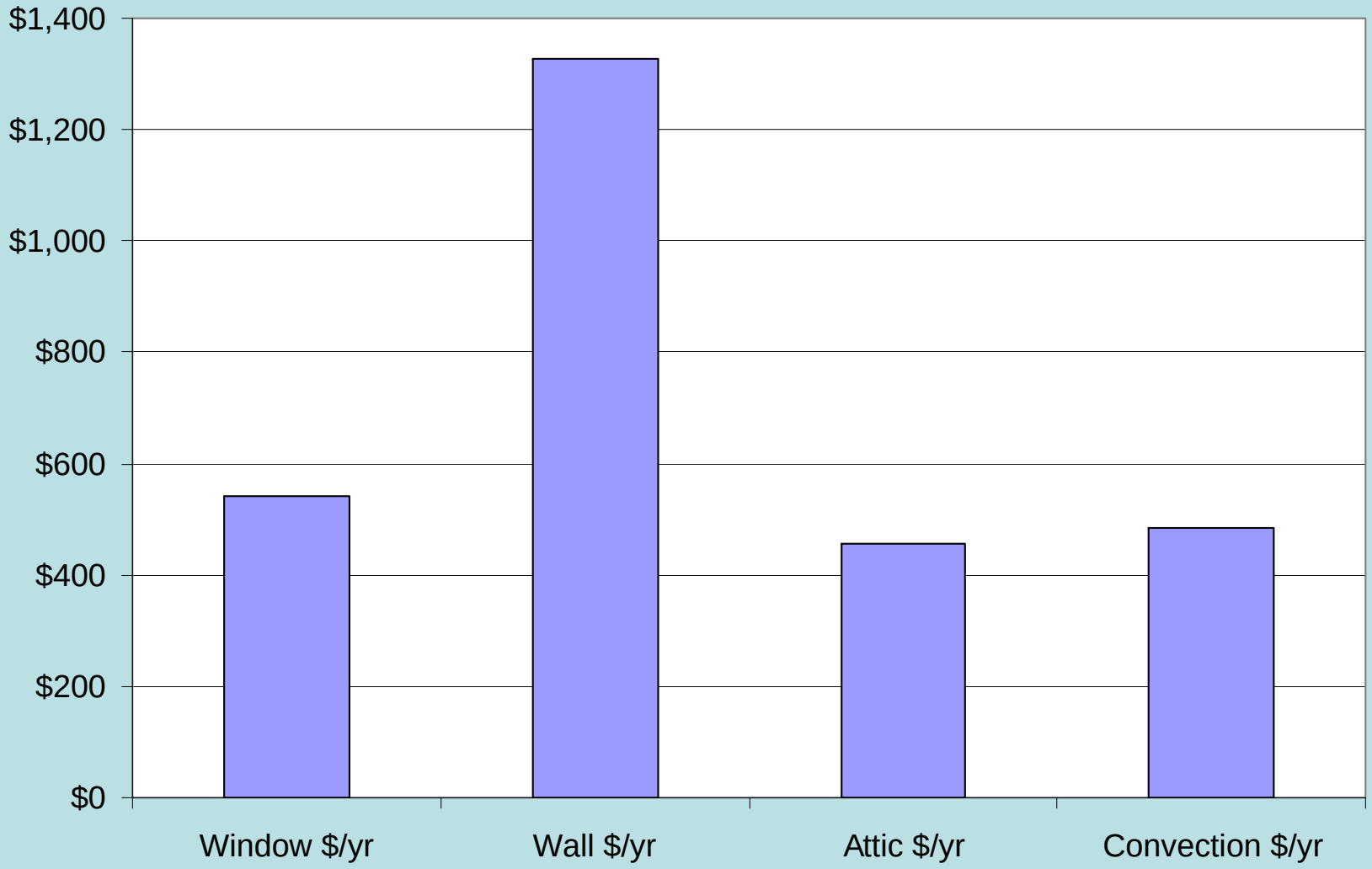
- The beautiful old brick walls have an R-value of only 3.
- The attic is very poorly insulated and has many holes in it, we estimate an R-value of 6.
- The building is leaky as a sieve, primarily because of openings to the top of the envelope that have existed since it was built. A blower door reading of 5400 cfm at 50 Pascals is quite substantial for a 3200 square foot building.

There’s a new closed-combustion, high-efficiency condensing furnace

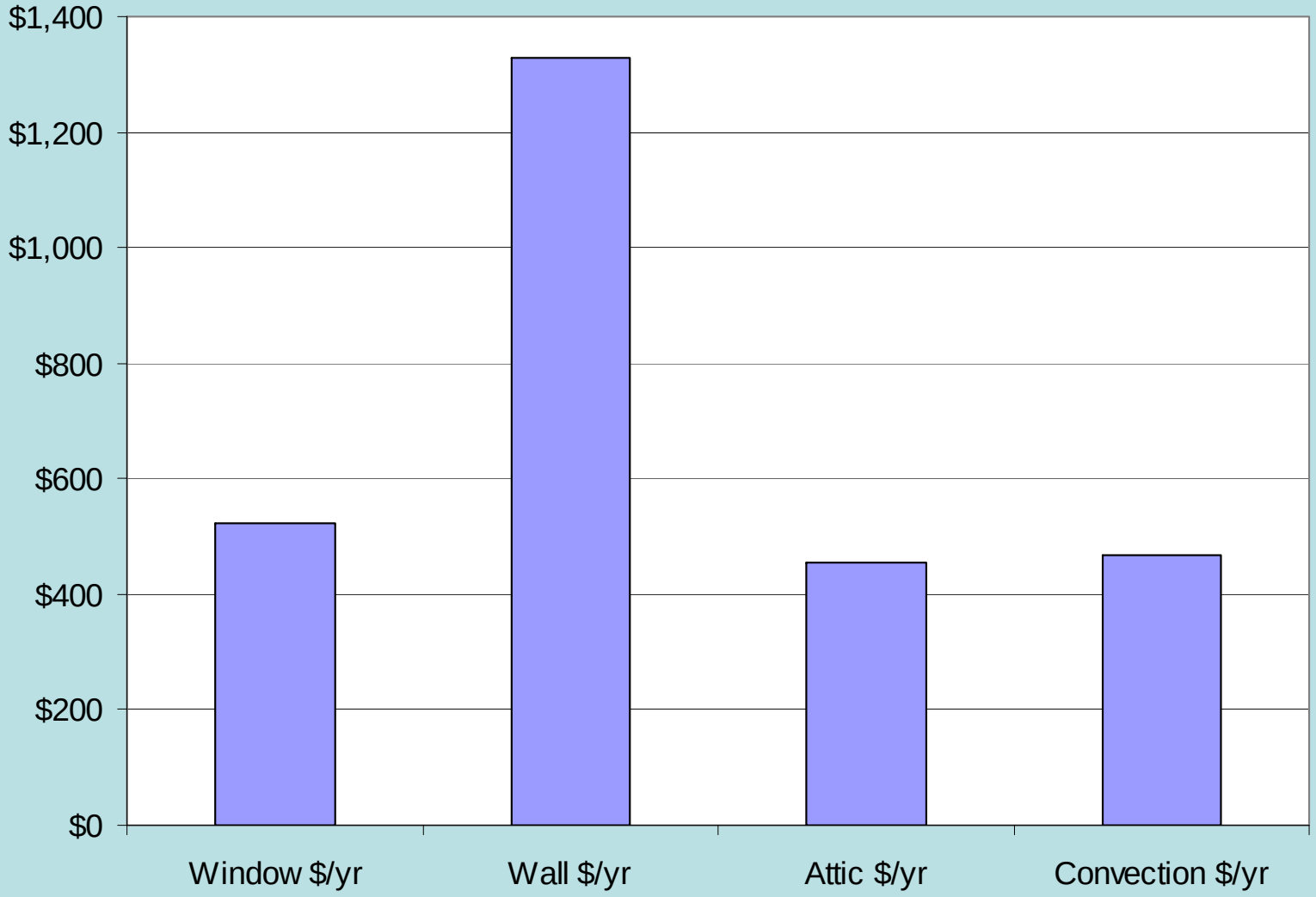
Modeling

- We analyzed energy flow through key elements of building during a typical meteorological year in Boulder (5466 hdd).
- With heating system at 85% system efficiency, we examined *individually*: three window options; air sealing and insulating attic; insulating wall.
- Then we examined combinations of above.
- Finally, we examined raising the efficiency of the heating system applied with other measures. This captures the effect of interaction between proposed retrofit options.

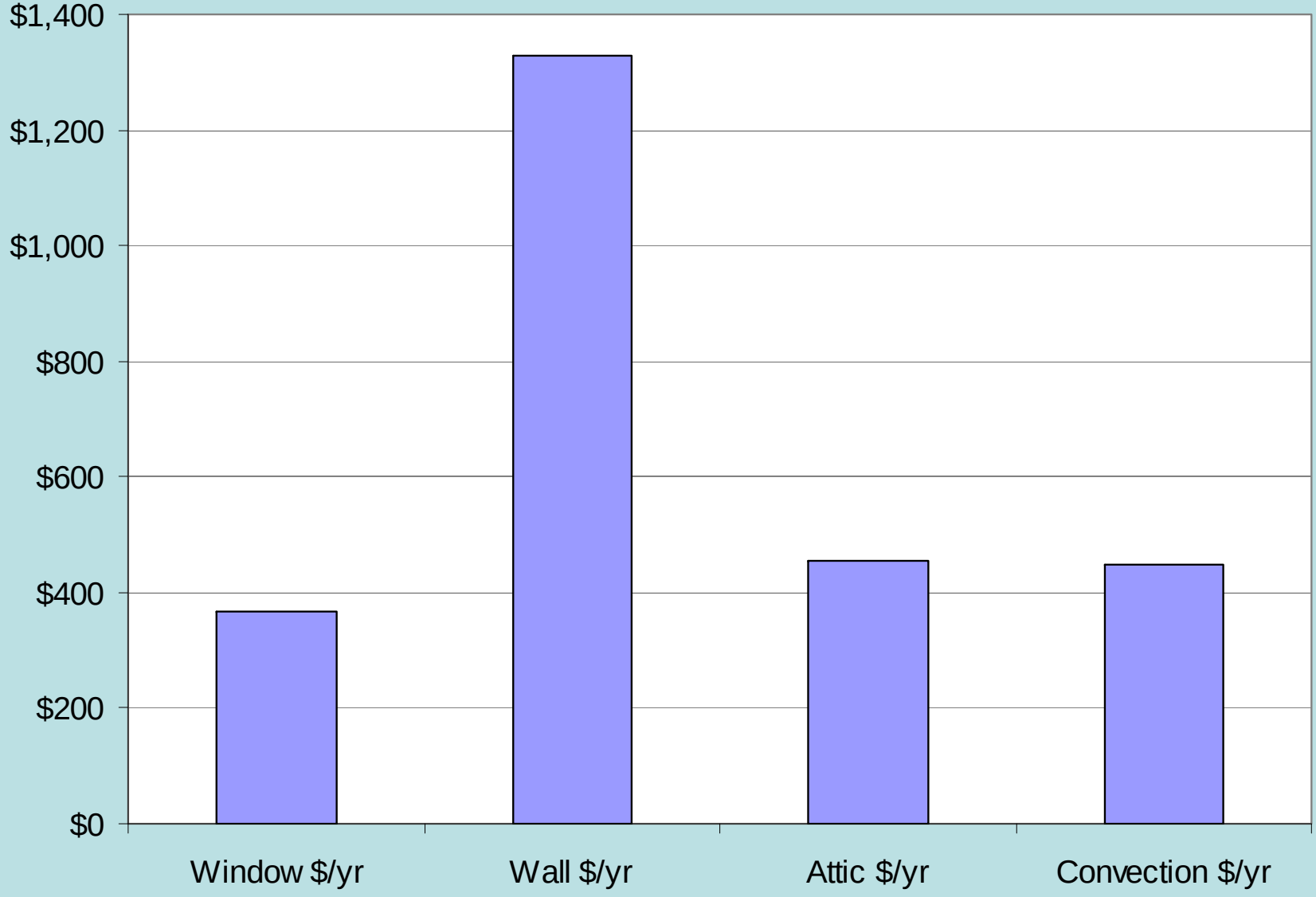
Existing circumstance, $2888/yr for space heating, windows 19% of total



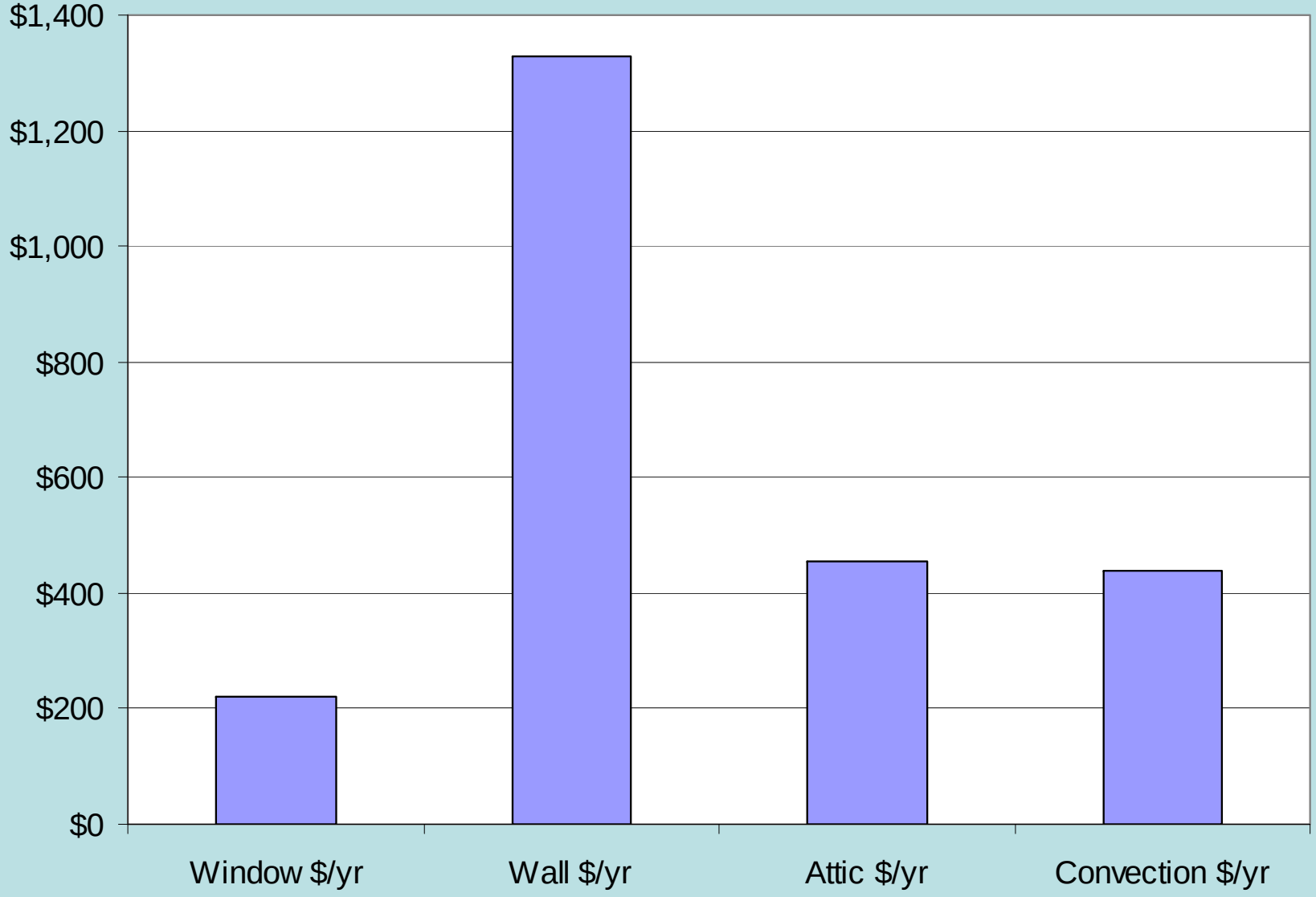
Window repair, $2869/yr, windows 19% of total. Savings from base case, $18/yr, 0.6%



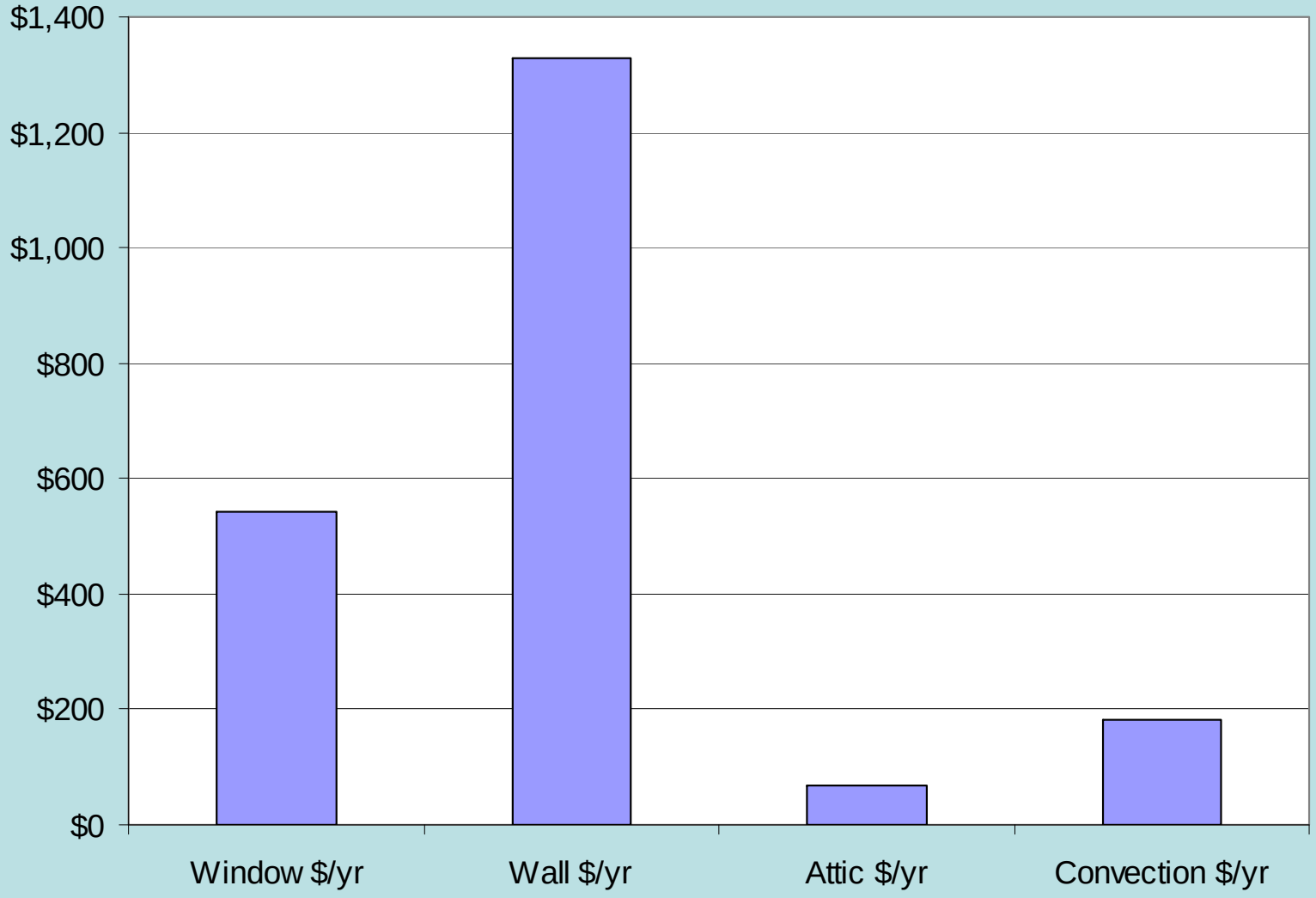
Storm windows added, $2713/yr, windows 15% of total. Savings from base case = $174, 6.0%



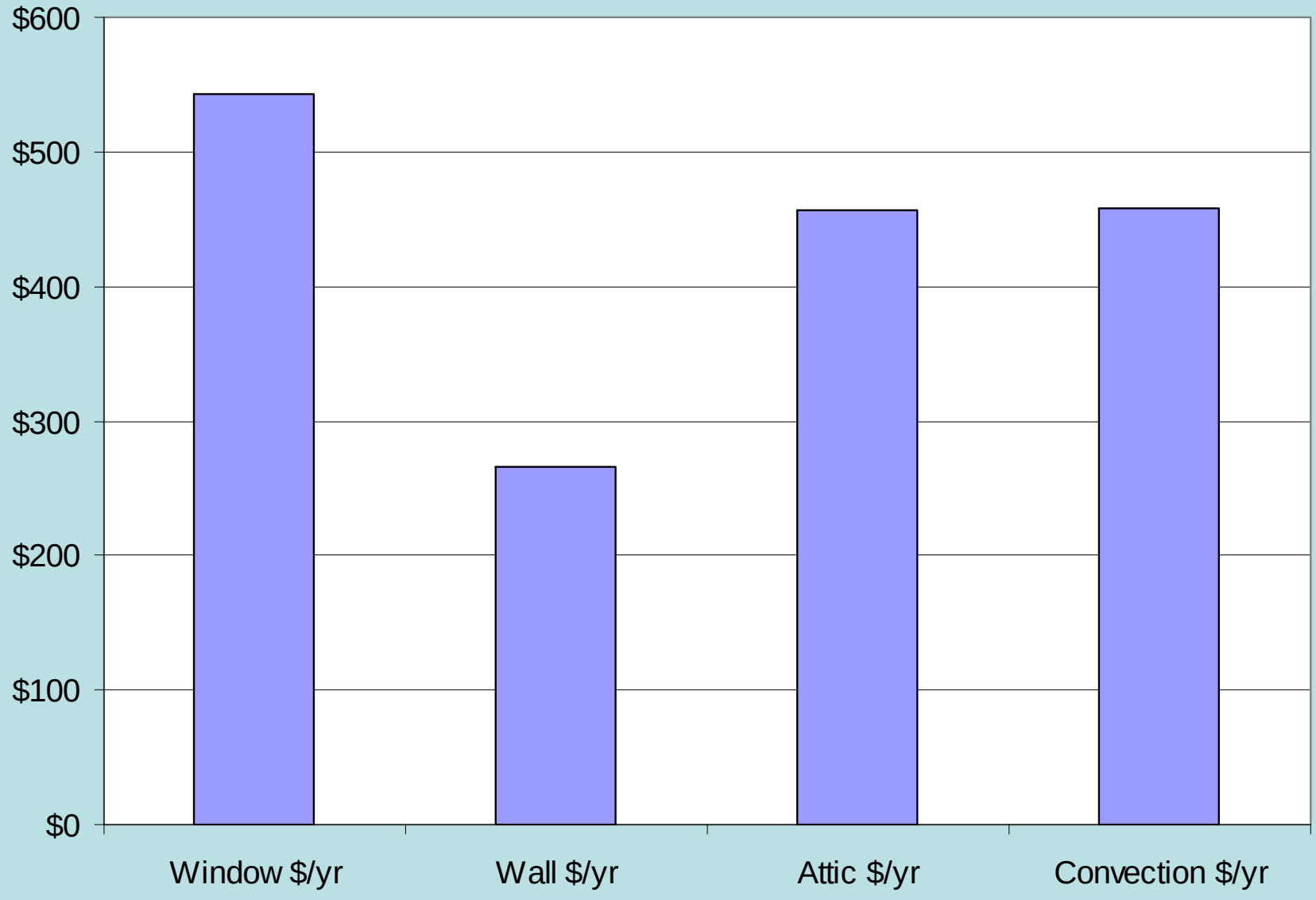
New windows, $2567/yr, windows 10% of total. Savings from base case = $321/yr, 11.1%



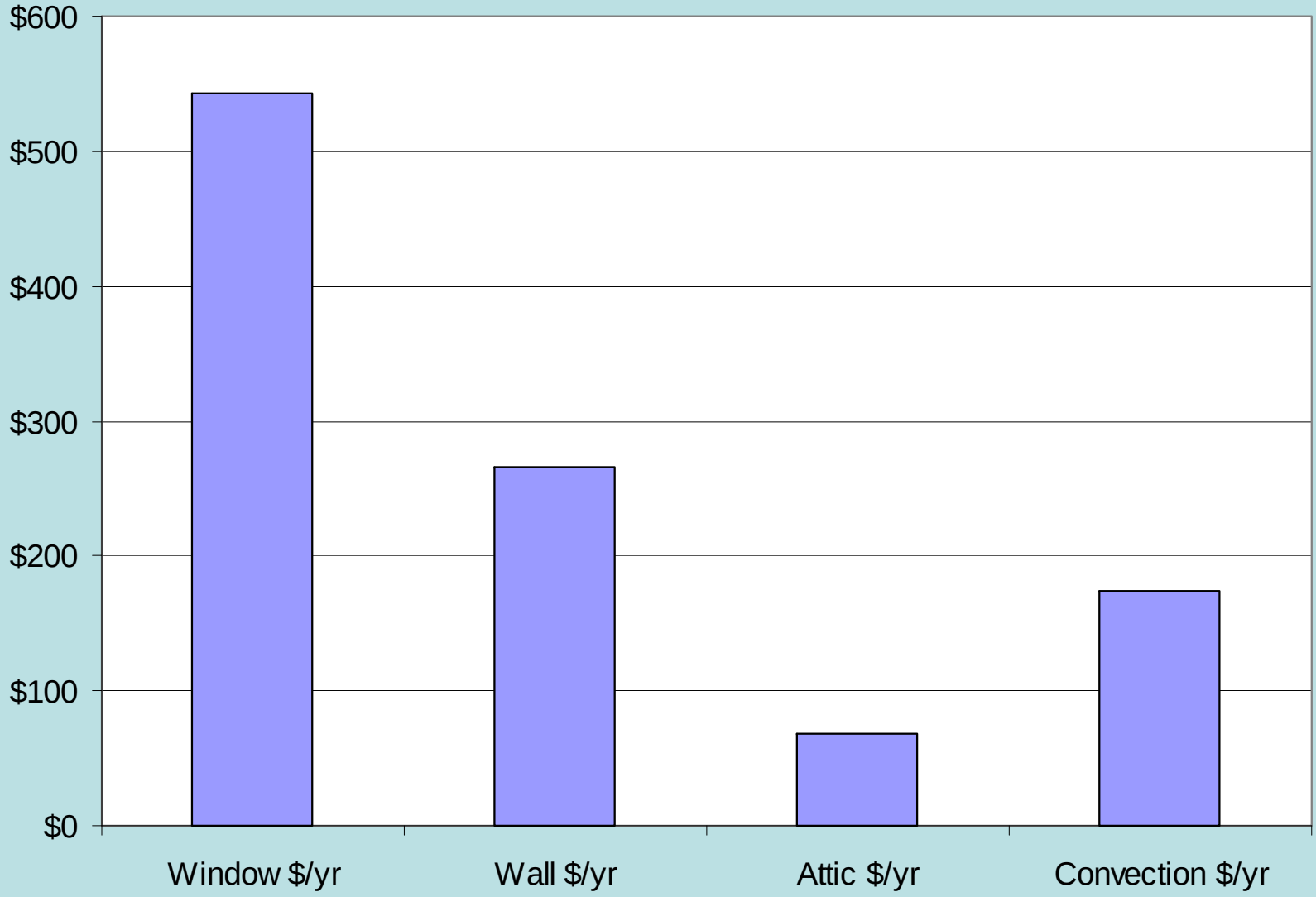
Air sealing plus attic insulation, $2197/yr, windows 25% of total. Savings from base case = $690, 23.9%



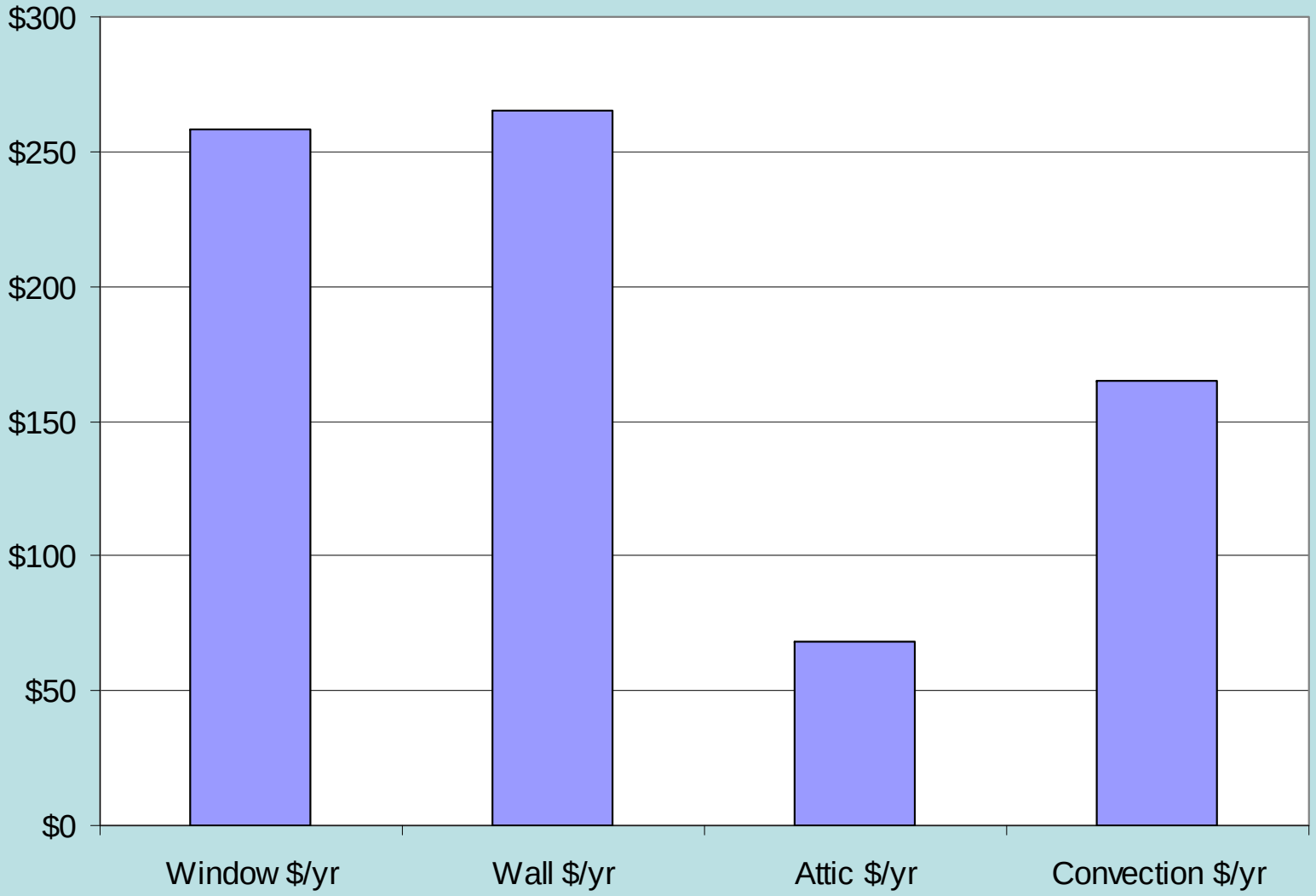
Insulate wall to R-15, $1798/yr, windows 30% of total. Savings over base case = $1090, 37.7%



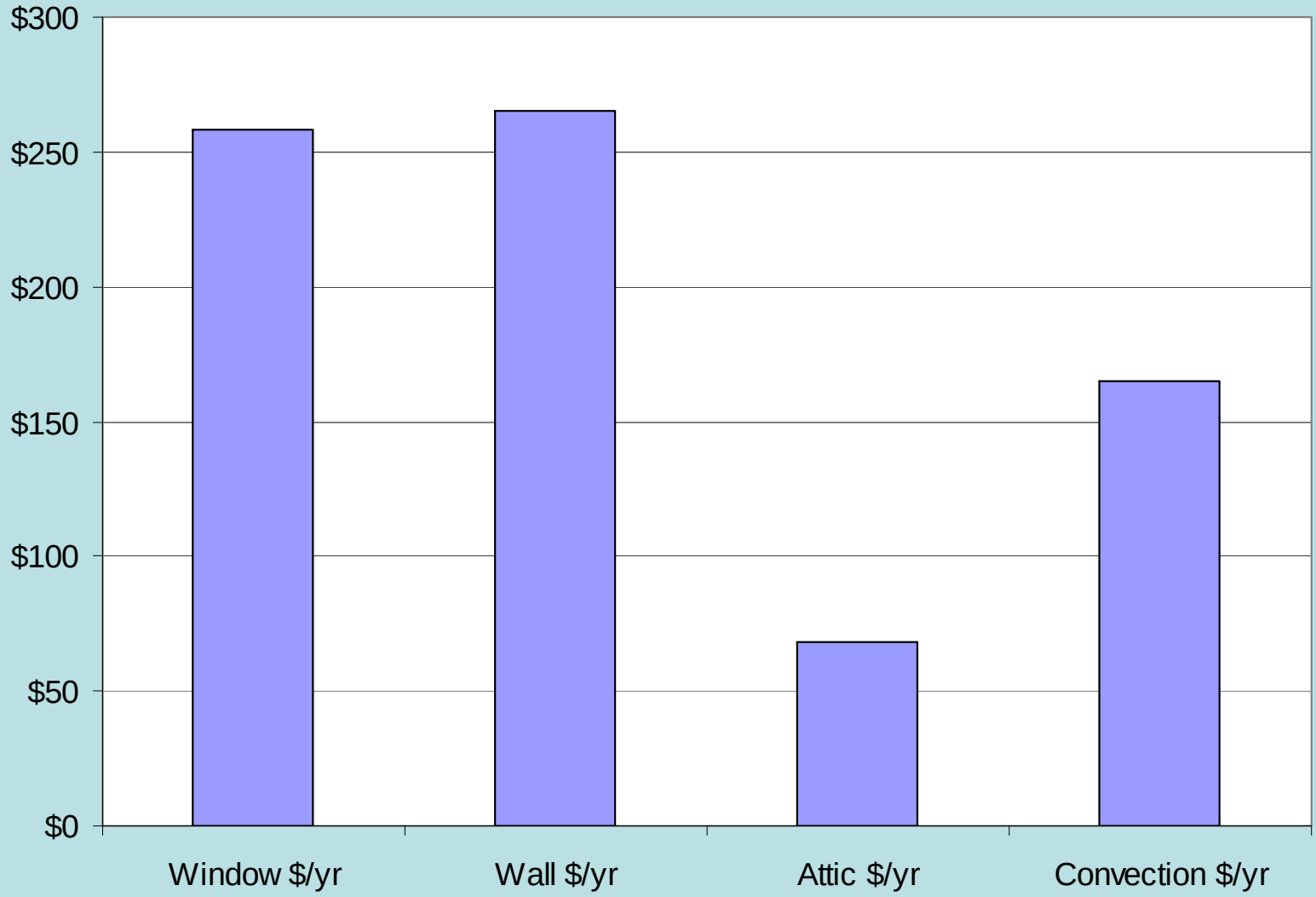
Air seal plus attic and wall insulation, $1126/yr, windows 48% of total. Savings over base case = $1762, 61.0%



Air seal plus attic and wall insulation plus new windows, $842/yr, windows 32% of total. Savings from base case = $2046, 70.9%



All of the above plus improve furnace distribution system, $795/yr, windows 32% of total. Savings from base case = $2093, 72.3%



An important part of the story

- Electric kilns inside in middle room on second floor use lots of juice, contribute to space heating in winter, misery in summer.
- Gas kilns outside use close to half of the gas used for heating building.

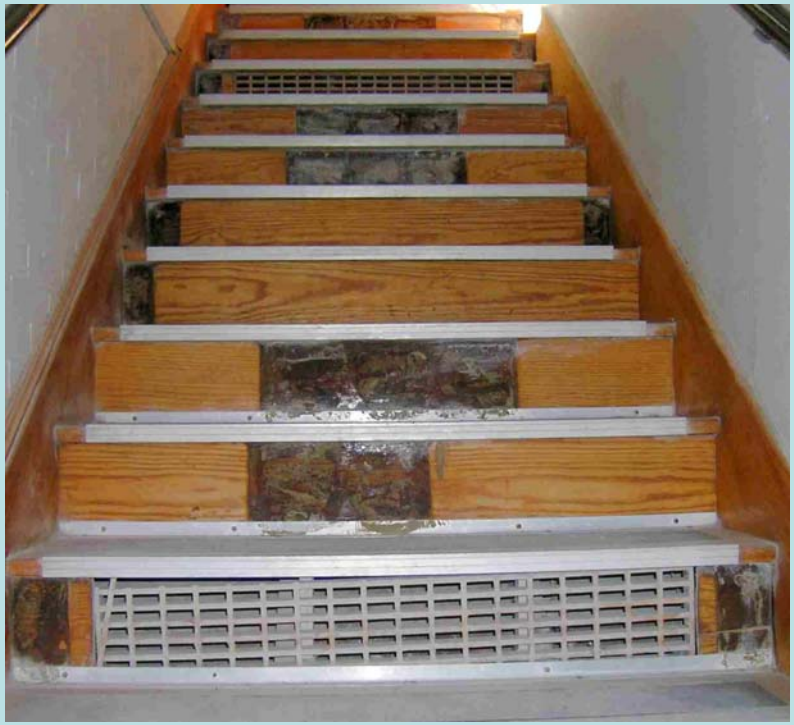
Commercial gas and electric rates

- Xcel meters both electric energy (56,789 kWh in photo) and demand (28.721 kW in photo)
- Demand averages 65% of electric bill, costs >$12.50/kW, energy about 5 cents/kWh
- Can control demand by not running all electric kilns at same time
- Electricity in aggregate costs about 2.5 x gas

Retrofits to HVAC

- Although the analysis looked at this as the last retrofit, if taken as the first, it will be the most cost effective retrofit.
- Furnace itself is a new condensing model, but the distribution system and control systems needs attention.
- After retrofit complete, a bit of staff education will be helpful in ensuring that savings are achieved while maintaining comfort.

Supply duct at top of stairs needs to be opened.
Also need more return opening in stairway.



Getting control of the HVAC system

- Opening the supply duct and adding more area on the return side (it's now at most 2.5 sq ft) will improve the system efficiency and the throw of warm air
- Moving the thermostat away from the furnace and setting it properly will help, too.
- Estimate a 5% increase in system efficiency

Defining the envelope

- Major problem in the building
- Need to make sure the attic of the building is outside of the conditioned envelope
- It’s fruitless to insulate the attic until it is carefully sealed.
- So finding and sealing leaks is a high priority

Open entry to attic. Note knob-and-tube wiring, sparse insulation

This is a vent into the attic from the kids' pottery area, second floor front of building. What modest insulation there was is decidedly tired…

Fans in attic not much use; left in roof, right at back of building on south-facing wall.

Ventilation is a twisted tale..

- The ceiling in the electric kiln room has ducts with filters.
- In the attic above, there is elaborate ducting with a fan controlled by a thermostat that pulls air from the kiln room into the ducts…

Part 2..

- Back down through the kids' pottery room where it gives up some of its heat by conduction and radiation.
- It's summer and hot, but no, the damper that would dump heat into the attic is closed!

Part 3

- And finally the pipe has a couple of right angle turns (slowing the velocity of air) and dumps into the front of the building.
- Some heat is recovered, to be sure, but the net result is probably negative.
- Substantial duct losses in attic plus thermo-siphoning during kiln off cycles.

Part B of ventilation saga

- The electric kilns dump moisture during bisque firings, moisture and sundry environmental nasties during glaze firings.
- So each kiln has a fan below it hooked up to its own duct which vents outside.

A twisted pathway through the attic to window at the front of the building

Historic Preservation?

- Vent pipes from the electric kilns are immediately behind the louver on the left
- North-facing (into prevailing wind)
- Fails for four reasons: venting function, heat recovery, elegance of design—and esthetics

So what to do?

- This is a classy building that performs a very important function in our community.
- There's a dedicated professional staff, a variety of people create pottery there, but it's very wasteful energy wise.
- The building needs a practical, carefully-designed retrofit that will breathe new life into the building and cut energy costs

Critical first step: Air seal the building and insulate the attic

- Need to remove all ducts and vent pipes from the attic, seal all openings, build an attic hatchway over the present entry way to the attic, ensure that it seals well and is insulated with rigid board insulation.
- Blow in 12 inches of cellulose (recycled newsprint, R = 3.8/inch)

New duct design for recovering waste heat from kiln room

- Install ducts within the envelope at ceiling on 2nd floor that vent high out the south (back) end of the building for summer configuration.
- Intakes at level of kiln room ceiling to single large duct, fan in duct takes air out of room toward back. After exiting kiln room, gentle Tee and dampers (don't torture air!) allows air to go down to first floor in winter where it is distributed high in the main room on the east side.
- Efficient, variable speed fan integrated into duct system controlled by temp sensor in at kiln room ceiling.

Vent pipes from electric kilns

- Just below ceiling, gently turned toward back (south), run parallel to one another in kiln room, left uninsulated there.
- Routed close to air intake from heat recovery ducts described in the last slide.
- After exiting kiln room, small round vent pipes run inside rectangular insulated master duct to back of building
- Individual vent pipes from each kiln used; back draft dampers at exit from pottery high on the south side.
- Heat recovery if needed and practical with small fan on rectangular insulated duct; where warmed air directed (via simple grilles) to be determined by users.
- Can recover existing ductwork from attic for much of job.
- Install louver in north attic opening that matches existing.

HVAC

- Make a short supply duct run to the master bathroom, remove electric resistance heater that is there (could save $20/month in demand alone).
- Increase size of return air by installing more grilles in risers in the back stairs.
- Adjust dampers in supply ducts.
- Move thermostat about 4 feet where it will no longer “see” the furnace.
- Adjust controls appropriately, brief staff, do energy ed with users.

Lighting

- Old style T-12, 8 foot fluorescent fixtures with inefficient iron ballasts used throughout.
- Replace with modern T-8s with electronic ballasts, save 50% on demand and energy costs, get better lighting.
- Ensure lights switchable for individual work areas.

Wall insulation

- Energy wise, would be best to insulate on outside, but would not be a good esthetic choice.
- Recommend installing two inches of polyisocyanurate rigid insulation on inside, followed with 5/8 inch gypsum fastened through insulation to bricks.
- May be more practical than it looks; paybacks are substantial to move from R-3 to R-15
- Option to install conventional stud wall, 24 inch centers adequate.
- Details around windows, between floors important.

Evaporative cooling

- Presently, the place is miserable in the summer, but with changes recommended and proper control settings, should be much more comfortable.
- Nonetheless, evaporative coolers are very efficient and comfortable without much demand, may be a useful retrofit.
- See discussion in the Boulder Green Building Journal of Summer 2006, www.bgbg.org

Oh, yes, and windows…

- Clean and tune, install weather strip and air seal.
- Insider storms where missing for single-glazed units
- New windows are not likely to be cost effective.
- This ain’t conventional residential housing stock!

Achieving energy efficiency

- Need to examine options for energy efficiency for firing.
- Making sure not all electric kilns are fired at the same time—will save demand charges.
- Fans on electric kilns unnecessary for bisque after 400 F; only necessary for glaze firings toward the end of firing cycles.
- Dampering and burner control of gas kilns may be optimized if stack temp and O_2 content monitored.
- Need an “Operators’ Manual” for building as part of energy ed for staff, others.

Feedback is most welcome

Larry Kinney
Synertech Systems Corporation
1335 Deer Trail Road
Boulder, CO 80302
303-449-7941
larryk@synertechsystemscorp.com
www.synertechsystemscorp.com