NIST Energy Savings Office Investigation

Presentation of Results

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Energy Savings Office Project Partnership

Building and Fire Research Laboratory (BFRL)

- Responsibilities
  - Calorimeter construction and instrumentation
  - Data collection and analysis
  - Presentation of results
  - Prediction of energy savings
- Contributors
  - Hunter Fanney
  - Mark Davis
  - Bob Chapman
  - Luis Luyo
  - Michael Couch

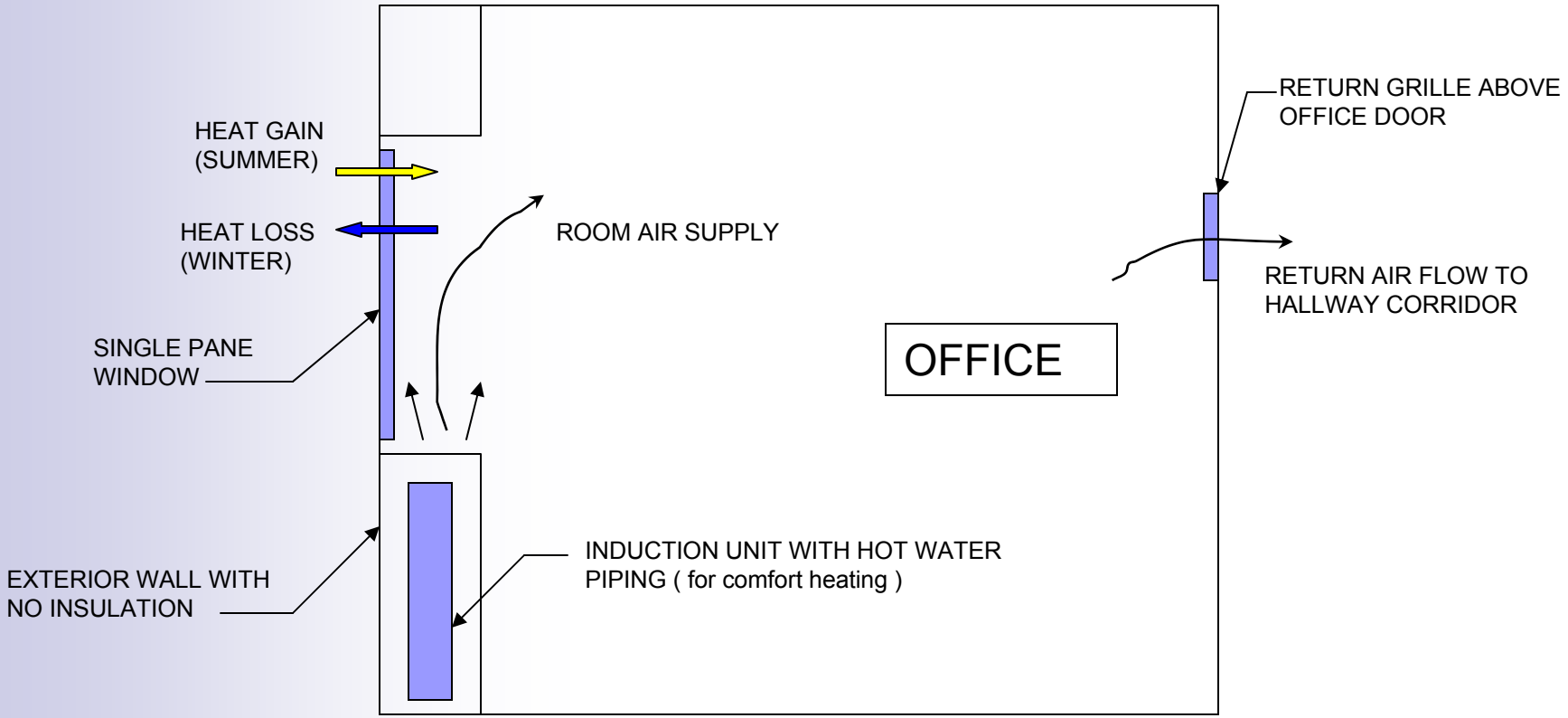
Plant Division

- Responsibilities
  - Implementation of energy saving features
  - Provide building and equipment specifications for modelers
- Contributors
  - John Bollinger
  - Daniel Gilmore
  - Jatin Patel
  - Daniel Mann

Typical Office Module

- Exterior walls
  - Zero insulation between metal panels and concrete structure
- Window unit
  - Single pane glass
  - Aluminum frame
  - No thermal break
  - Uninsulated aluminum panel below window unit
- Heating/Cooling
  - Forced air from attic
  - Induction coil unit (not shown)

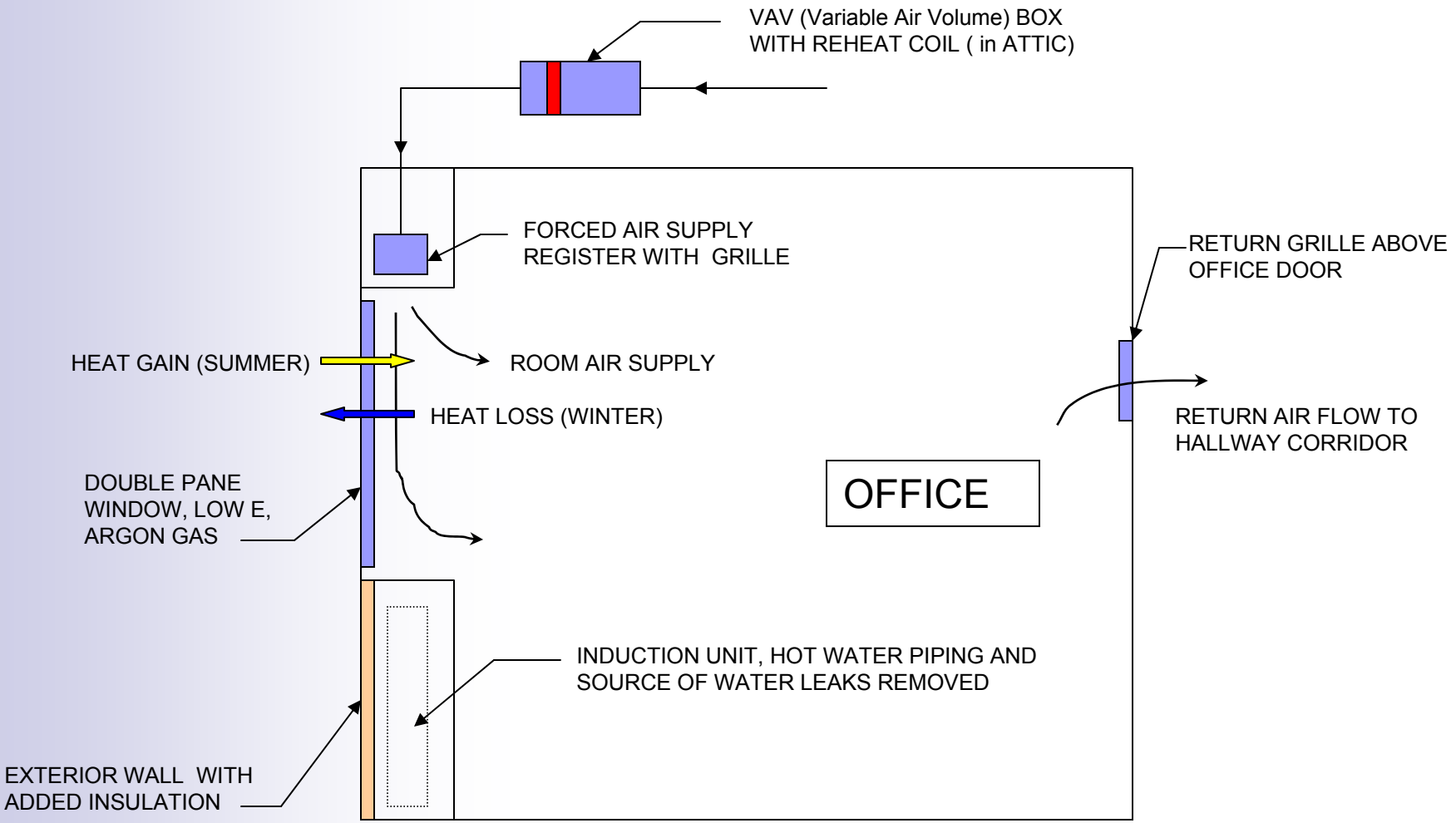
Existing Typical GPL Office



Modified Office Module

- Exterior walls
  - R-32 glass fiber insulation
  - Air leaks sealed
- Window unit
  - Installed insulated window unit
    - Double glazed
    - ½" gap, Argon-filled
  - Insulated panel below window
    - R-20 polystyrene board
    - R-13 fiberglass batt
- Heating/Cooling
  - Forced air register moved to top of window
  - Induction coil unit removed

Proposed Typical GPL Office



How Energy Savings Is Determined

- Two adjacent office modules
  - Control office
  - Test office with energy saving features
- Calorimetric method
  - Fabricated insulated partition wall in each room
  - Heated window-side space to maintain zero temperature difference across partition wall
  - Heat loss confined to exterior wall
  - Energy required to maintain each room at an equivalent temperature measured

Instrumentation and Control

- Thermopile across insulated partition wall
  - Measures temperature difference across wall
  - Used to control heater on window-side of each room
    - PID controller turns heater ON/OFF until thermopile reads zero
- Power analyzers measure electrical energy added to each room
- Thermocouple grid measures air temperature throughout rooms
- Thermocouple measures outdoor temperature
- Calibrated heat flux transducer measures heat flux through window
  - Mounted in center of each window
  - Guarded area ensures one-dimensional heat transfer through window

Define Heat Transfer Coefficient (UA Factor)

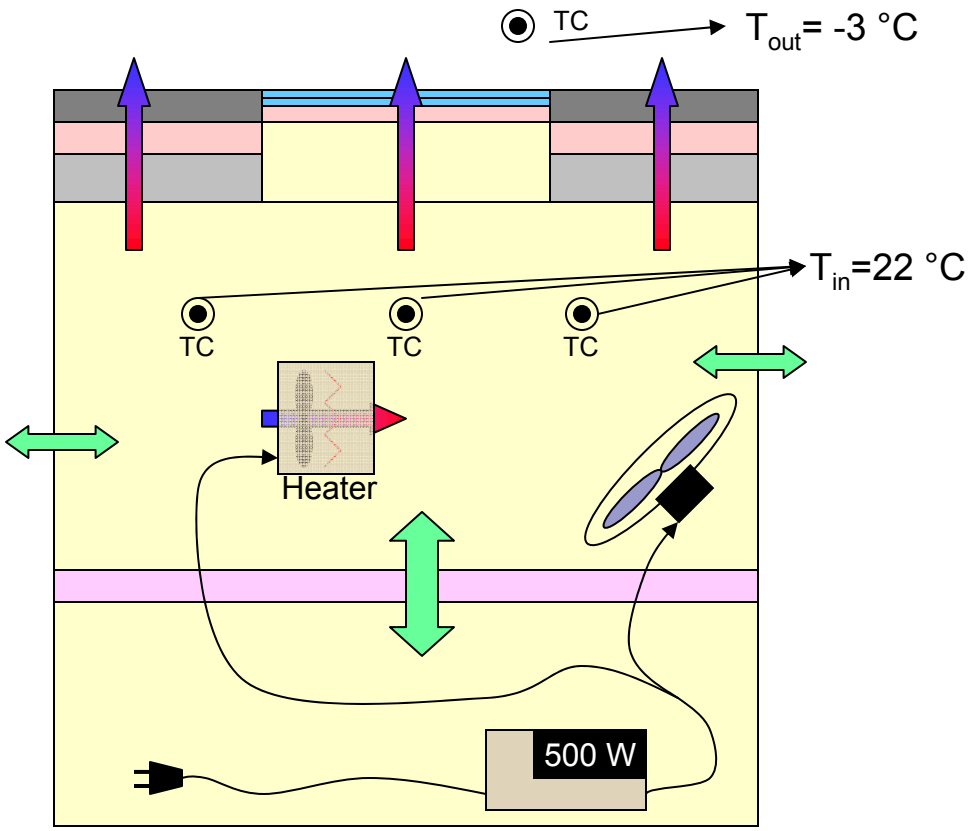
- UA factor expresses heat loss as a function of temperature difference across a surface

$$UA = \frac{\text{Heat lost through wall}}{(T_{in} - T_{out})}$$

- Assume that electrical energy input to room passes through exterior wall as heat

$$UA = \frac{500\ W}{22°C - (-3°C)} = 20\ W/°C$$

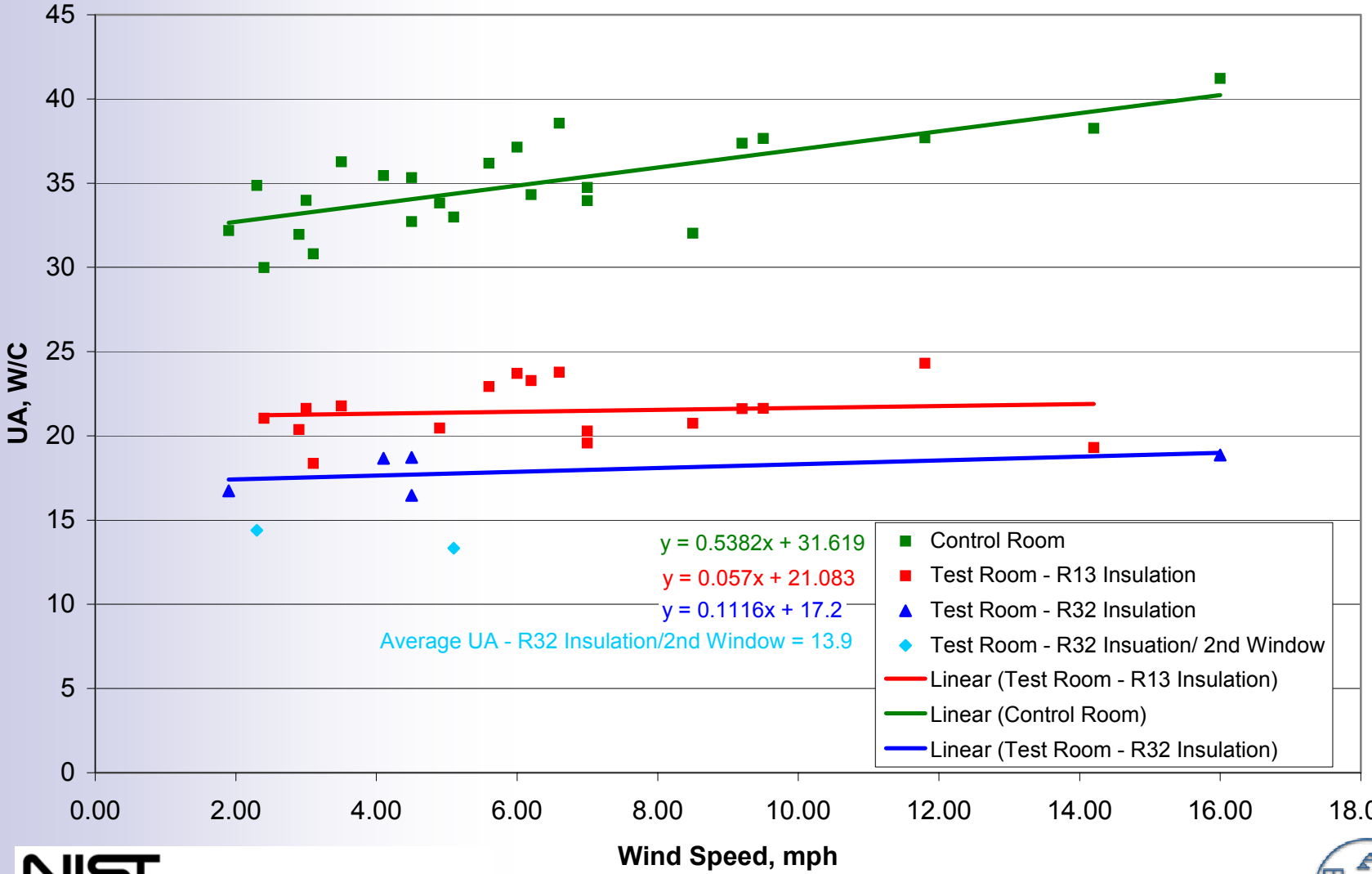
- **Smaller UA factor means better energy efficiency**



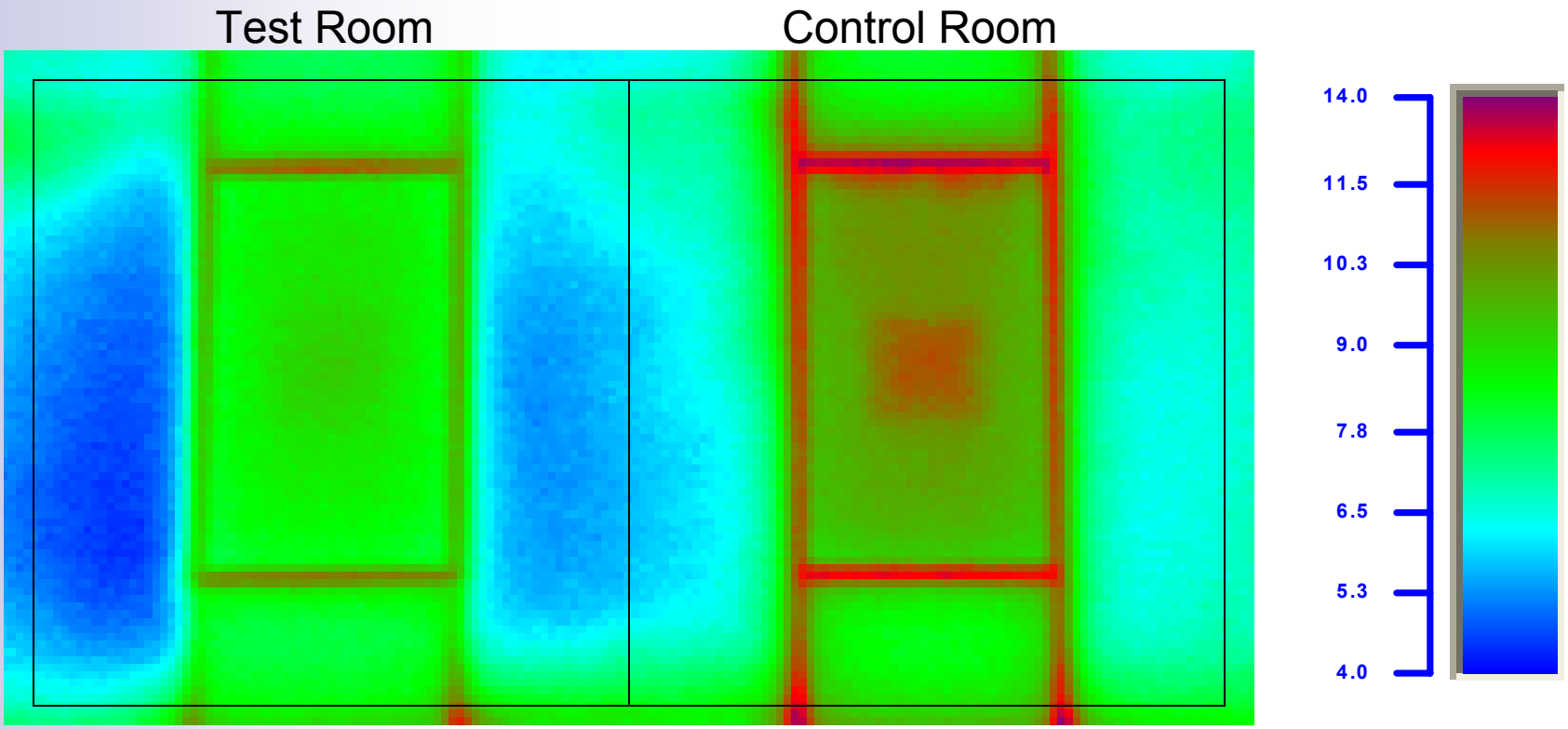
Presentation of Results

- Summarize results for
  - UA factor for exterior wall
    - R-13 insulation level
    - R-32 insulation level
    - R-32 insulation level with low-E argon-filled window unit
  - Infrared thermography
  - Heat flux through window
- Notes
  - Only two days of acceptable test data were recorded with Low-E, Argon-filled window unit due to its installation late in the winter
  - Experiments do not include new air distribution vent at top of window and supplemental heat exchanger

UA Factor for Exterior Wall vs. Wind

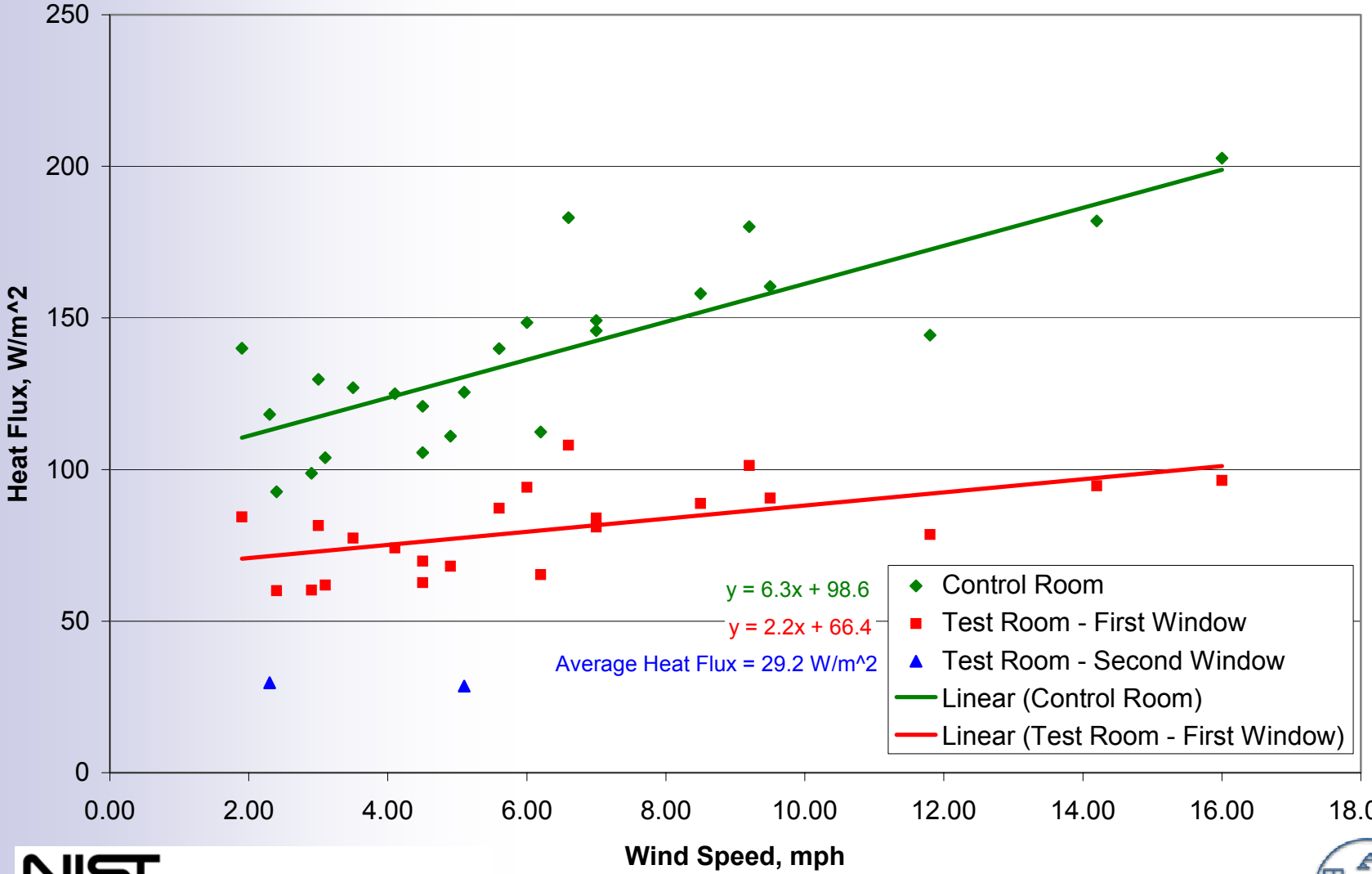


Infrared Image of Control and Test Room Exteriors



Blue (cold) areas indicate less heat lost from building

Heat Flux Through Window vs. Wind



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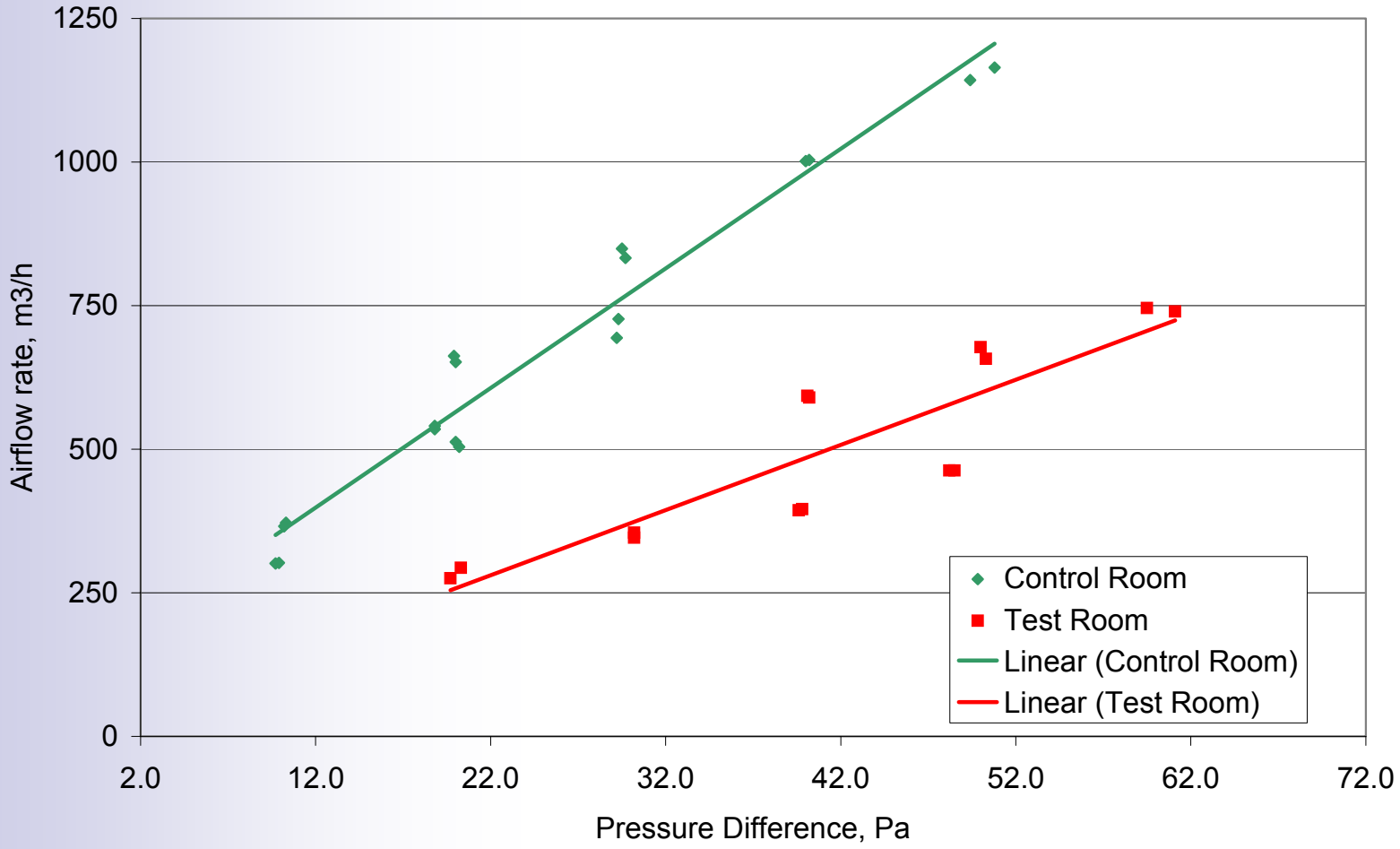
Air Leakage Rate Reduced by Half



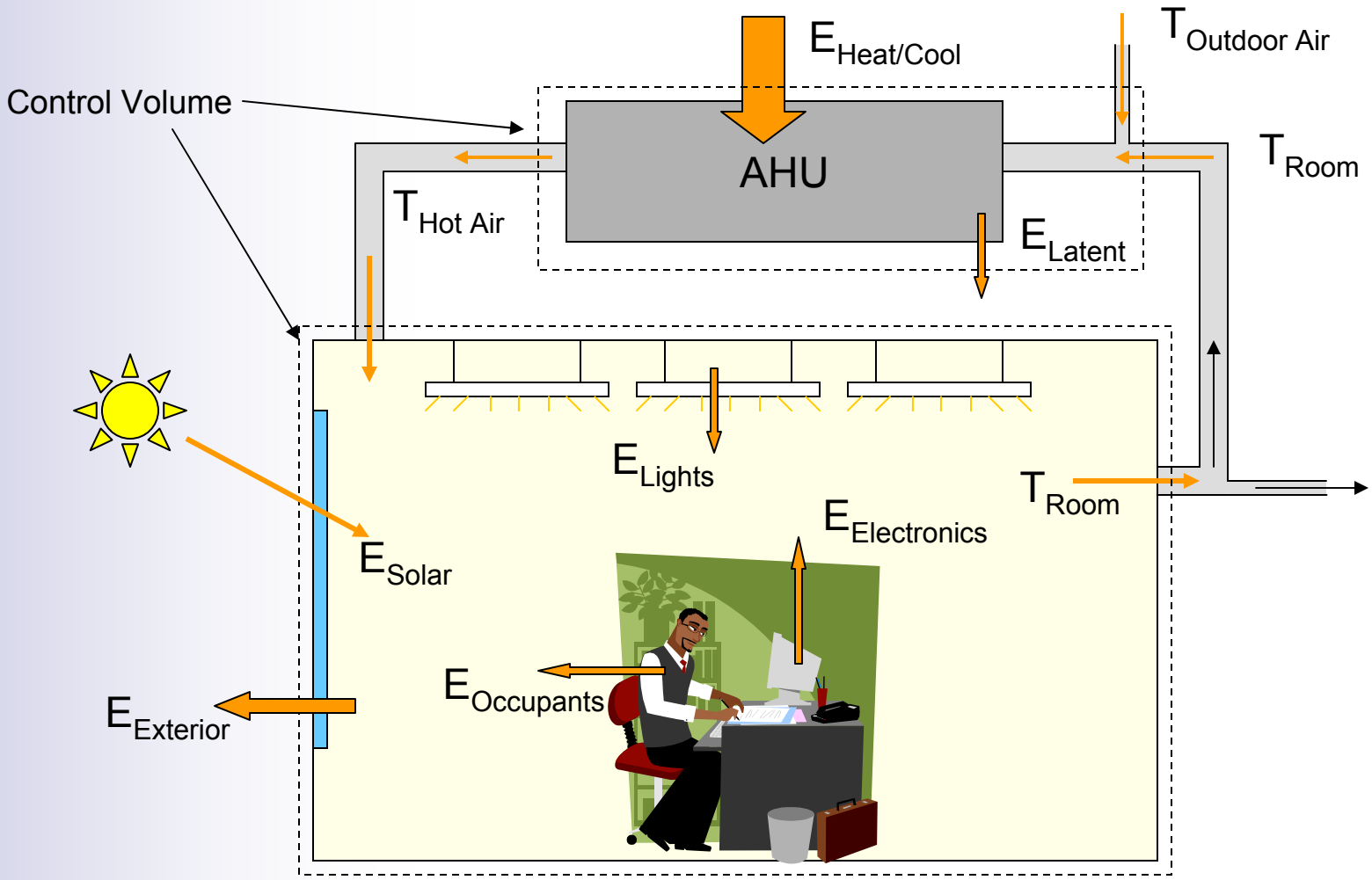
Summary of Measured Results

- R-13 insulation on exterior wall plus double-glazed window unit decreased exterior UA factor by **38%**
- Adding an extra layer of R-19 insulation (for a total of R-32) decreased exterior UA factor use by **48%**
- Low-E, Argon-filled window with R-32 insulation decreased exterior UA factor by **59%**
- Low-E, Argon-filled window unit decreased window heat flux by **70%**
- Efforts to seal exterior wall penetrations reduced leakage by **50%**

Estimation of Annual Energy and Cost Savings

- Hourly energy usage for modified and unmodified office module calculated for entire year
- Energy required to heat/cool room results from a balance of
  - Heat transferred through exterior wall
  - Heat generated from
    - Lights
    - Computers and monitors
    - Occupants
    - Sunlight
  - Energy required to heat/cool makeup air
- Weather data from Baltimore, MD

Office Module Energy Balance



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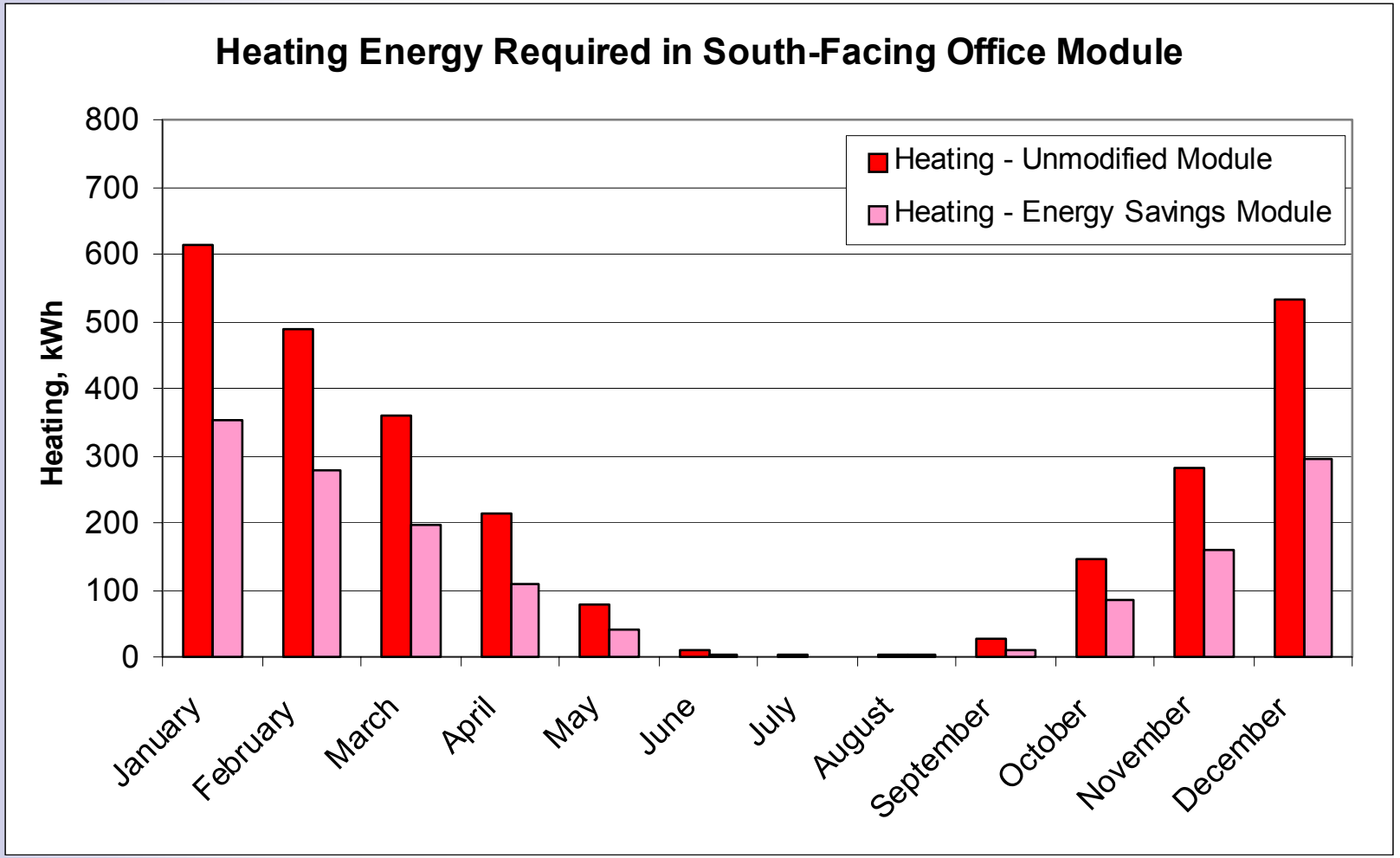
Estimation of Energy and Cost Savings

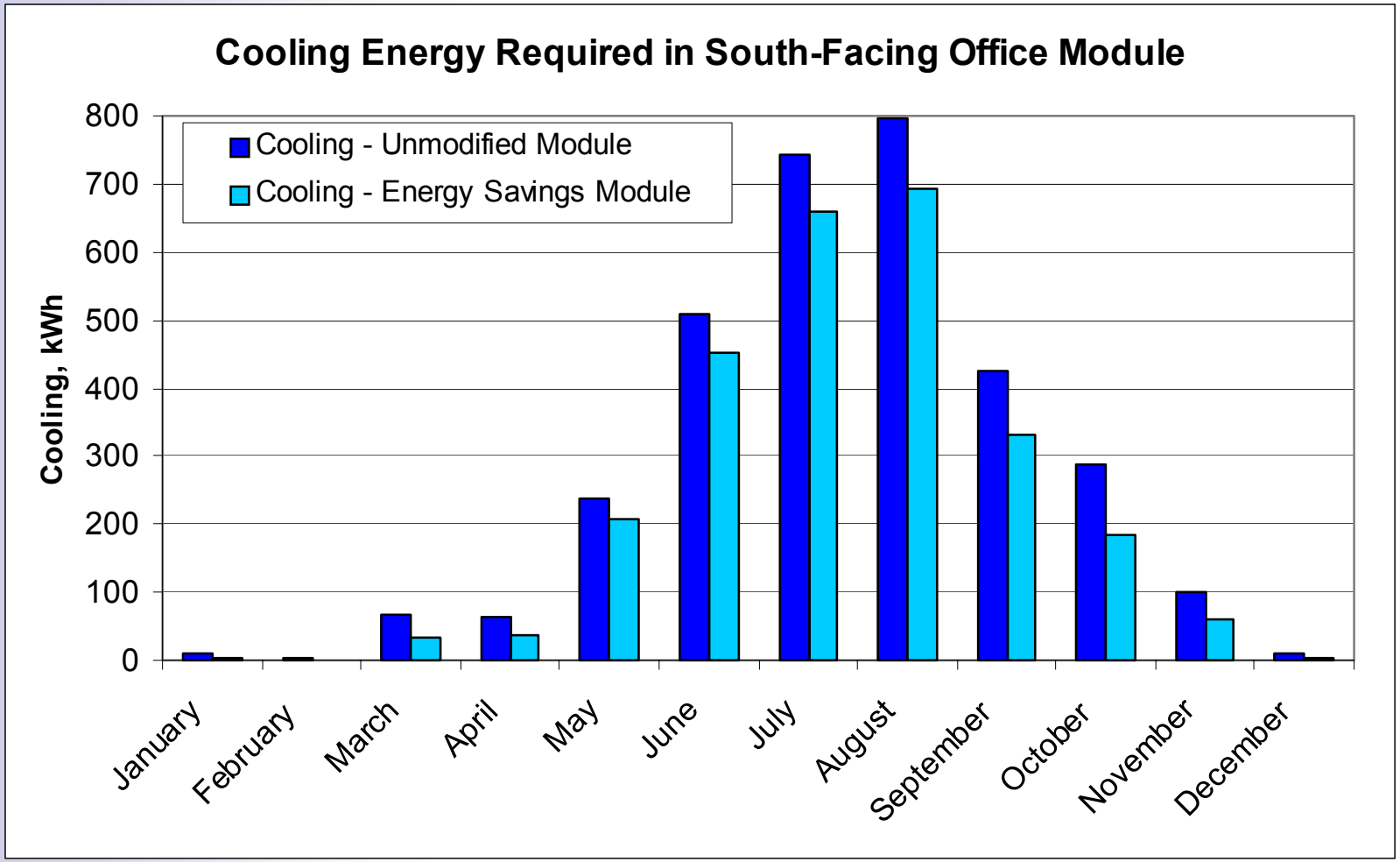
- $E_{Heat/Cool}$ calculated hourly for entire year
- Standard weather data (TMY2) from Baltimore, MD
- Compute energy required at central plant per module using efficiencies
- Compute cost of energy
  - $15.80 per 1000 cubic feet of gas
  - $0.12 per kWh electricity
  - $0.771 per kW of maximum demand
  - $1.81 per kW of on-peak demand in summer months

Efficiency (%)	Heating	Cooling
AHU	70%	70%
Distribution	80%	90%
Primary Source	70%	0.79 kW/ton

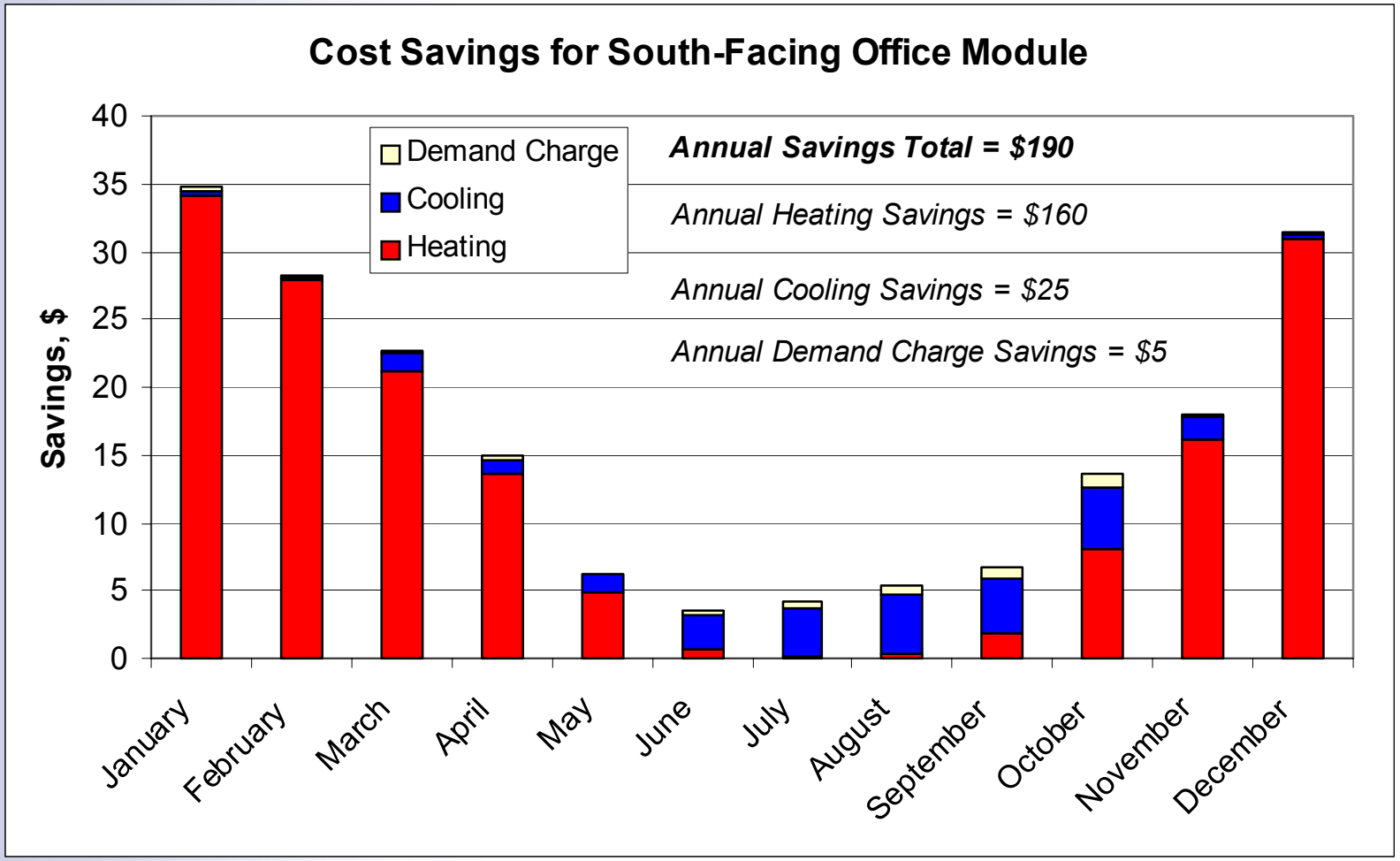
Estimated Monthly Heating Load



Estimated Monthly Cooling Load



Estimated Monthly Cost Savings



Summary of Costs

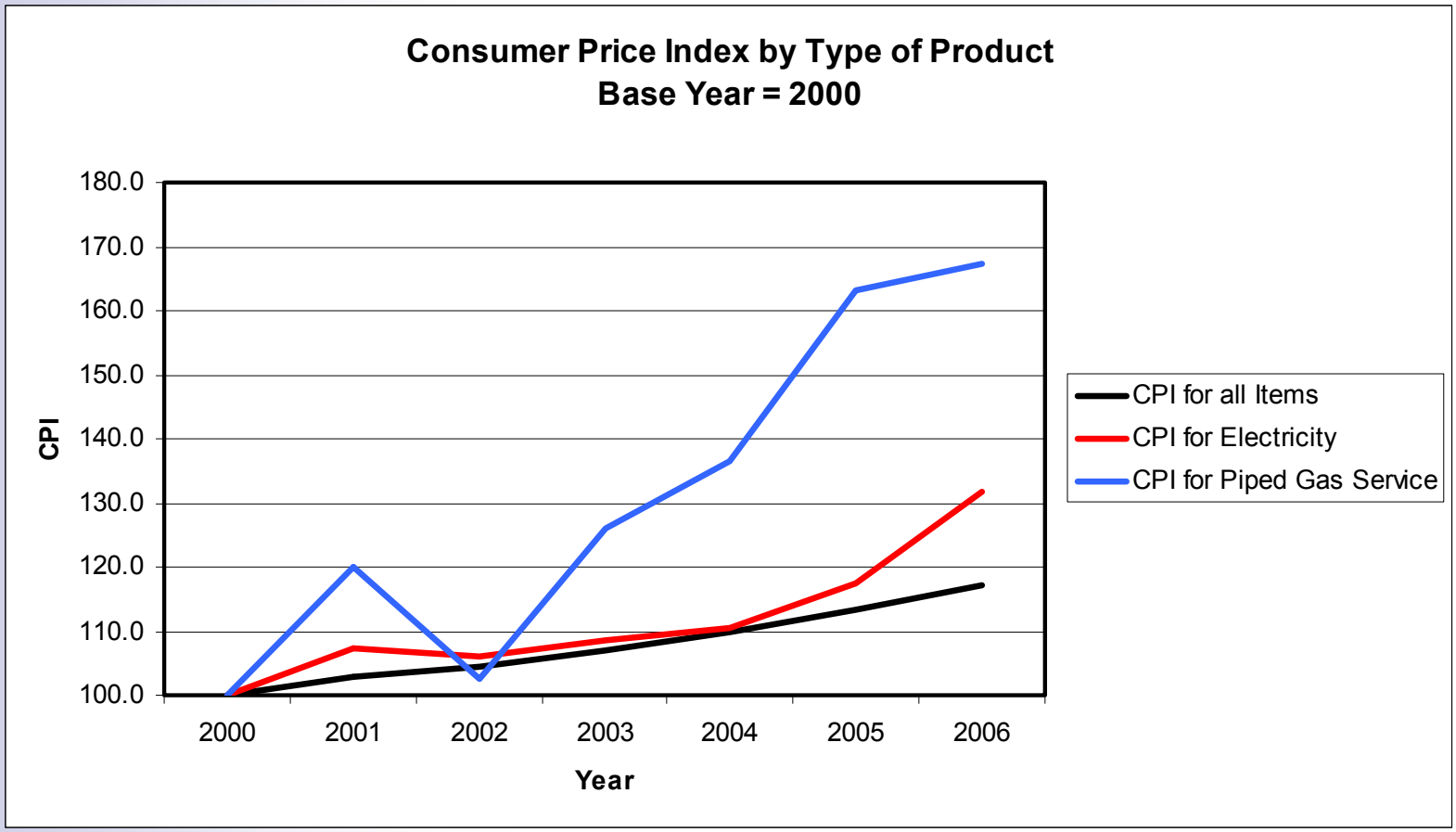
- Cost savings per module based on energy costs for 2007:
  - South-facing = $190 per year
  - North-facing = $201 per year

- Cost of improvements per module
  - Window unit - $1800 installed (quote from Glazing Contractors)
  - Insulation - $375 ($125 material / $250 labor)
  - Remove/Replace wall panels - $650 (12 hours @ $54/hour)
  - **Total = $2825 per module**

Life Cycle Cost Analysis

- BFRL's Office of Applied Economics performed Life Cycle Cost (LCC) analysis over 25 year period – 2007 through 2031
- Uses 2007 DOE FEMP Discount Rate of 3%
  - Discount rate adjusts for the time-value of money
  - Discount rate is real, all amounts expressed in dollars of constant purchasing power
- Energy costs could increase in future years
  - Scenario 1: electric and natural gas rates remain constant
  - Scenario 2: electric and natural gas rates increase by 1% per year over the general rate of inflation
  - Scenario 3: electric and natural gas rates increase by 3% per year over the general rate of inflation

Recent History of Energy Costs



Source: Bureau of Labor Statistics. "Consumer Price Index," (Washington DC: Bureau of Labor Statistics, 2000-2006), http://www.bls.gov/cpi/home.htm.

Economic Analysis is Conservative

- Historical escalation of energy costs shown to be greater than those included
- Productivity of occupants increased as a result of more comfortable office
- Energy savings due to decreased outdoor air infiltration not considered

Results of Life Cycle Cost Analysis

Window Orientation	Energy Cost Escalation Rate	Life Cycle Cost		Savings to Investment Ratio
		Control	Modified	
South-Facing	0%	$8,701	$8,227	**1.17**
	1%	$9,778	$8,896	**1.31**
	3%	$12,492	$10,580	**1.68**
North-Facing	0%	$9,064	$8,392	**1.24**
	1%	$10,186	$9,081	**1.39**
	3%	$13,013	$10,817	**1.78**

Other Tangible Benefits - Plant's Perspective

- Eliminates source of many water leaks in GPL perimeter offices - from leaking hot water piping, di-electric fittings, induction unit coils.
- Ease of maintenance on individual offices' HVAC systems – furniture often hides induction units and can't reach di-electric fittings; now VAV boxes and re-heat coils will be accessible in the attics and won't have to disturb occupants.
- No better opportunity to "refresh" these 40^{+} year old offices.

Conclusions

- **Upgraded window and insulation is cost effective even with most conservative assumptions**
- Measured heat loss through exterior reduced by 59%
- Annual energy usage in modified office module projected to use about 50% of energy consumed by unmodified module
- Comfort level increased in energy savings modules
  - Window temperature increased from 13 °C to 20 °C
  - Reduced feeling of cold air drafts

Implementing the work (GPL offices in Bldgs 226, 225, 224)

Work Elements, 3rd Flr Bldg 226 south side offices	Cost ($)	In Facility Condition Assessment Study?	Urgency
■ Replace windows – single pane -> double pane, Low E, argon gas	120K	Y	3-5 yrs
■ Add exterior wall insulation – none -> R32	80K	N	
■ Abate asbestos – floor tile and mastic – insulation on hot water piping	281K	Y	not stated
■ Repair / upgrade HVAC systems – remove window induction units – remove hot water piping – replace room air supply ■ new externally insulated duct work from attic to office ■ VAV control box & reheat coil in attic ■ new forced air supply register	230K	Y	1-5 yrs
■ Replace floor covering (carpet squares / floor tile)	30K	Y	3-5 yrs
■ Repaint rooms	65K	N	
■ Office move outs / move back-ins (Trailer 412)	22K	N	
■ Telephone / IT support during moves	10K	N	
Total	**$838K**		