

# Field Tests of Cool Walls in Cooling and Mixed Climates

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**Progress Report on  
Joint Research Project**

**Textured Coatings of America  
and the  
Oak Ridge National Laboratory**

**28 October 2005**

# Quiz



With Comfort and Energy Efficiency in mind,  
which car do you select to drive in the  
Panama City during the summer?

# Potential Answers

- **The black car (!)**
- **The white car**
- **Pick the black car and move to Denmark**
- **Who cares about energy efficiency or comfort?**

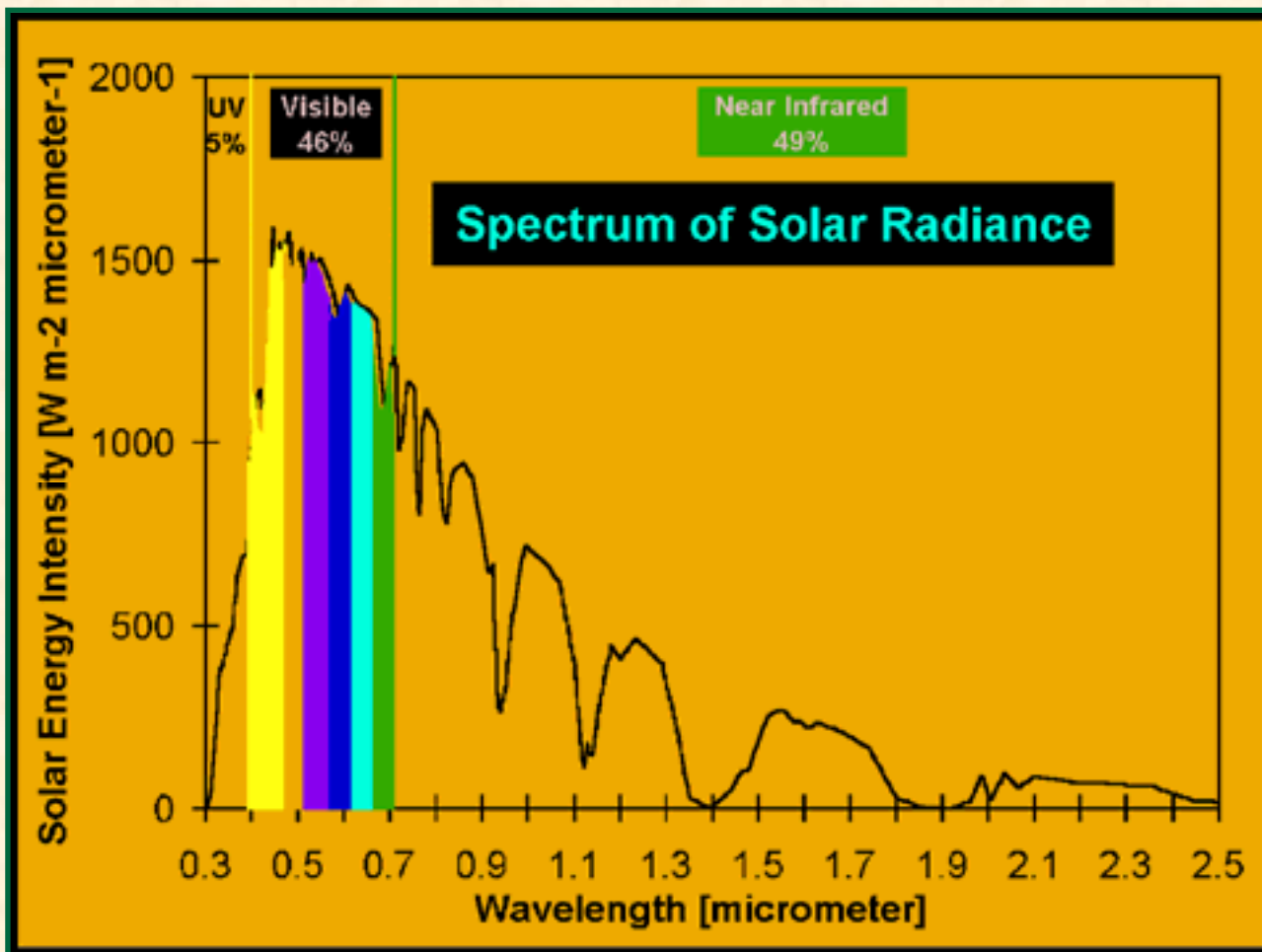
# Proof of Concept



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# Solar Energy Spectrum



# Critical Properties

**Reflectance ( $\rho_{\text{solar}}$ )**

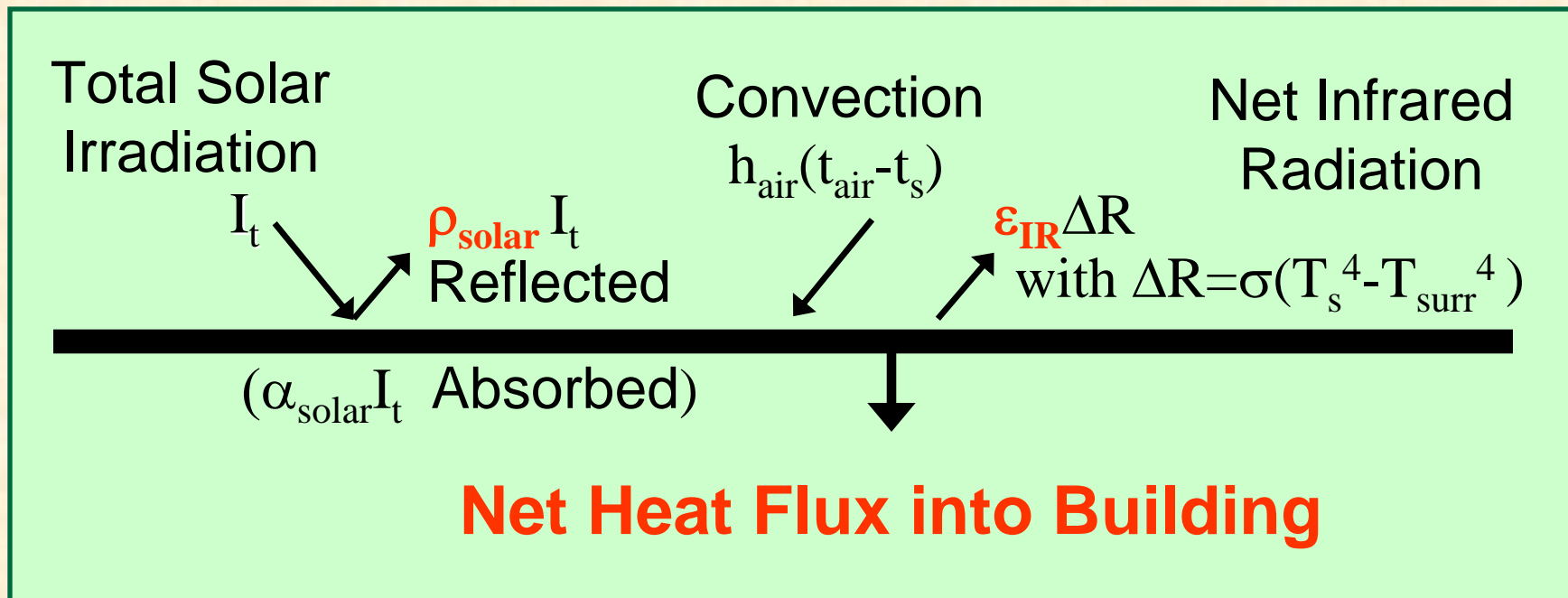
**Emittance ( $\epsilon_{\text{IR}}$ )**



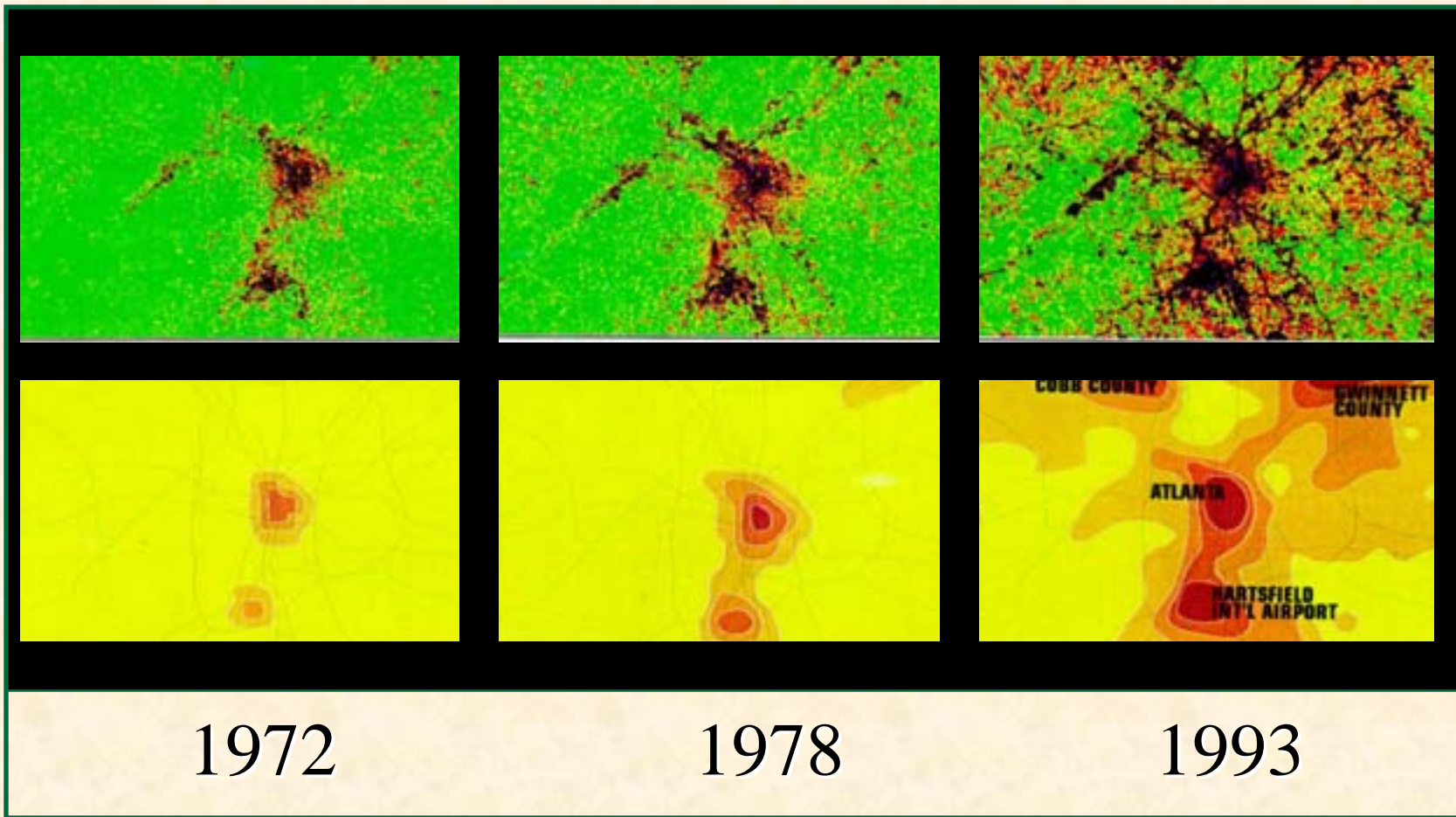
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# $\rho_{\text{solar}}$ and $\epsilon_{\text{IR}}$ are Both Very Important



# Atlanta's Changing Environment



# Working with Industry Partners

- **Team with metal roof, single ply membrane, and roof coating associations and their members and Textured Coatings**
- **Federally co-funded**

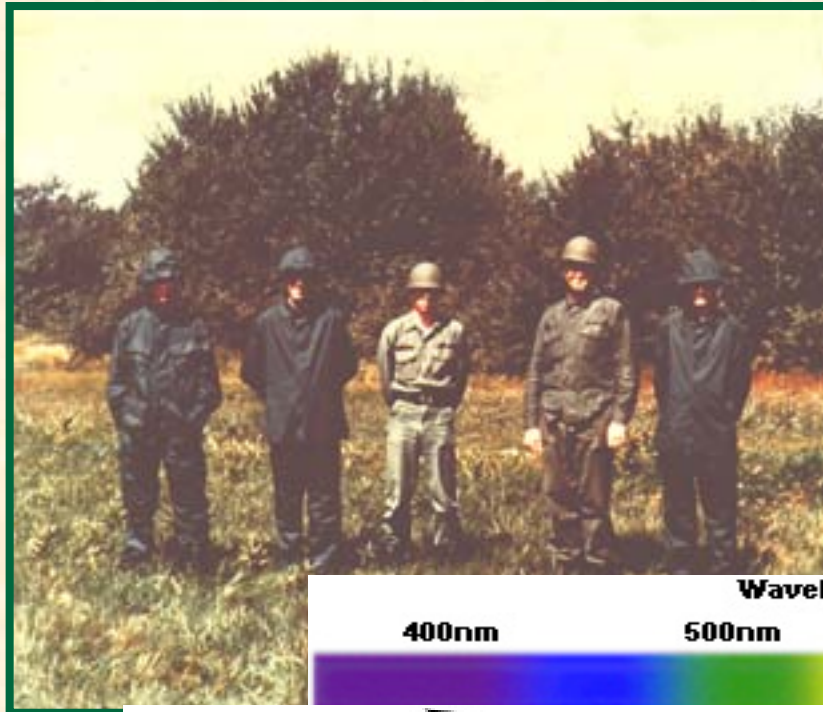


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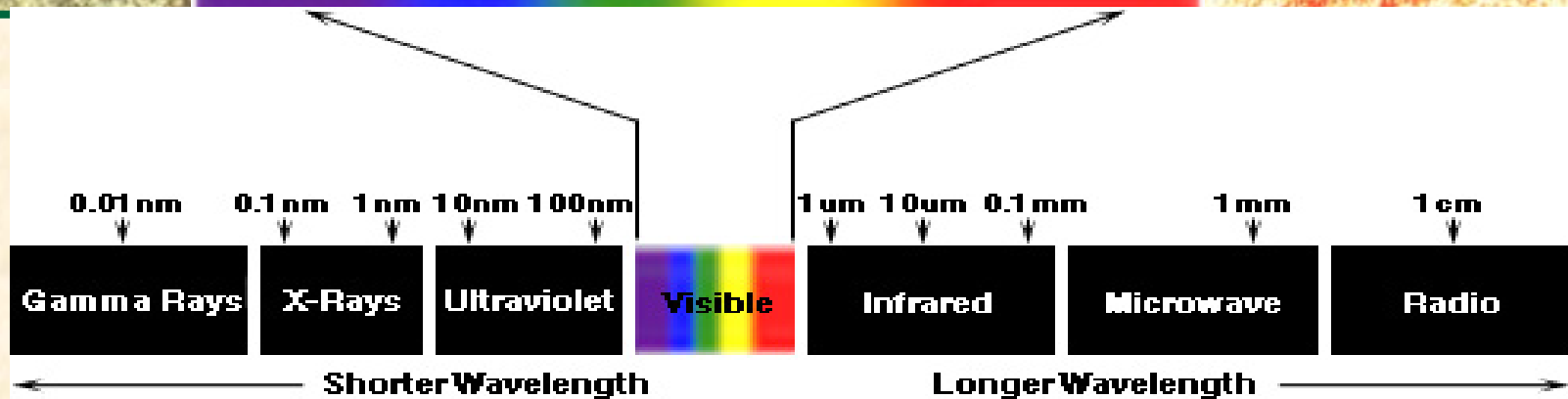
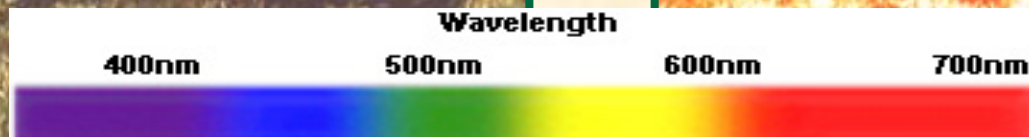
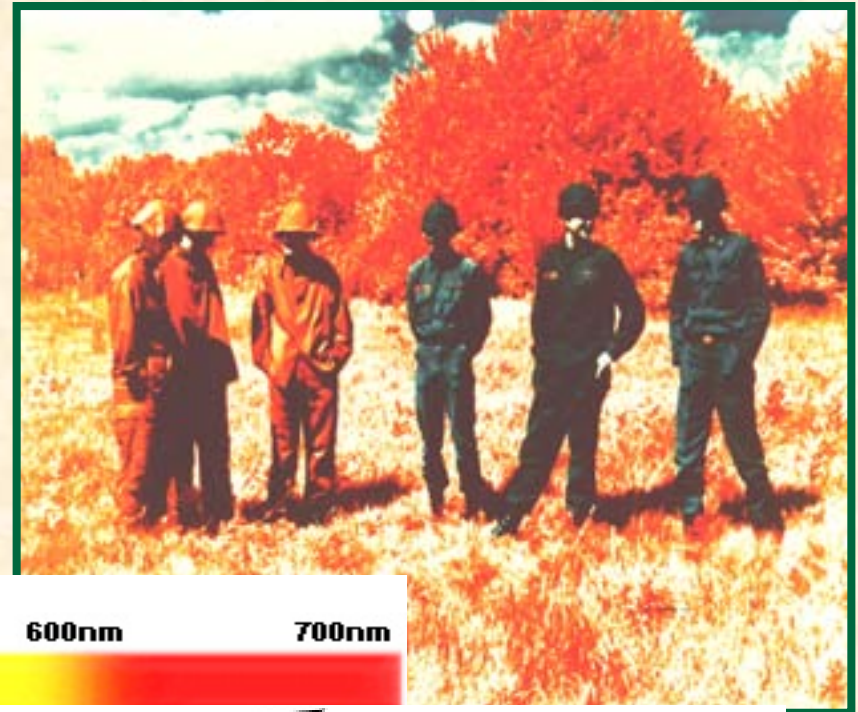
  
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# Camouflage Invisible to Night Vision

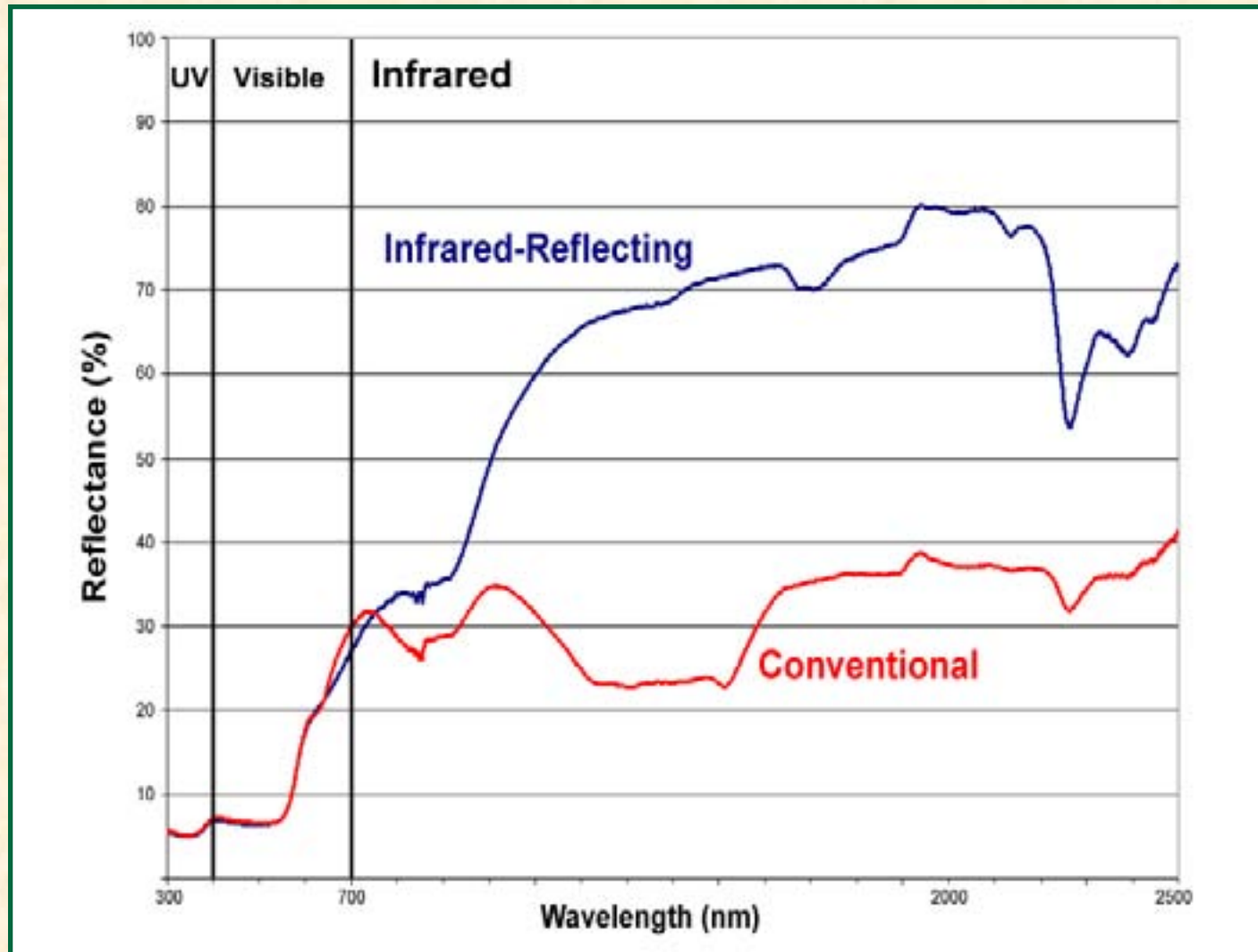
Conventional Film



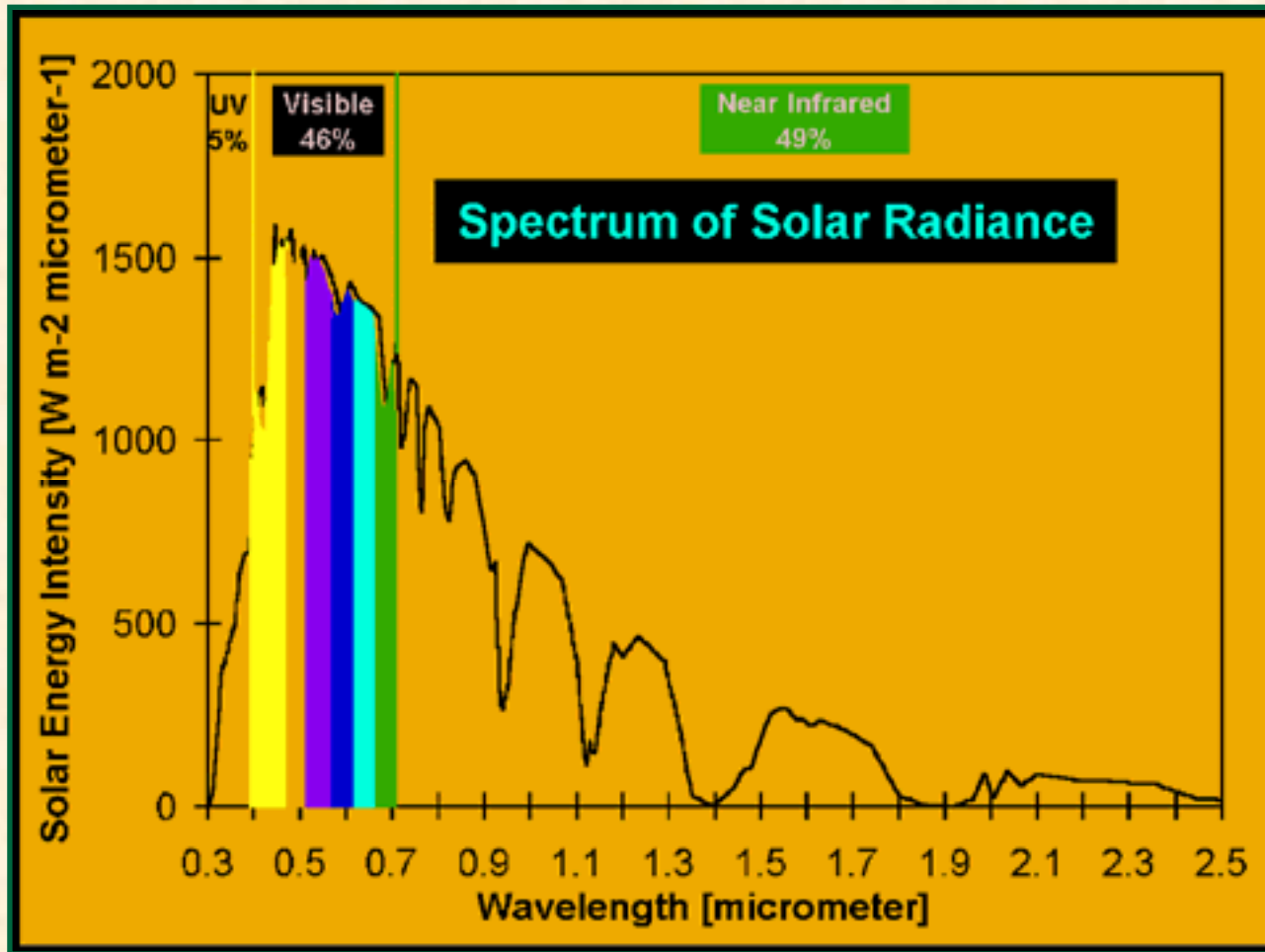
Near Infrared Film



# Conventional vs. Infrared Pigments



# Solar Energy Spectrum



# Overview: Scope of Work

- **Compare thermal performance of walls with cool (high infrared reflectance) and standard colors**
- **Use Textured Coatings of America's SuperCote Platinum and SuperCote products**

# Overview: Scope of Work

- **Phoenix site: Stucco-coated with various constructions facing east, south, southeast and southwest already covered with Mountain Gray color. Install instrumentation and recoat test areas.**
- **Jacksonville site: Wood siding facing south already covered with Underseas color. Install instrumentation and recoat test areas.**
- **Oak Ridge campus site: Bare stucco-coated test area facing south. Add instrumentation; prime and coat test areas.**

# Phoenix Site

- **Single-story wings with central vaulted ceiling area for family room + dining room/kitchen**



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## Phoenix Site

- **Southeast and southwest exposures on walls of office in west wing. Outside temperature sensors attached to 10<sup>3</sup>/<sub>4</sub> in. thick walls**



# Phoenix Site

- **Add gypsum panels for instruments to sense inside temperatures and heat flow through walls**



# Phoenix Site

- **South and east exposures on walls of exercise room. South 15 in. thick; east 6¼ in. thick**



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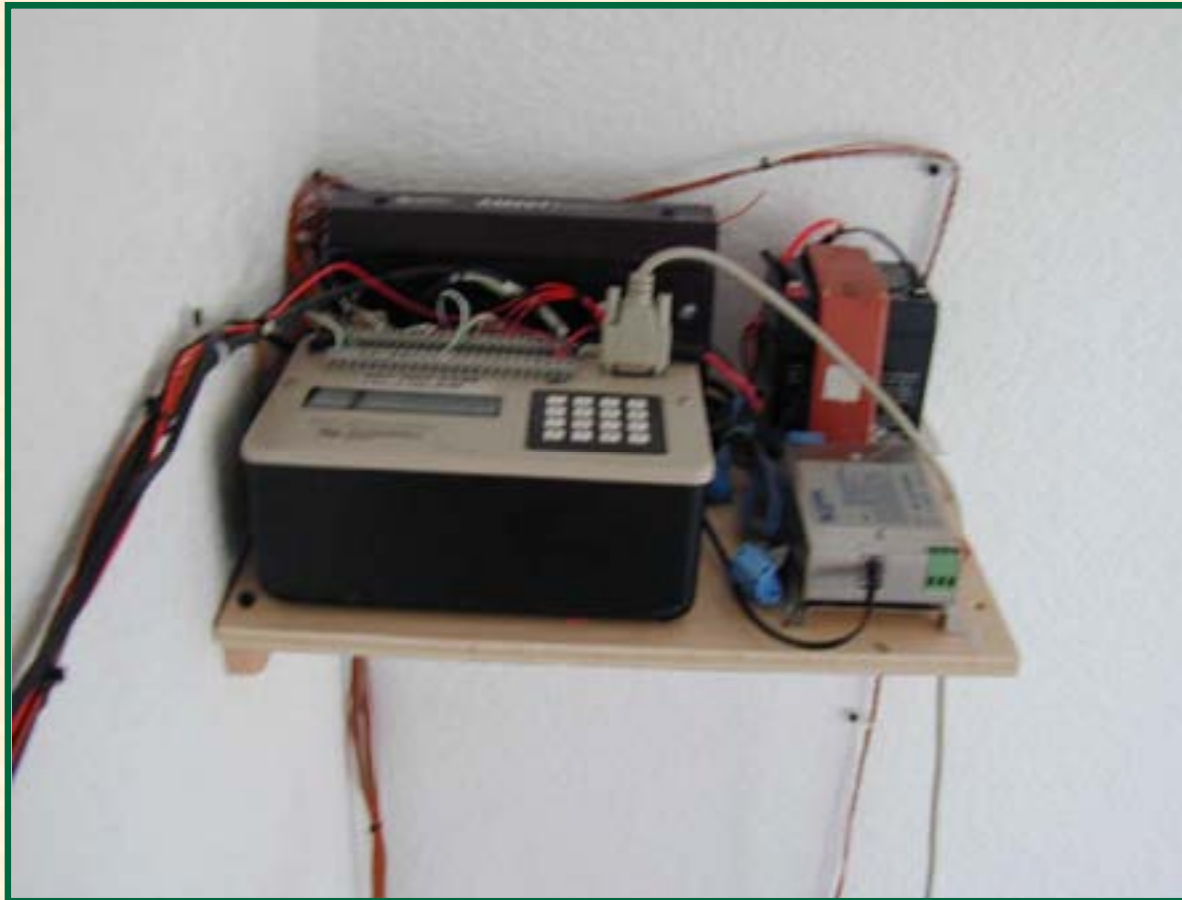
# Phoenix Site

- **Data logger and modem in exercise room. Wires from west wing in shallow trench through yard**



# Phoenix Site

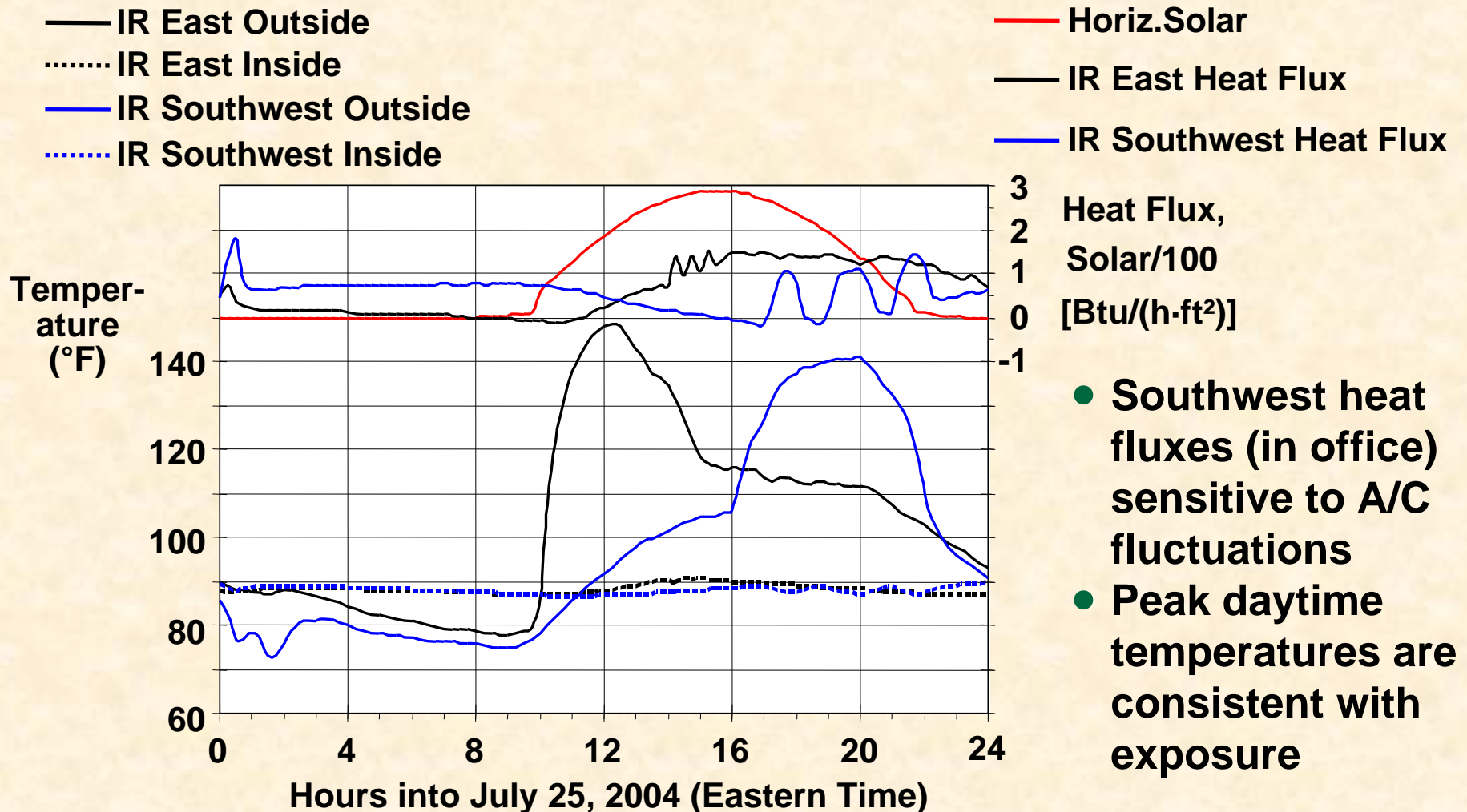
- **Data logger transmits data through modem to computer at Oak Ridge over dedicated line**



# Phoenix Site

- **Data obtained 5/2/04 through 11/30/04. Remove instrumentation on 12/2/04.**
- **Check consistency of data with program that estimates wall properties from measured temperatures and heat fluxes. R-values vary as expected.**
- **Different directions of exposure and varying thickness make it tough to interpret data.**
- **Limited height of walls and decorative overhang cause shadowing problems.**

# Phoenix Site: IR East vs IR Southwest

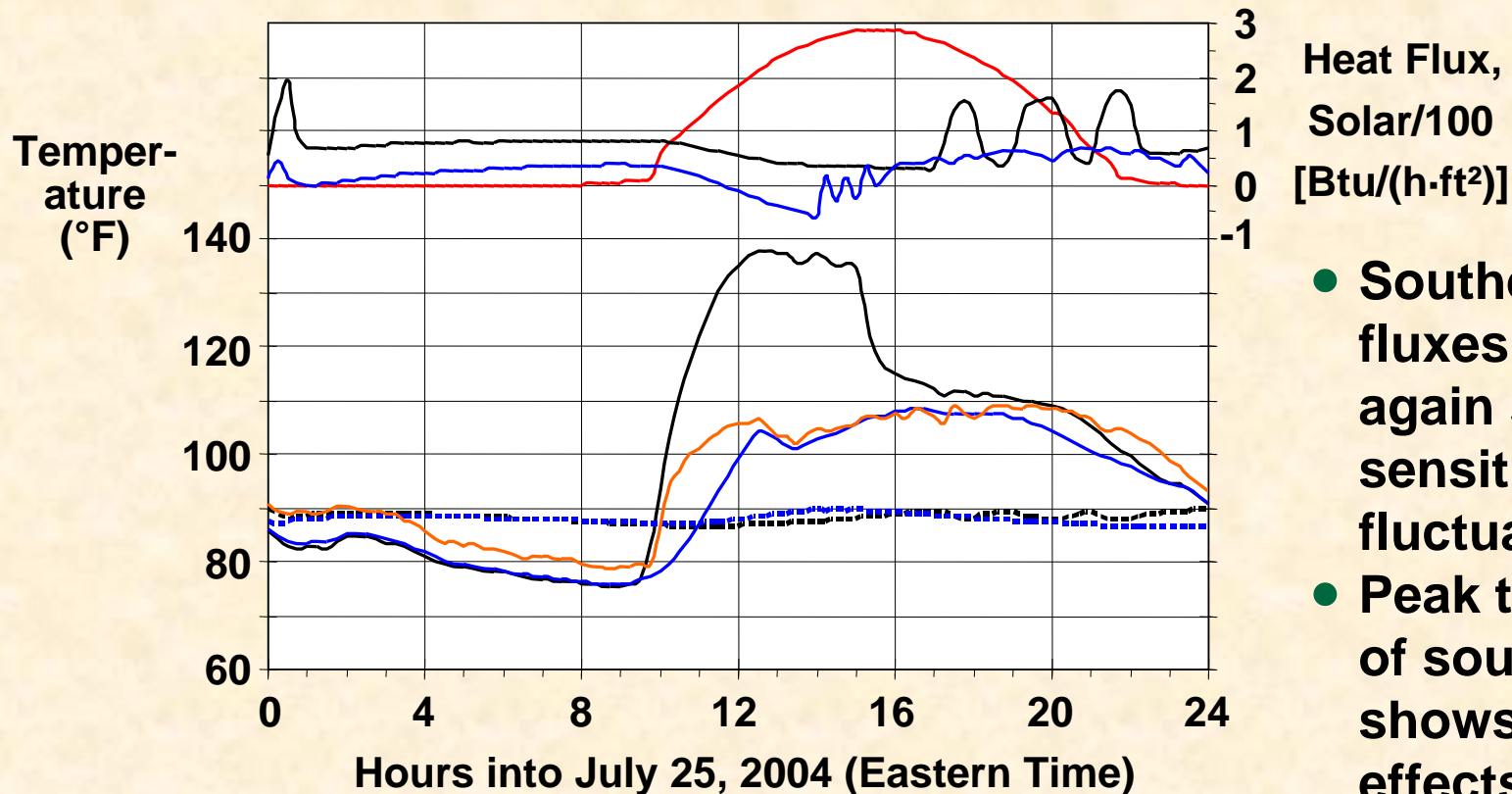


- Southwest heat fluxes (in office) sensitive to A/C fluctuations
- Peak daytime temperatures are consistent with exposure

# Phoenix Site: Non southeast vs IR South

— Air Temperature  
— Non Southeast Outside  
⋯ Non Southeast Inside  
— IR South Outside  
⋯ IR South Inside

— Horiz.Solar  
— Non Southeast Heat Flux  
— IR South Heat Flux



- Southeast heat fluxes (in office) again show sensitivity to A/C fluctuations
- Peak temperature of south exposure shows shadowing effects

# Jacksonville Site

- **Two-story house on Ponte Vedra beach**



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# Jacksonville Site

- **South-facing test exposures outside family room above steps from deck that faces ocean**



Meter  
for wall  
solar  
between  
test  
areas

# Jacksonville Site

- **Gypsum panels on inside walls painted to match existing decor**



# Jacksonville Site

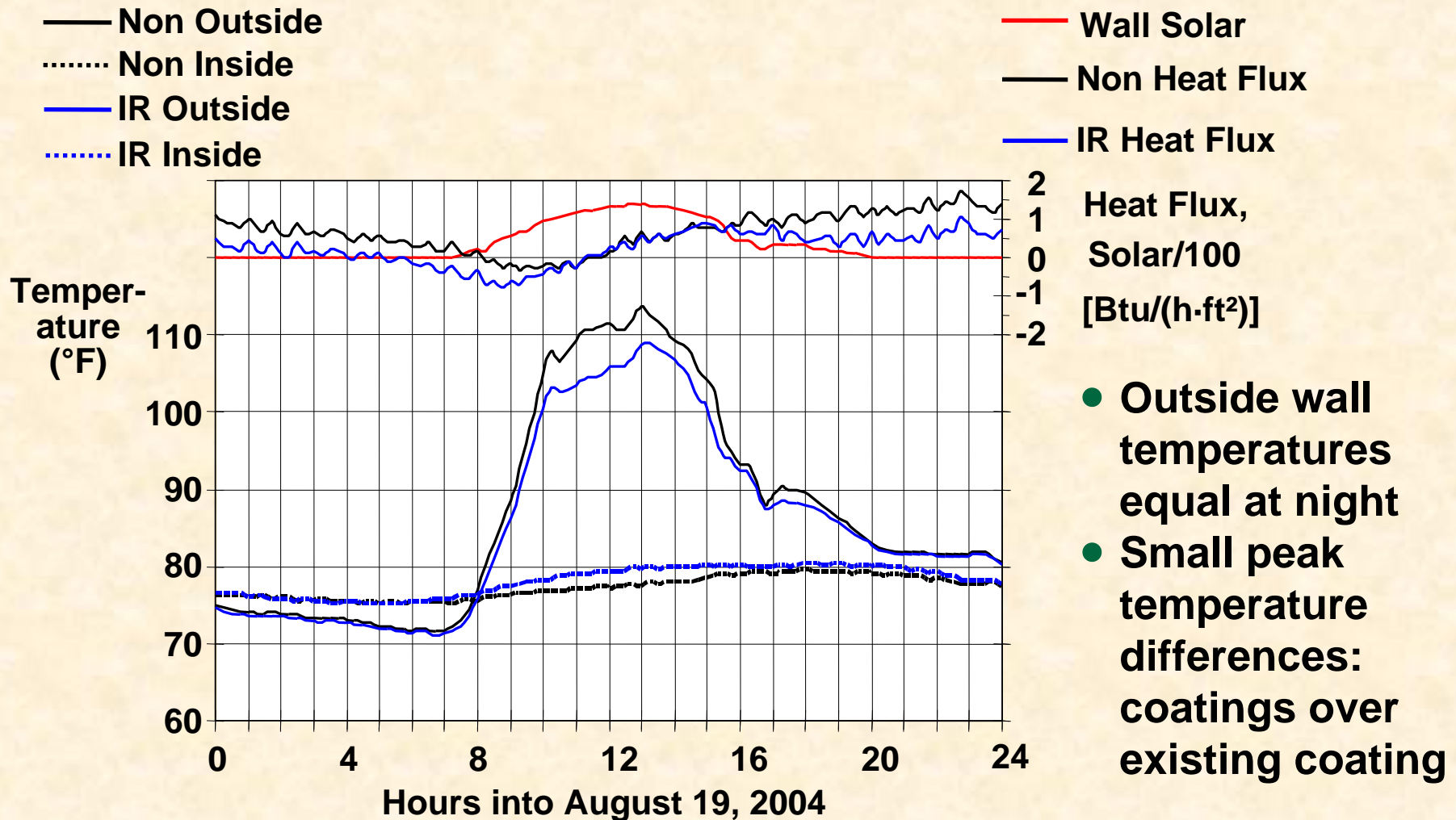
- **Data logger and modem tucked into corner behind TV. Used house phone line for monthly download. Owner plugged in phone line for call**



# Jacksonville Site

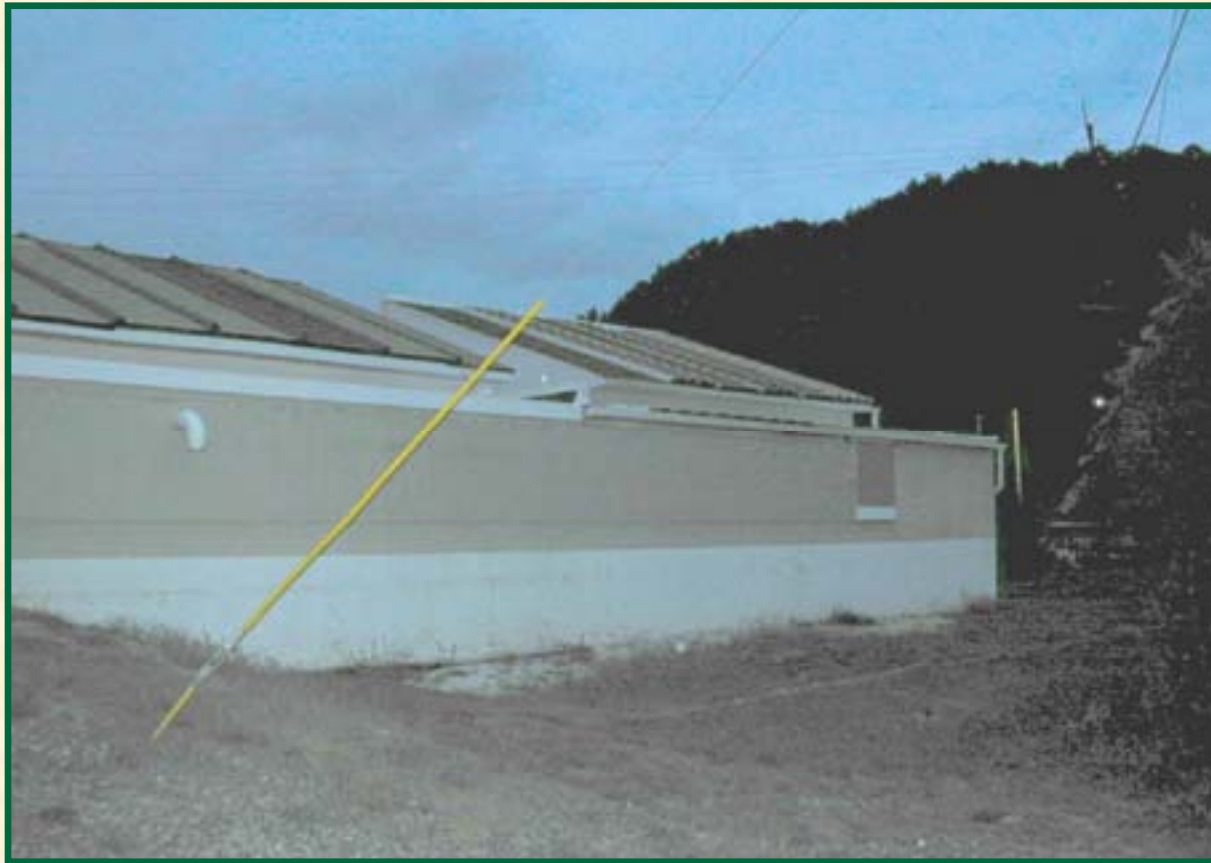
- **Data obtained 5/5/04 through 12/3/04 with recoating on 7/9/04. Remove instrumentation on 12/8/04**
- **Behaviors of solar flux incident on wall and outside surface temperatures show more cloudiness and rain than in Phoenix. Saw effects of Hurricanes Frances and Jeanne**
- **Exposures not at same level (followed slope of steps) so some height effects both outside and inside**
- **Railing for steps and enclosure for fireplace flue cause shadowing.**

# Jacksonville Site: Non Lower vs IR Upper



# ORNL Site

- **Stucco test section on south wall of Envelope Systems Research Apparatus (ESRA)**



## ORNL Site

- **Underseas Supercote Platinum (IR) on right stud space and upper half of middle; Supercote (Non) on rest except for strip of uncoated primer at bottom**



## ORNL Site

- **Add gypsum panels on inside like at Phoenix and Jacksonville sites**



## ORNL Site

- **Have ESRA data acquisition system in place and complete weather station next door**



# ORNL Site

- **Computer dedicated to ESRA data acquisition records detailed thermal performance**



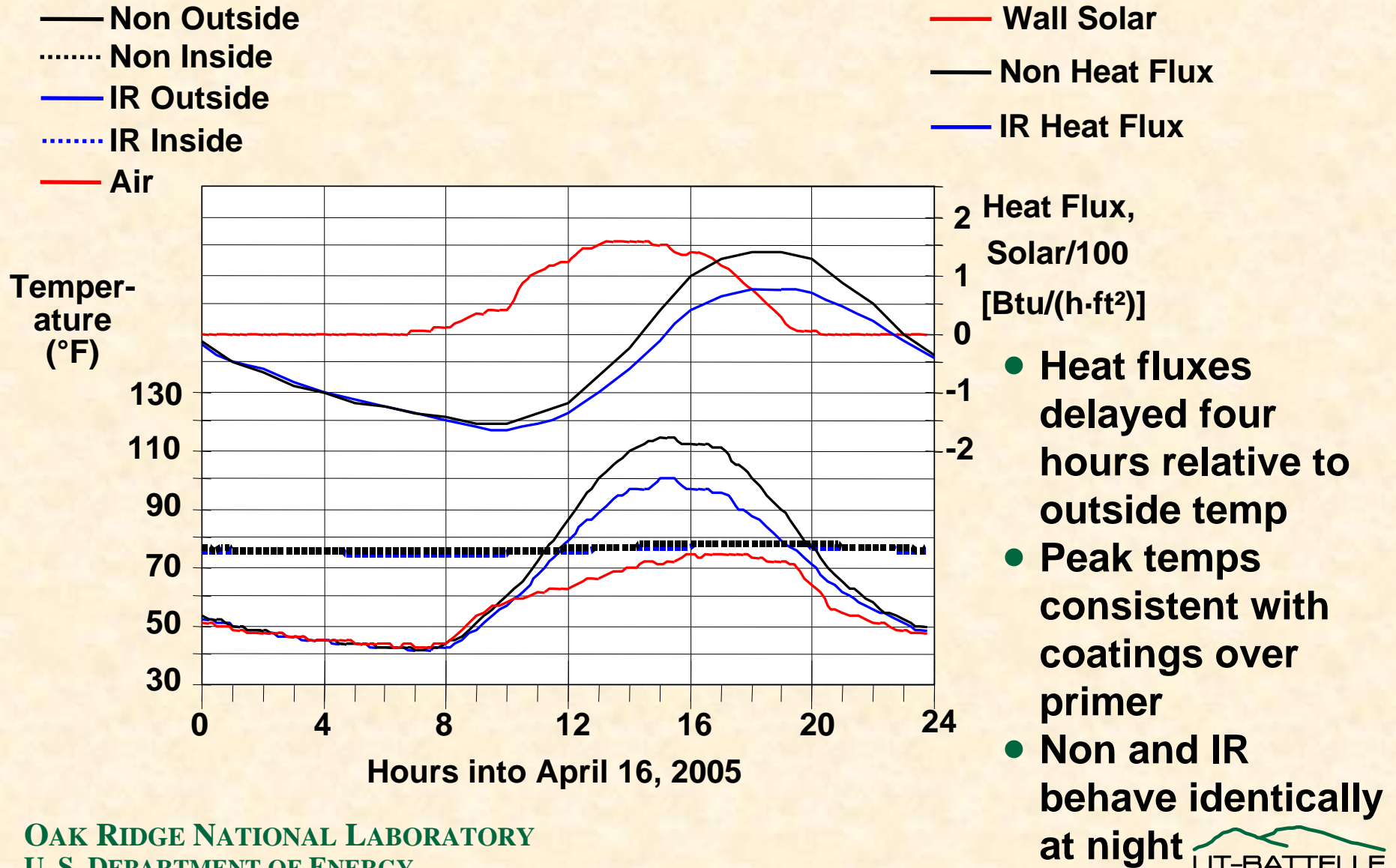
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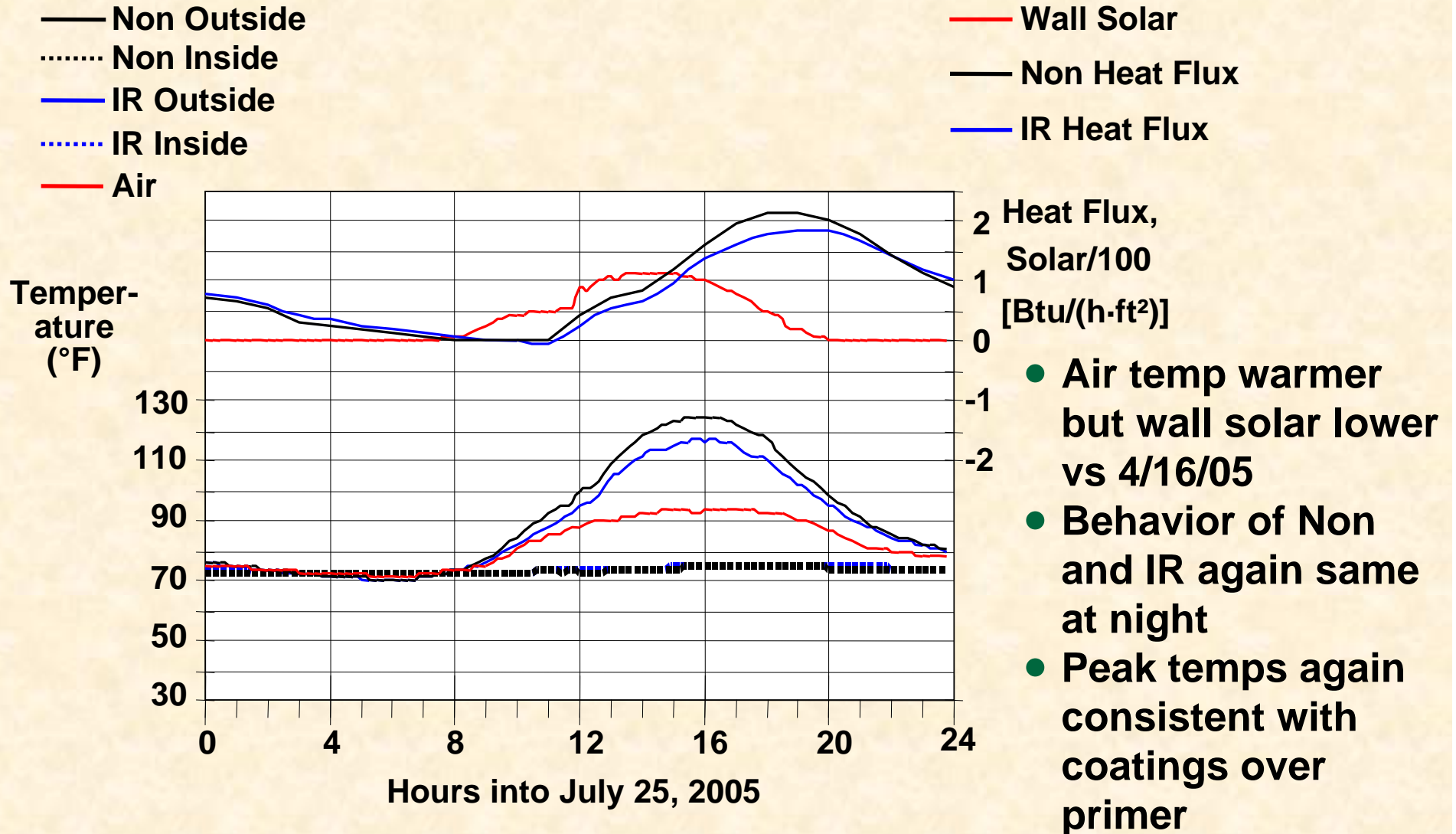
# ORNL Site

- **Data starting 7/30/04 with coating on 8/3/04. Data acquisition through August 2005**
- **Check consistency of data with program to estimate wall properties from temperature and heat flux measurements. Data very consistent from month to month**
- **Behavior of solar radiation control on vertical walls more complicated than low-slope roofs. Difficult to generalize simply**

# ORNL Site: Non vs IR -- Spring Day



# ORNL Site: Non vs IR -- Summer Day



## Model for Wall Behavior

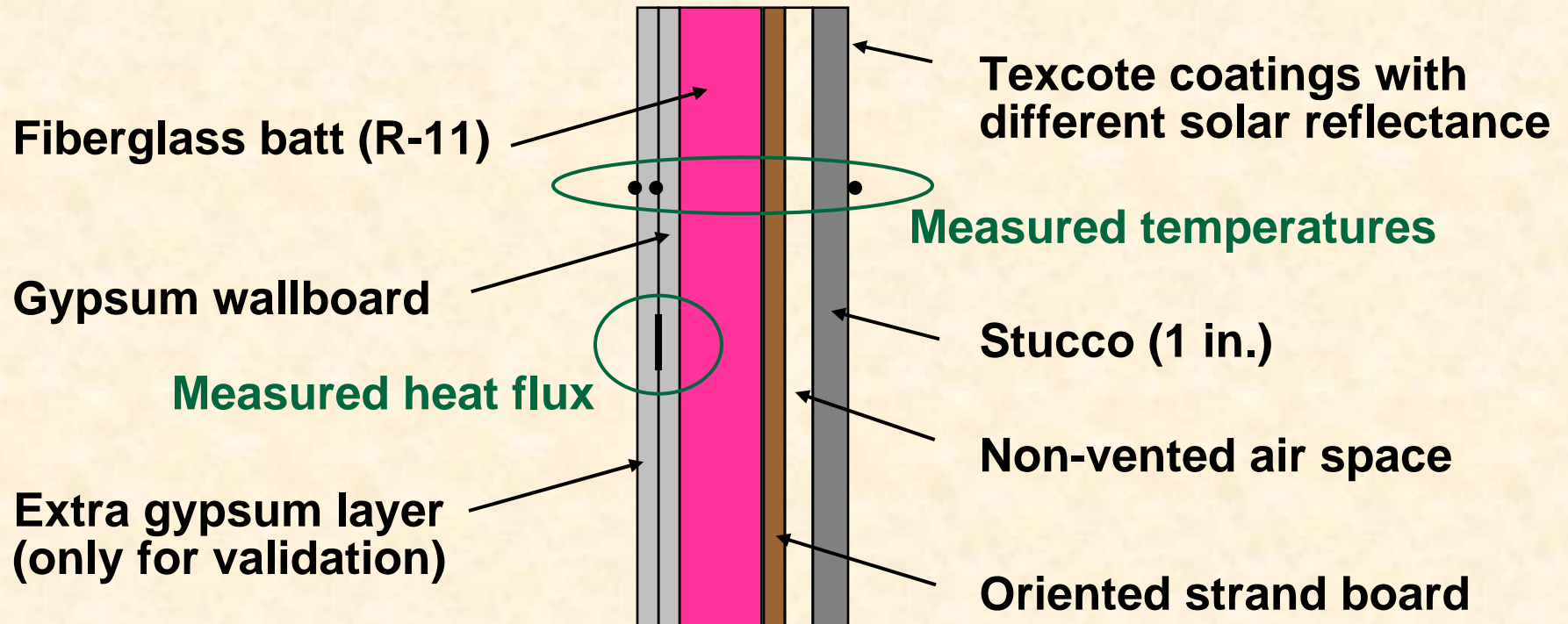
- **Seek a model that can be generalized to give results for whole buildings**
- **Have done extensive validation of a model in DOE 2.2 for a 1100 ft<sup>2</sup> ranch house**



- **Heat/cool with heat pump: 68°F winter; 76°F summer; size heat pump for climate**
- **Occupy with 3 people + Building America energy use profiles**

# Model for Wall Behavior

- To validate model, generate climatic data from ORNL weather station records for year of test
- Use properties of wall materials along with construction details for test section



# Solar Reflectance of Coatings

- **Samples over primer: Mountain Gray (Phoenix) and Underseas (Jacksonville and ORNL) 7/2/04**

Mountain Gray Supercote Platinum	0.44
Mountain Gray Supercote	0.30
Underseas Supercote Platinum	0.51
Underseas Supercote	0.25

- **Jacksonville on wood siding and existing coating 12/8/04**

Underseas Supercote Platinum	0.40
Underseas Supercote	0.24

- **ORNL on Stucco**

	8/4/04	9/27/04	5/18/05	8/3/05
Texcote Primer	0.71	0.67	0.72	0.66
Underseas Supercote Pt	0.49	0.50	0.49	0.49
Underseas Supercote	0.24	0.24	0.24	0.24

0.50  
0.24

Use averages

# Features of DOE 2.2 of interest

- **Can specify wall and solar reflectance of exterior surface and nearby ground**
- **Sun tracked hour by hour and can shade exterior surfaces by building and landscape**
- **Simulation of annual energy use by heating and cooling system includes response to thermostat schedules and to thermal mass in envelope**

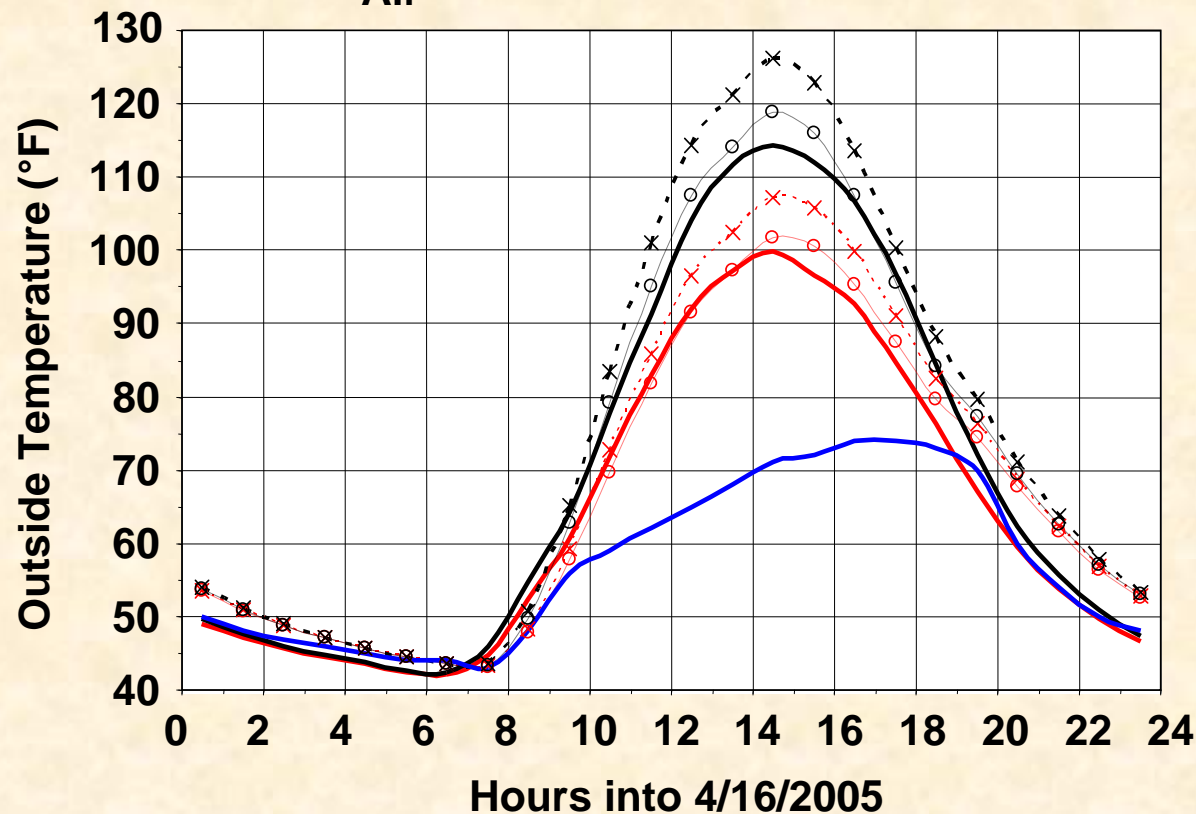
# Model of South Wall vs Measurement: Temperatures at Outside - Spring Day

Measure (solar reflectance):

- IR surface (0.495)
- Non surface (0.238)
- Air

DOE 2.2 with ground reflectance =

- ⋯×⋯ 0.24
- ⋯○⋯ 0.08
- ⋯×⋯ 0.24
- ⋯○⋯ 0.08



- Surface measurements and DOE 2.2 predictions equal air temperature at night
- DOE 2.2 peak predictions above peak measurements
- Ground reflectance of 8% (dark soil, asphalt) better than 24% (dry grass) for spring day

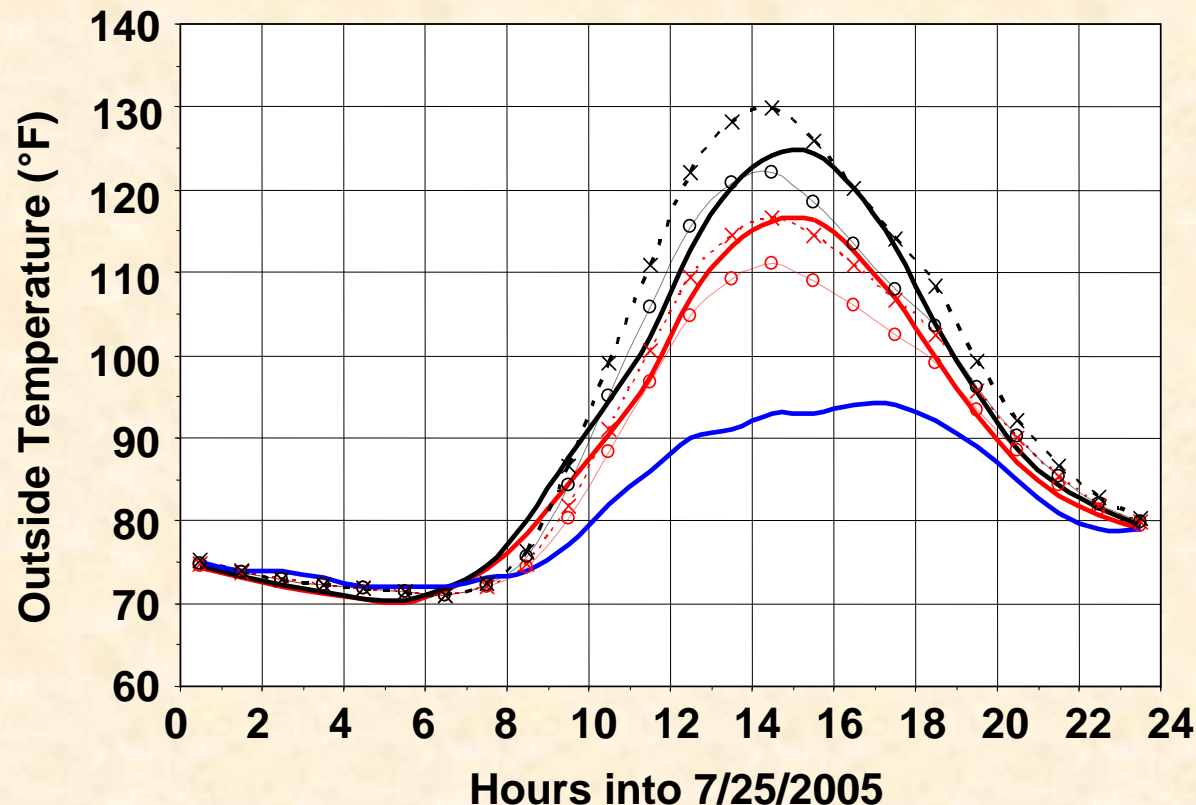
# Model of South Wall vs Measurement: Temperatures at Outside - Summer Day

Measure (solar reflectance):

- IR surface (0.495)
- Non surface (0.238)
- Air

DOE 2.2 with ground reflectance =

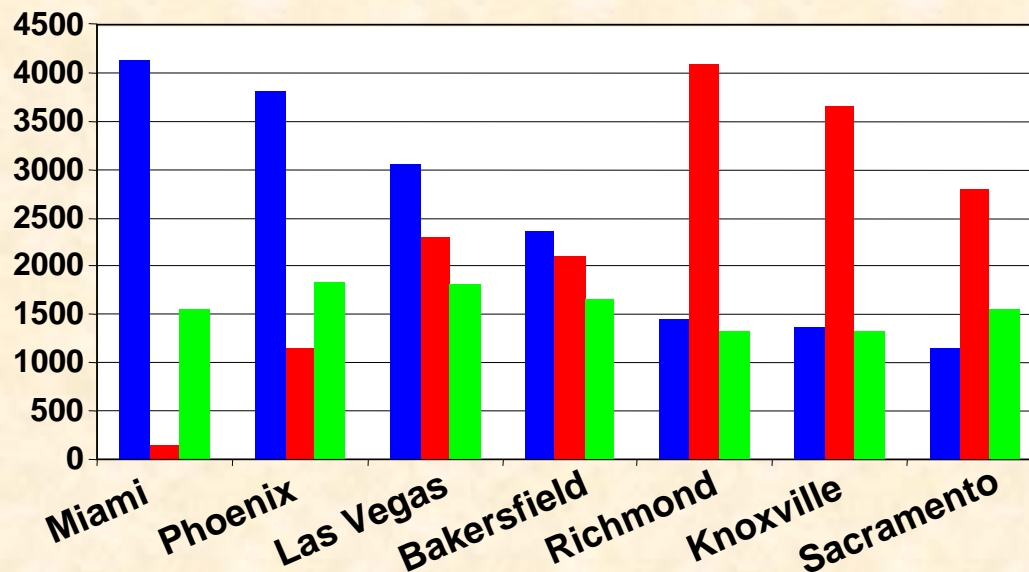
- ⋯x⋯ 0.24
- ⋯o⋯ 0.08
- ⋯x⋯ 0.24
- ⋯o⋯ 0.08



- DOE 2.2 peak behavior vs measurements not as regular as for 4/16/05
- Ground reflectance of 24% (dry grass) closer than 8% (dark soil) for this summer day.

# Model Generalizations

- **Building America Performance Analysis Resources at [http://www.eere.energy.gov/buildings/building\\_america/pa\\_resources.html](http://www.eere.energy.gov/buildings/building_america/pa_resources.html) gives energy use profiles for three occupants (3 BR home). Choose to heat and cool with air-to-air heat pump (76°F cooling; 68°F heating; no setup or setback)**
- **Choose seven different climates to show response of typical house to cooling and mixed climates of interest**

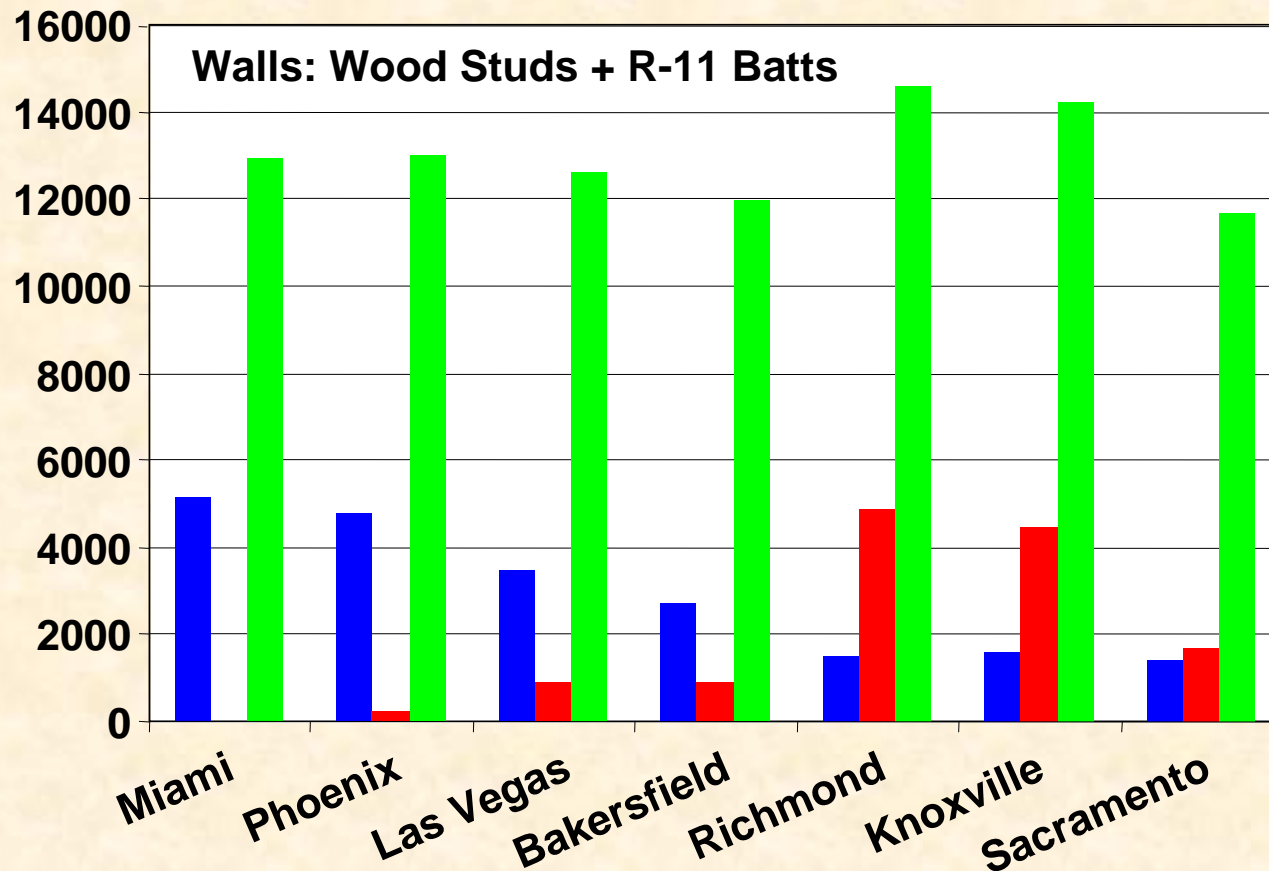


- CDD65 (°F-day)
- HDD65 (°F-day)
- Average Daily Solar (Btu/ft²)

- **Cities arranged by decreasing cooling degree days**

# Model Generalizations

- Ranch house with non-IR reflecting coating on walls shows variation in heating and cooling energy use that is consistent with climate variation



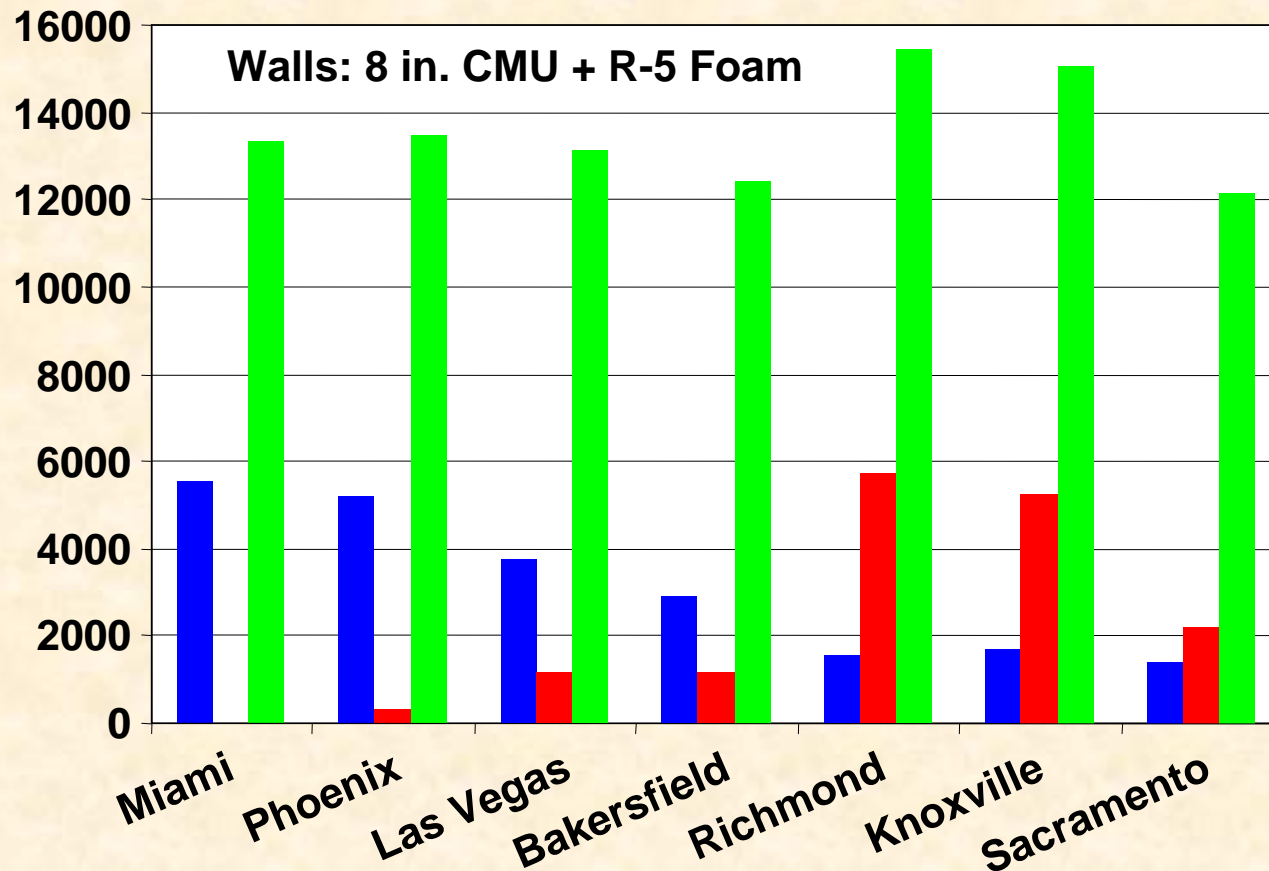
Annual Electricity Use (kWh)

- Cooling
- Heating
- All Uses

- Heating + Cooling is 26% (Sacramento) to 44% (Richmond) of Total Electricity Use
- Rest of use is 4250 for appliances, 1330 for lights and 2200 (Miami) to 3230 (Richmond) for domestic hot water (varying  $T_{\text{water}}$  supply)

# Model Generalizations

- **Alternate wall configuration of interest for cooling climates. Keep attic and floor insulation levels for consistency**



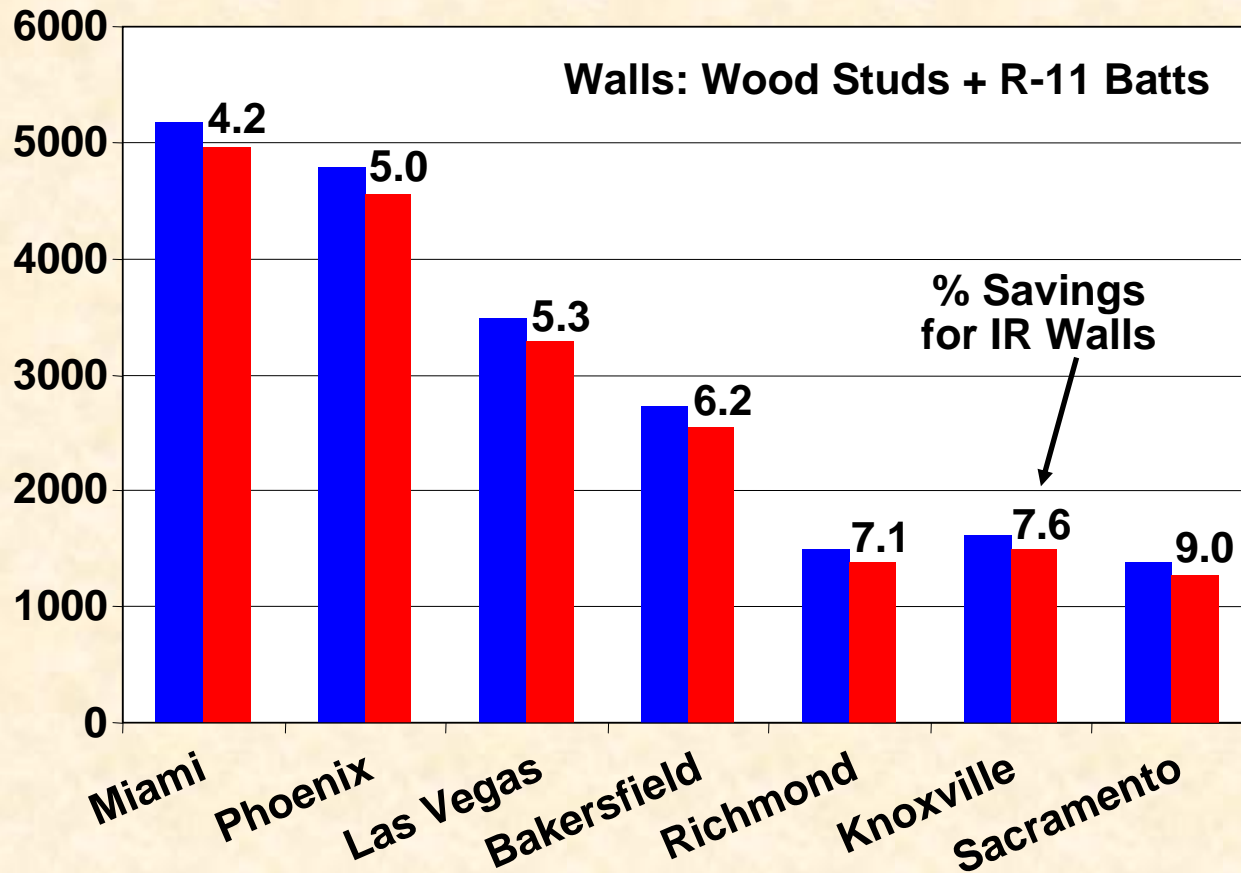
Annual Electricity Use (kWh)

- Cooling
- Heating
- All Uses

- Heating + Cooling is 29% (Sacramento) to 47% (Richmond) of Total Electricity Use
- Concrete block walls cause more total energy use in all climates: +270 (Miami) to +850 (Richmond)

# Model Generalizations

- IR reflective coating on conventional walls saves cooling energy. Savings are 4% to 9% compared to non-IR reflecting walls



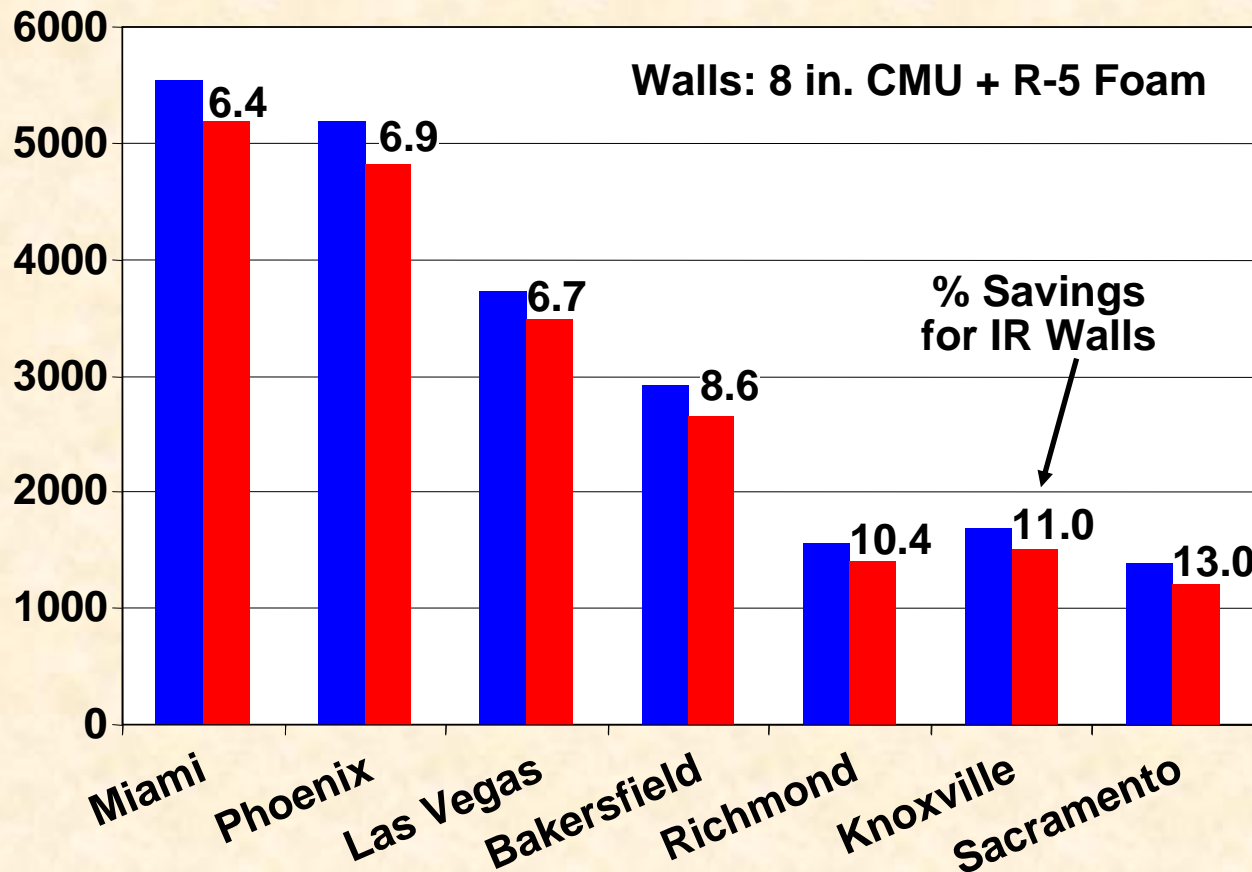
Annual Electricity for Cooling (kWh)

- Non Walls
- IR Walls

- Absolute savings vary from +240 (Phoenix) to +110 (Richmond)

# Model Generalizations

- IR reflective coating on CMU walls shows larger savings of cooling energy. Savings are 6% to 13% compared to cooling energy with non-IR reflecting walls



Annual Electricity for Cooling (kWh)

- Non Walls
- IR Walls

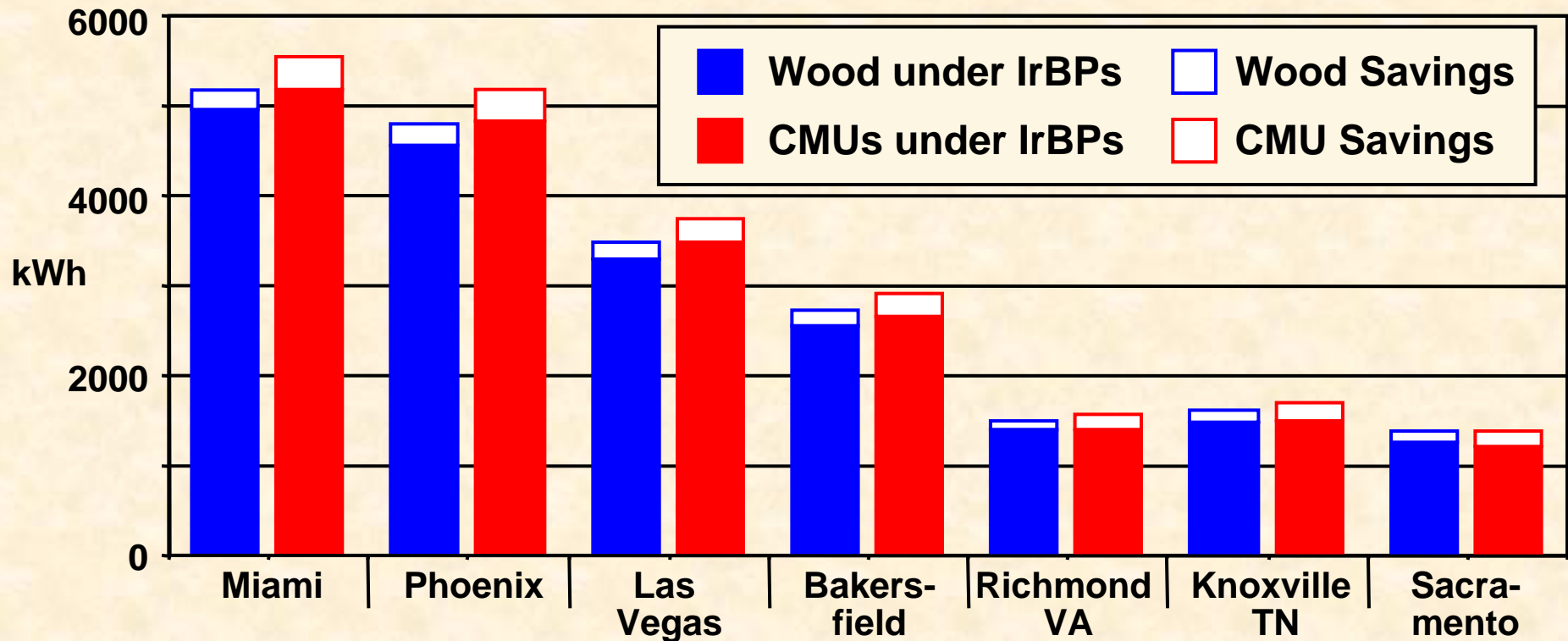
- Absolute savings vary from +360 (Phoenix) to +160 (Richmond)

# Project Summary

- **Demo sites in Phoenix and Jacksonville depict energy savings**
- **Full year of ORNL data validated DOE 2.2 model**
- **Complexity of real wall applications (different orientations, shading and construction) makes generalization very difficult**
- **DOE 2.2 whole building annual energy estimates for ranch house show that IR reflecting pigments save 4% to 13% of cooling energy**

# Project Summary

- **Cooling a 1100 ft<sup>2</sup> ranch house in various climates**



# Field Tests of Cool Walls in Cooling and Mixed Climates

**Questions or comments?**