



# EVS-15: A Future for the City

## Opportunities to Reduce Vehicle Climate Control Loads

Time for World Class Solutions



National Renewable Energy Laboratory

Robert B. Farrington Ph.D., P.E., Deborah L. Brodt, Steven  
D. Burch, Matthew A. Keyser

*CENTER FOR TRANSPORTATION TECHNOLOGIES AND SYSTEMS*



# NREL Mission

Lead the nation toward a sustainable energy future by developing renewable energy technologies, improving energy efficiency, advancing related science and engineering, and facilitating commercialization

*CENTER FOR TRANSPORTATION TECHNOLOGIES AND SYSTEMS*



# NREL Background

- ▶ Established in 1977 as Solar Energy Research Institute
- ▶ Current staff of approximately 800
- ▶ Operating budget of \$170M for FY96

# NREL Facilities



*CENTER FOR TRANSPORTATION TECHNOLOGIES AND SYSTEMS*

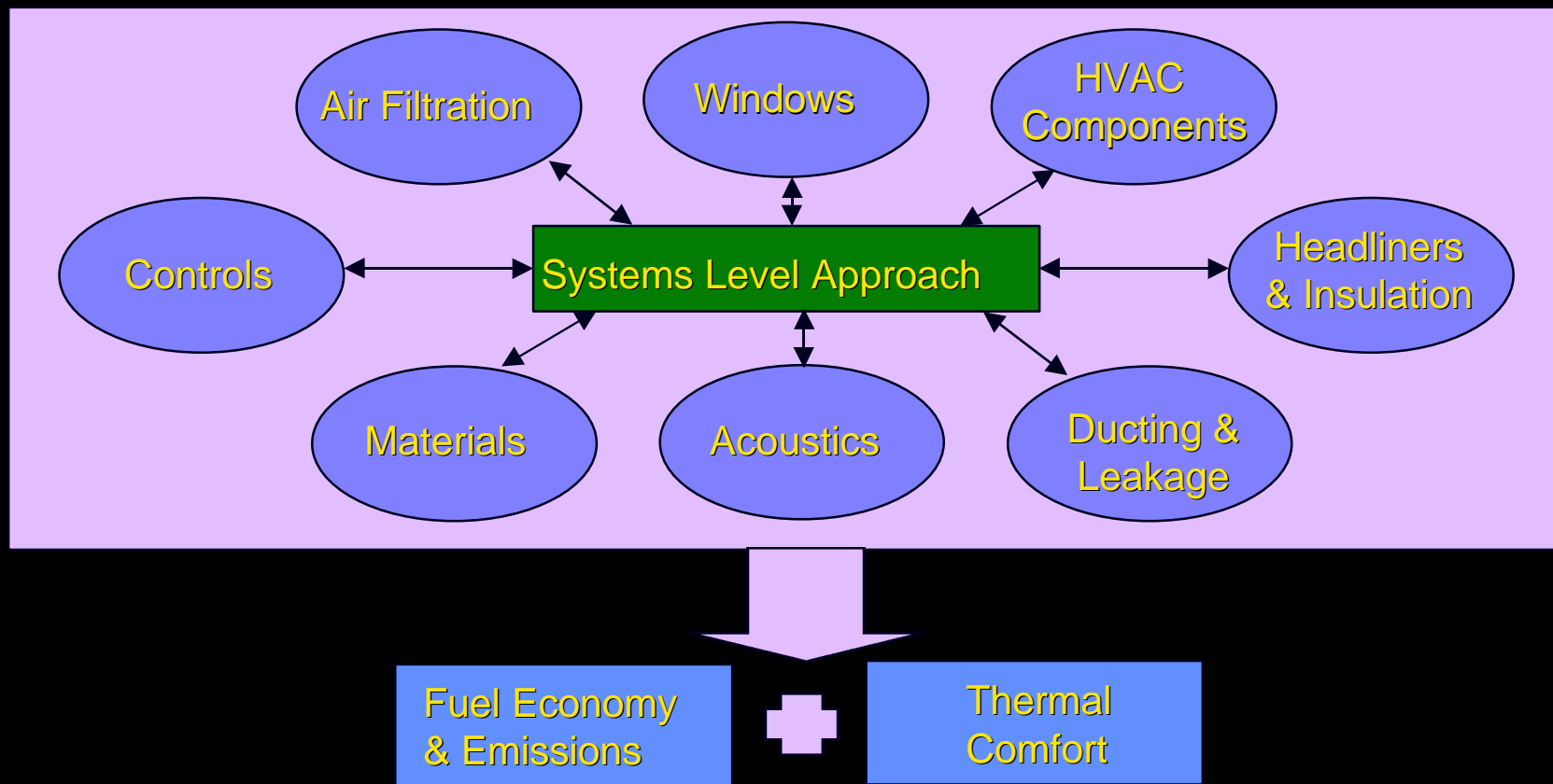
# Cool Car Goal

To reduce energy use for vehicle climate control by 50% while maintaining passenger thermal comfort and safety.



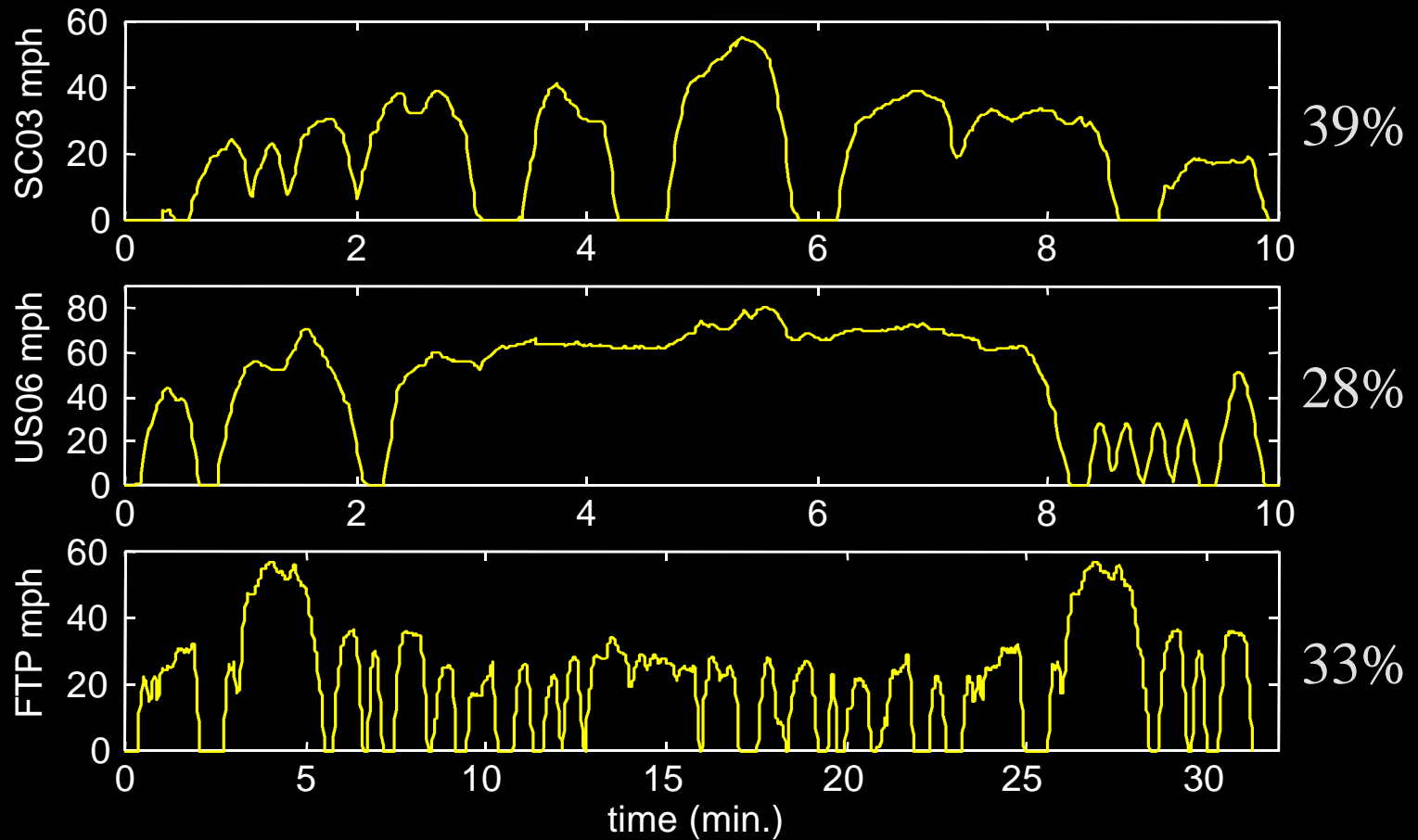
# Our Approach

A systems approach to integrate components and systems to provide thermal comfort while reducing fuel consumption and emissions.



*CENTER FOR TRANSPORTATION TECHNOLOGIES AND SYSTEMS*

# Supplemental Federal Test Procedure: Velocity Profiles





# Supplemental Federal Test Procedure: Timeline

- MY 2000: 40% of manufacturer's fleet
- MY 2002: 80%
- MY 2004: 100%

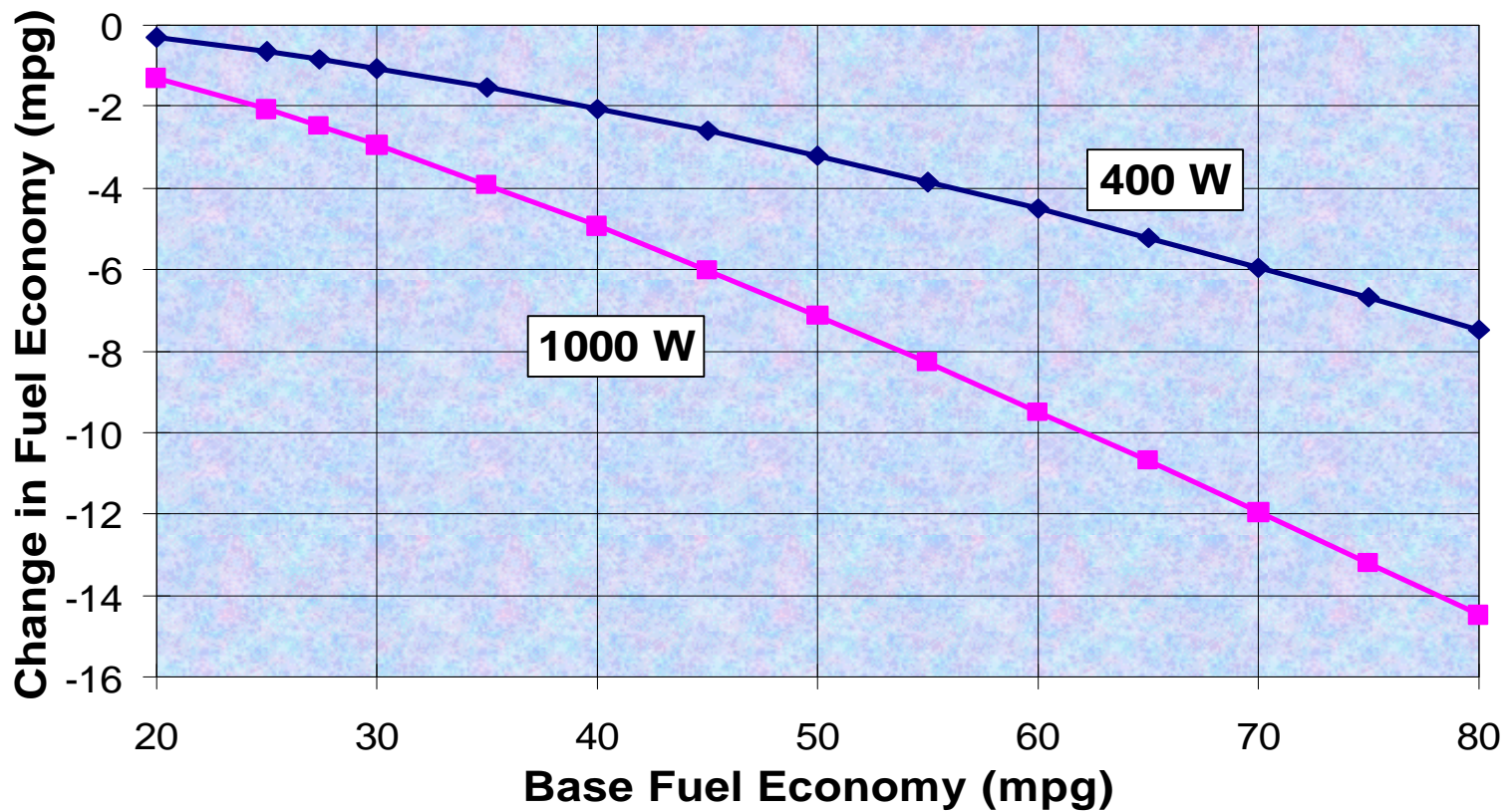
-For cars & trucks under 6000 lb GVW

-Phase-in starts in MY2002 for 6001-8500 lb GVW

Source: John German (EPA-Ann Arbor)



# Fuel Economy Penalties From Auxiliary Loads





# Reducing Vehicle Auxiliary Loads Saves Energy and Money

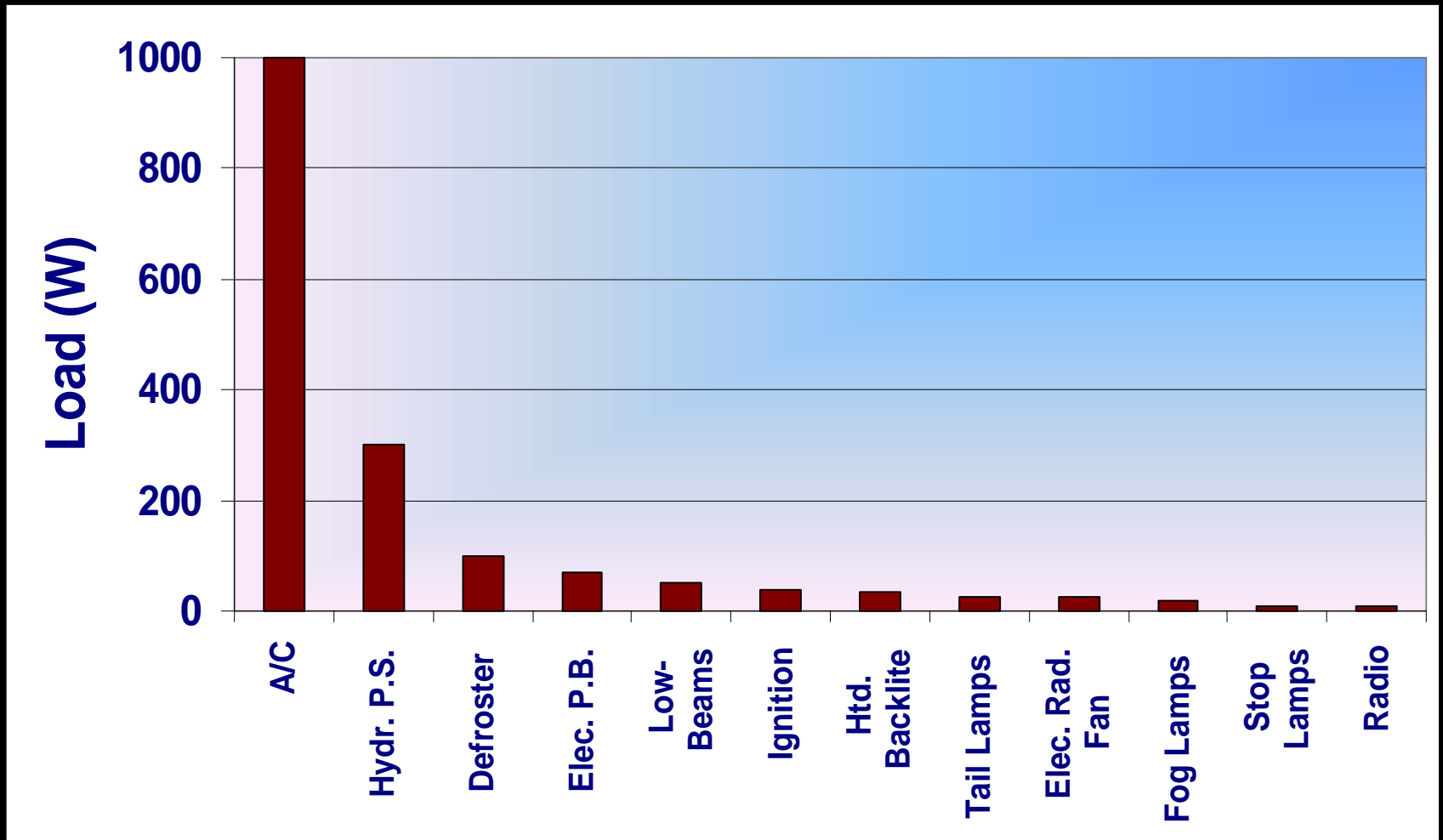
## ➤ MPG Effect

- 400 W load on 40 mpg vehicles reduces fuel economy by 2.3 mpg

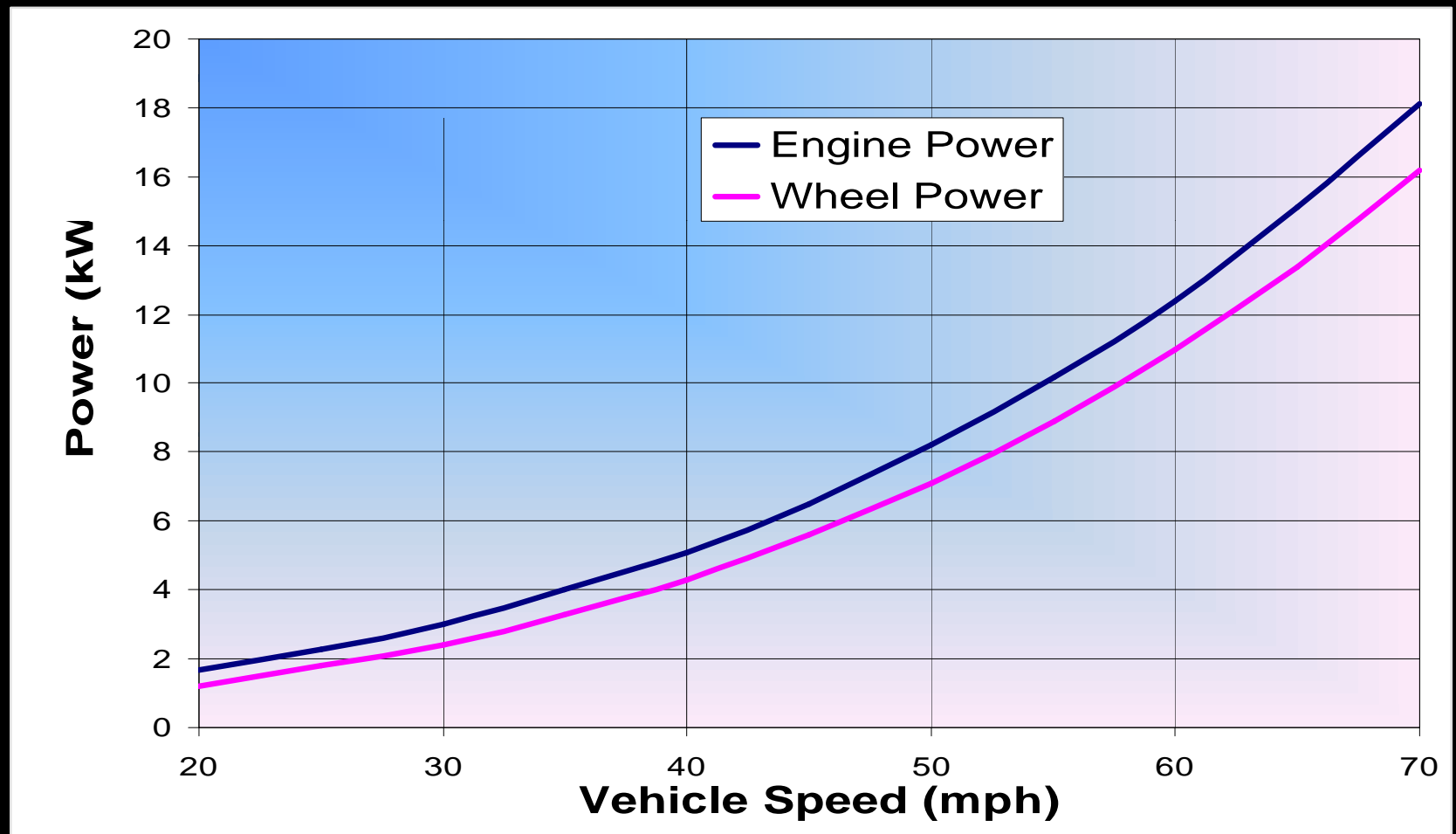
## ➤ \$ Effect

- 1 mpg increase saves \$4 billion/yr nationally
- Consumers spent \$104 billion on fuel and oil, 1993
- 5% reduction in fuel consumption => \$5 billion/yr and 127M barrels/yr.

# Average Accessory Loads



# Power vs. Vehicle Speed

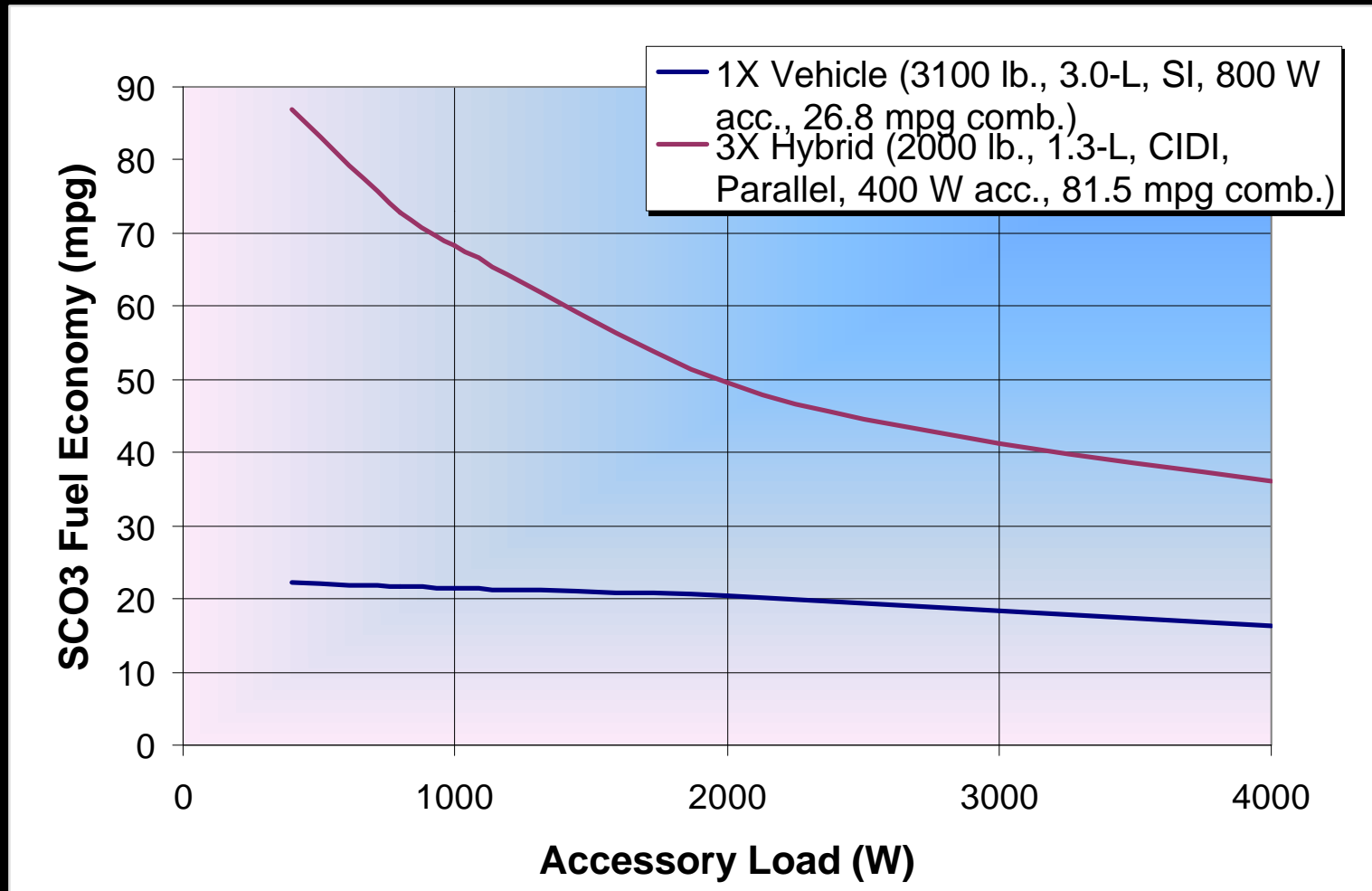




# A/C Increases Engine Loading

*CENTER FOR TRANSPORTATION TECHNOLOGIES AND SYSTEMS*

# Fuel Economy Impact

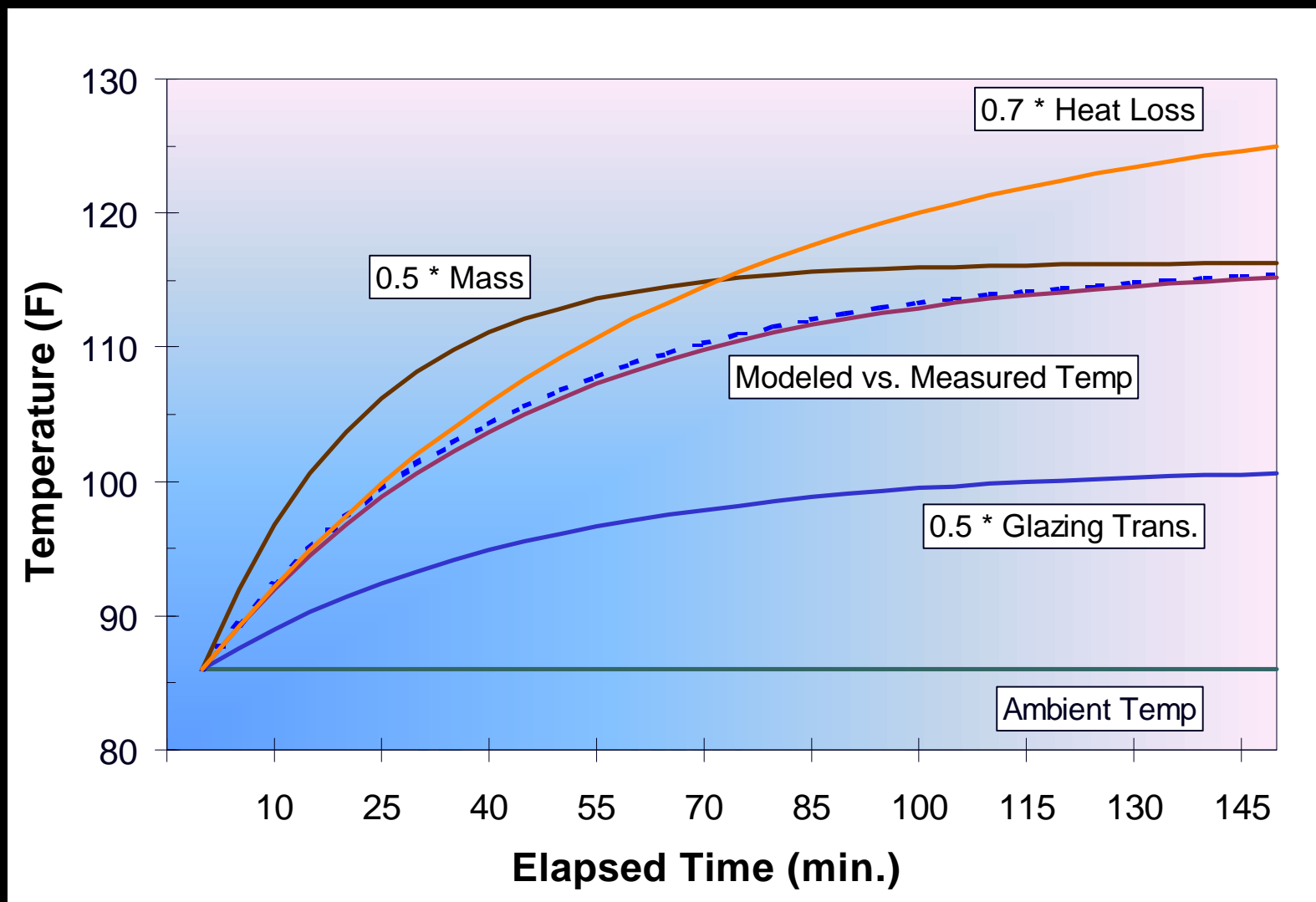




# Benefits of Cool Interiors

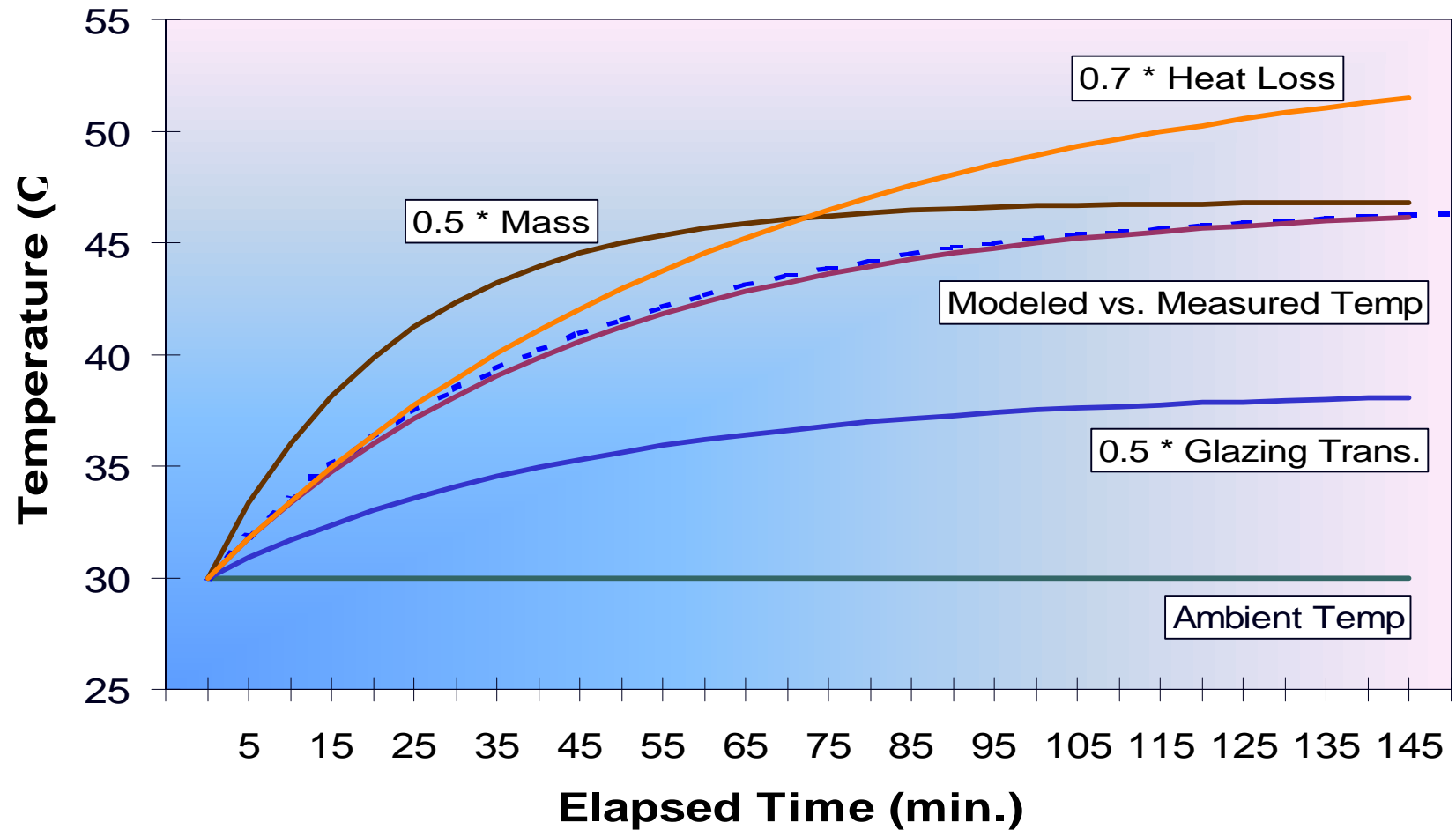
- ▶ Higher fuel economy
- ▶ Reduced emissions
- ▶ Greater initial occupant comfort
- ▶ Less harsh interior materials environment
- ▶ Driver safety - alertness, cooler surfaces

# Soak Temperature Sensitivity

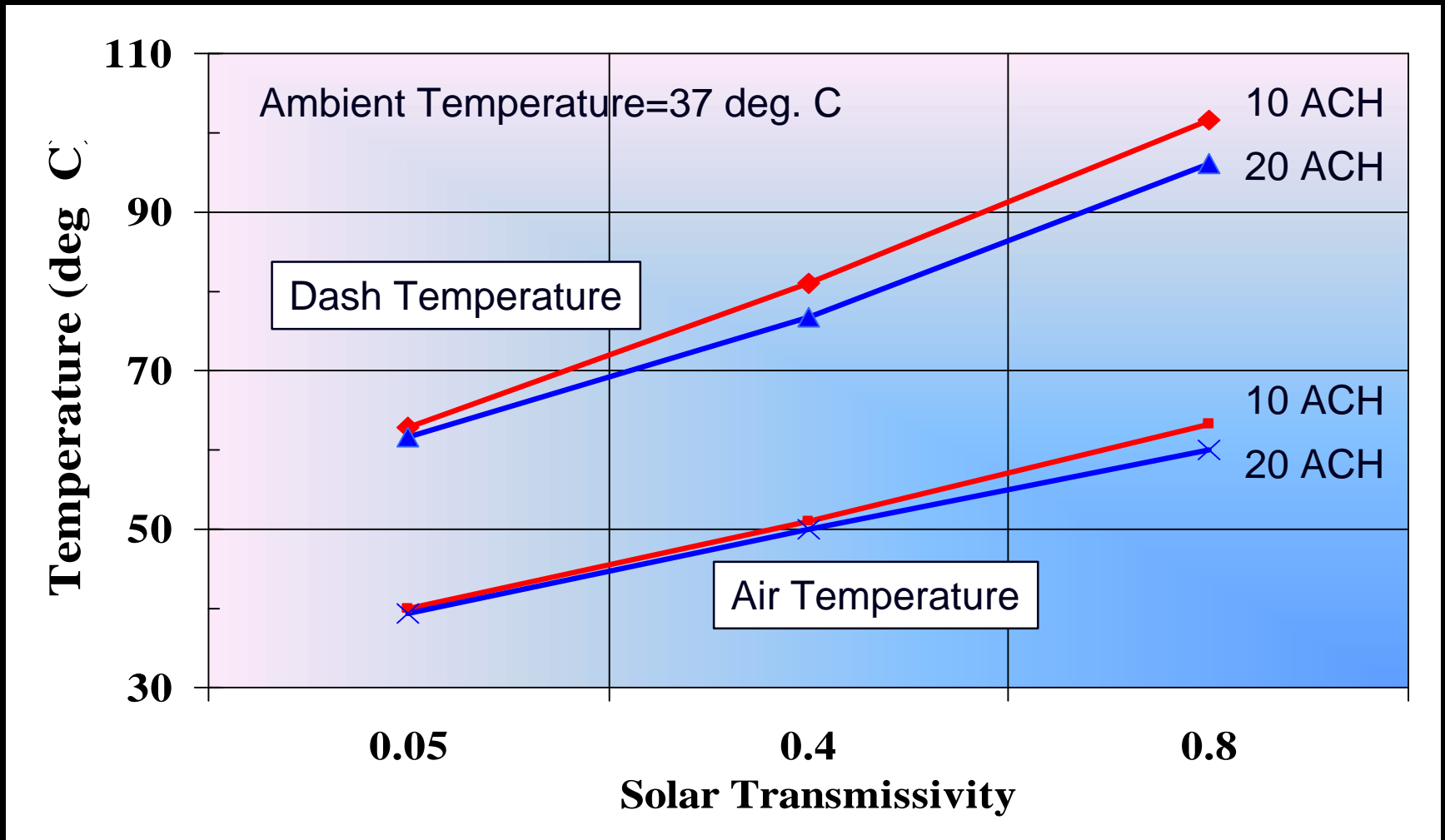




# Soak Temperature Sensitivity



# Predicted Peak Dash/Air Temps.



# NREL's Breeze Test Vehicle



*CENTER FOR TRANSPORTATION TECHNOLOGIES AND SYSTEMS*

# Solar Gain Reducing Windshields

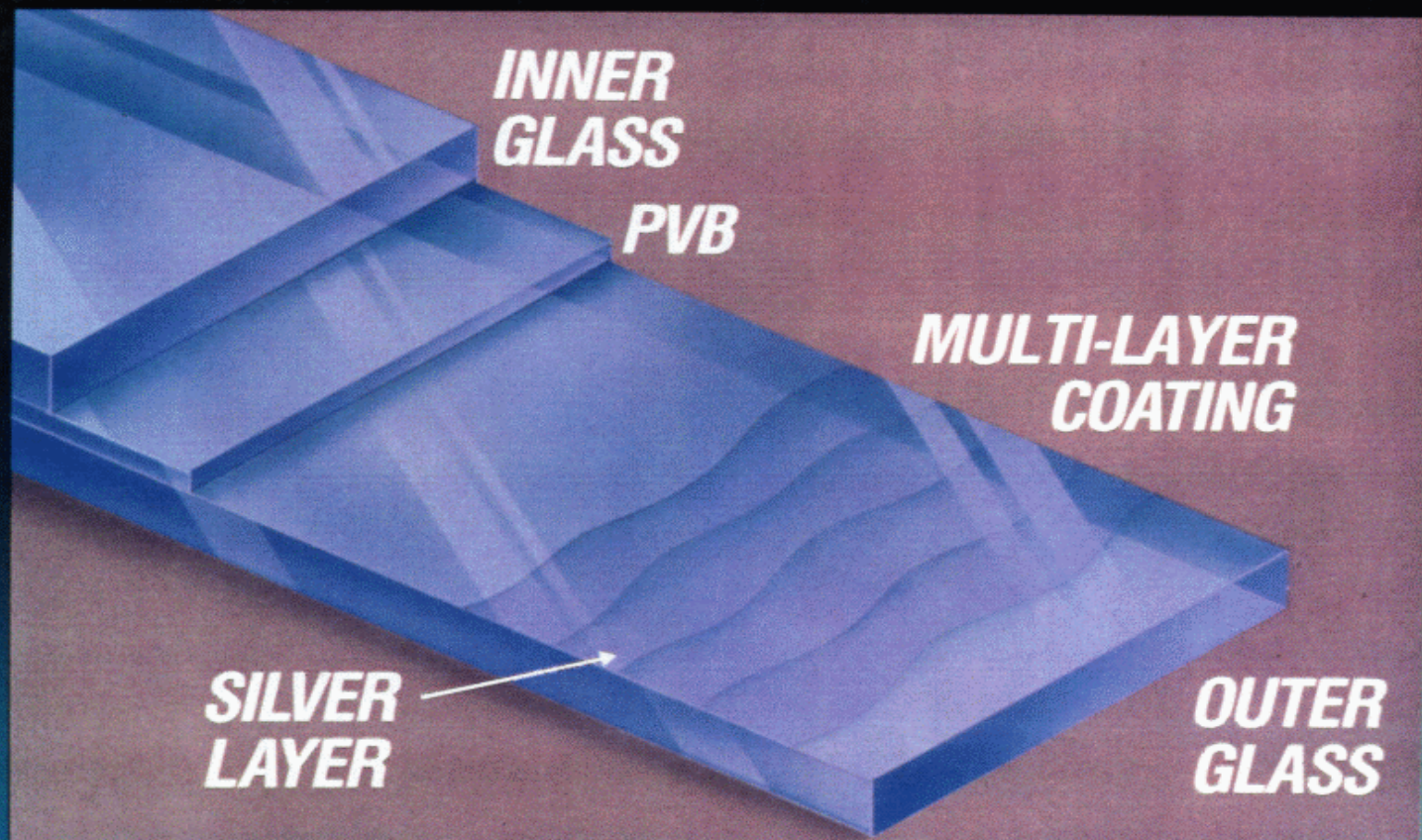
NREL tested 3  
different  
windshields:  
Sungate  
Solex  
Solar green



# Sungate Windshield Description

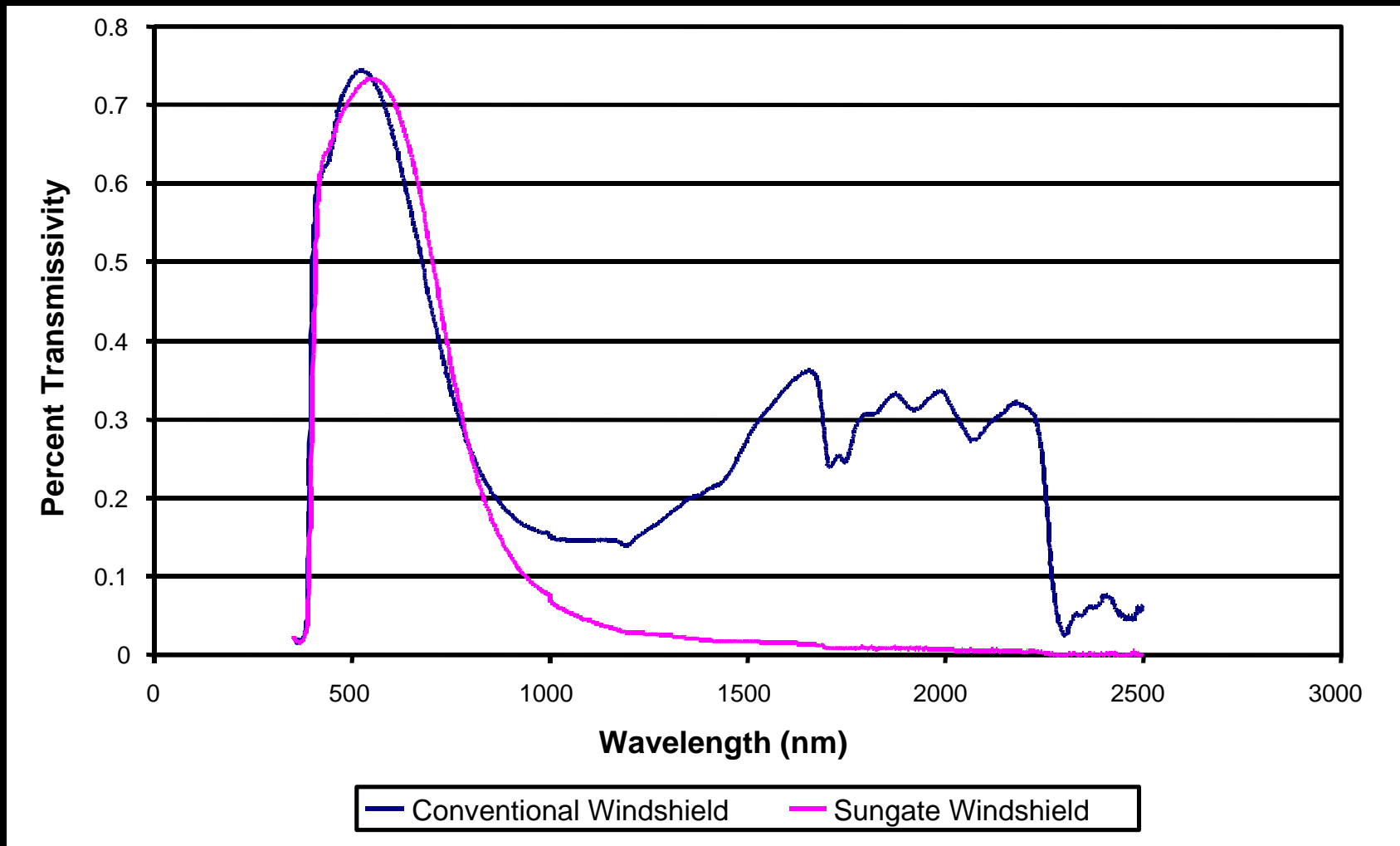


*THE SUNGATE™ AUTOMOTIVE WINDSHIELD*



*CENTER FOR TRANSPORTATION TECHNOLOGIES AND SYSTEMS*

# Solar Reflective Windshield



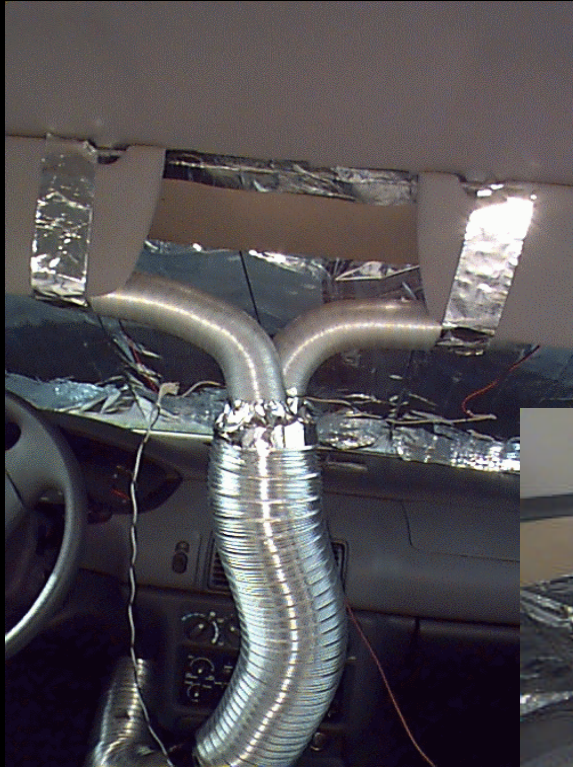
*CENTER FOR TRANSPORTATION TECHNOLOGIES AND SYSTEMS*

# Fuel Economy Results

(assuming a compressor efficiency of 75%)

Windshield	Mechanical Accessory Load (kW/hp)	SFTP		SCO3 Only	
		Fuel Econ. (mpg)	% Change from Solex Baseline	Fuel Econ. (mpg)	% Change from Solex Baseline
Solex®	3.9/5.2	26.2	--	20.4	--
Sungate®	3.5/4.7	26.7	1.7%	21.1	3.4%

# Boundary Layer Technique



Testing set-up  
inside the Neon



NREL is evaluating how the hot boundary layer that forms along windows inside a vehicle can be effectively removed.

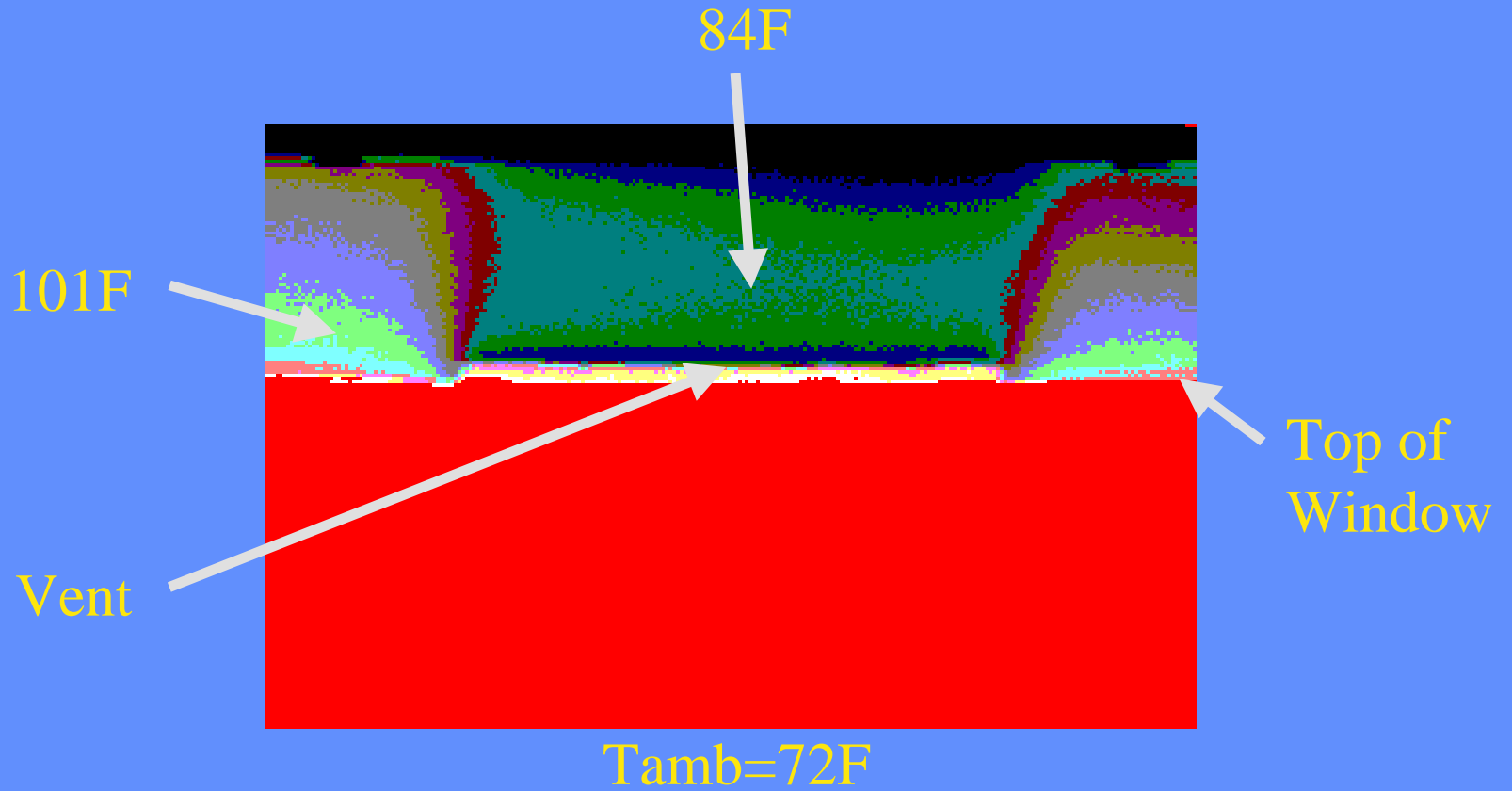


# Boundary Layer Mockup

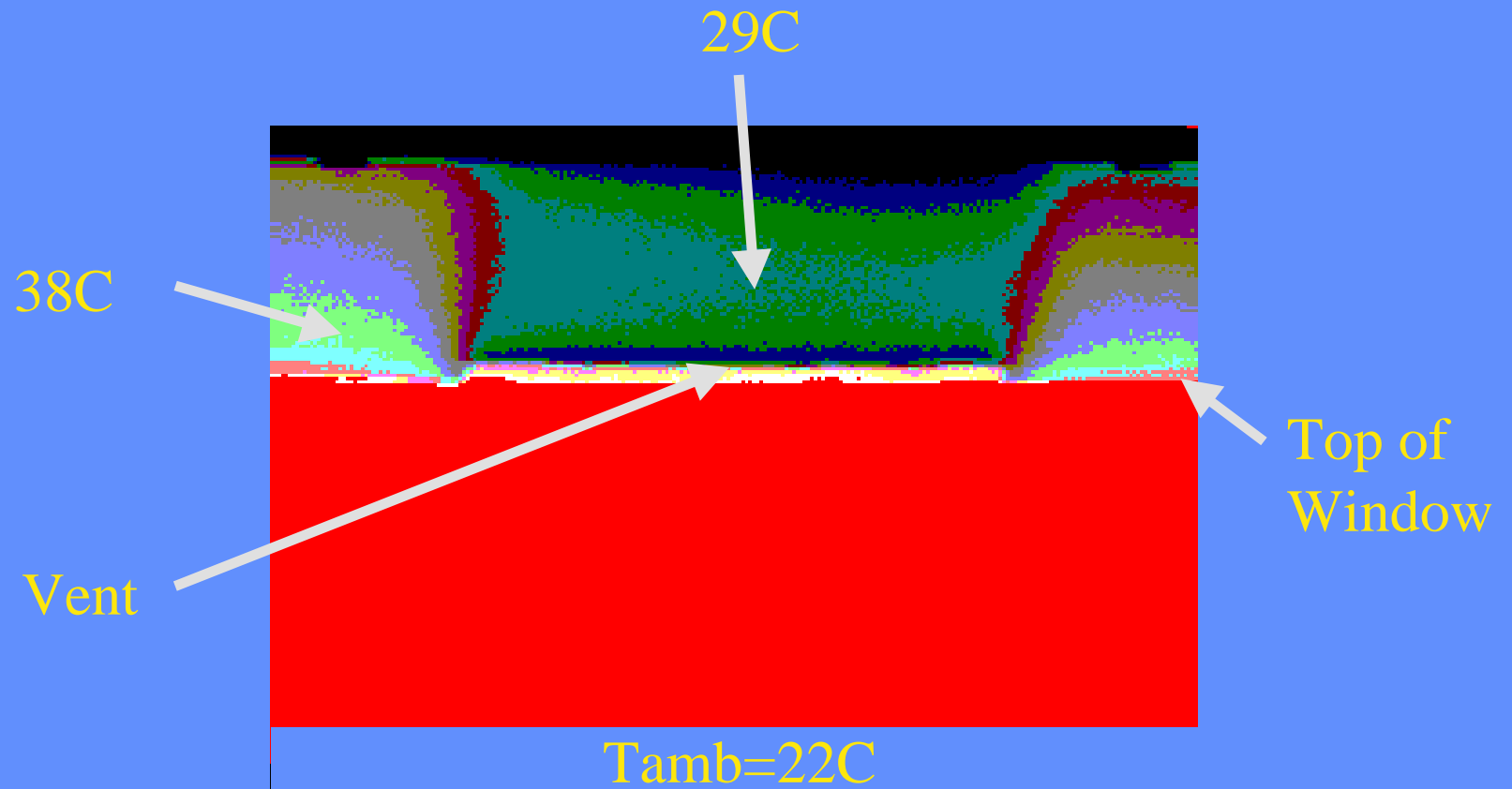


*CENTER FOR TRANSPORTATION TECHNOLOGIES AND SYSTEMS*

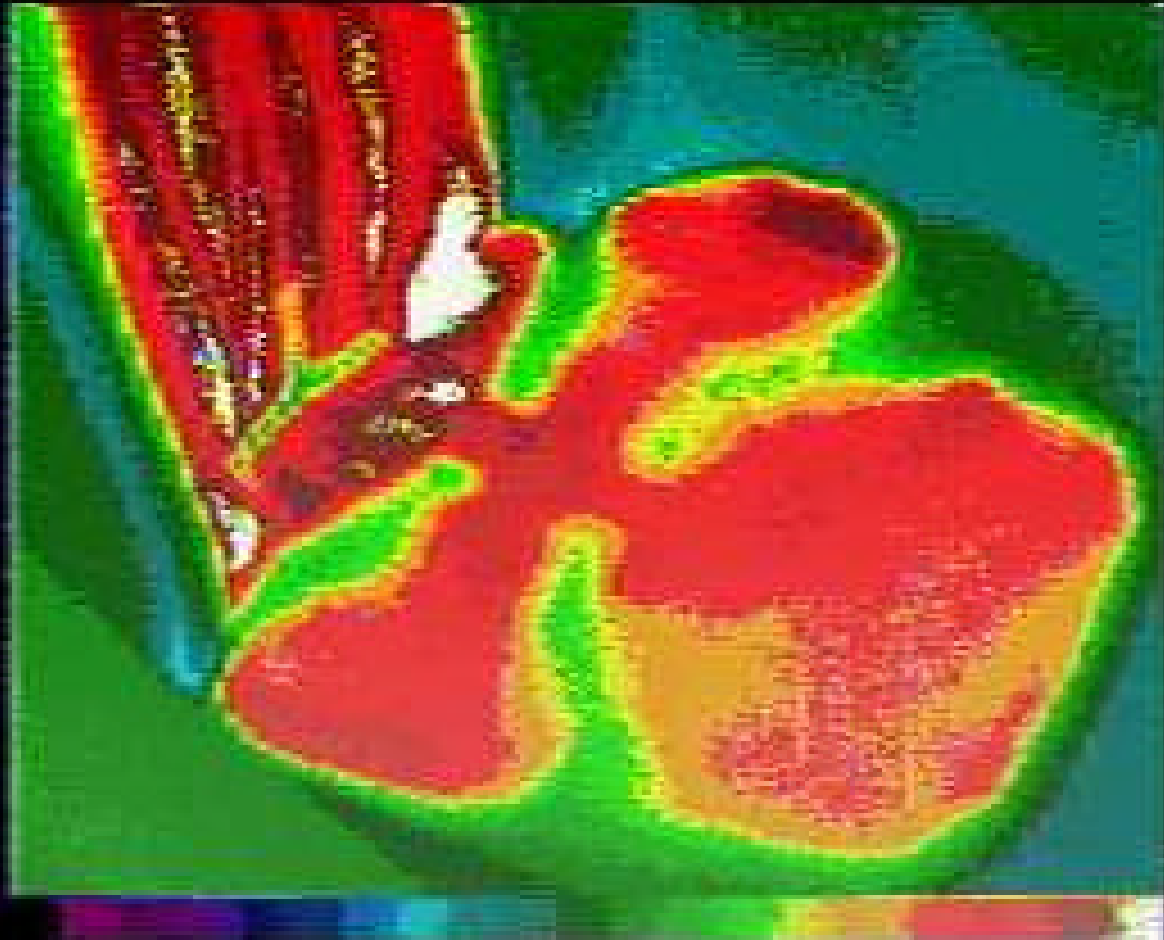
# Impact of BL Control on Local Surface Temperature



# Impact of BL Control on Local Surface Temperature

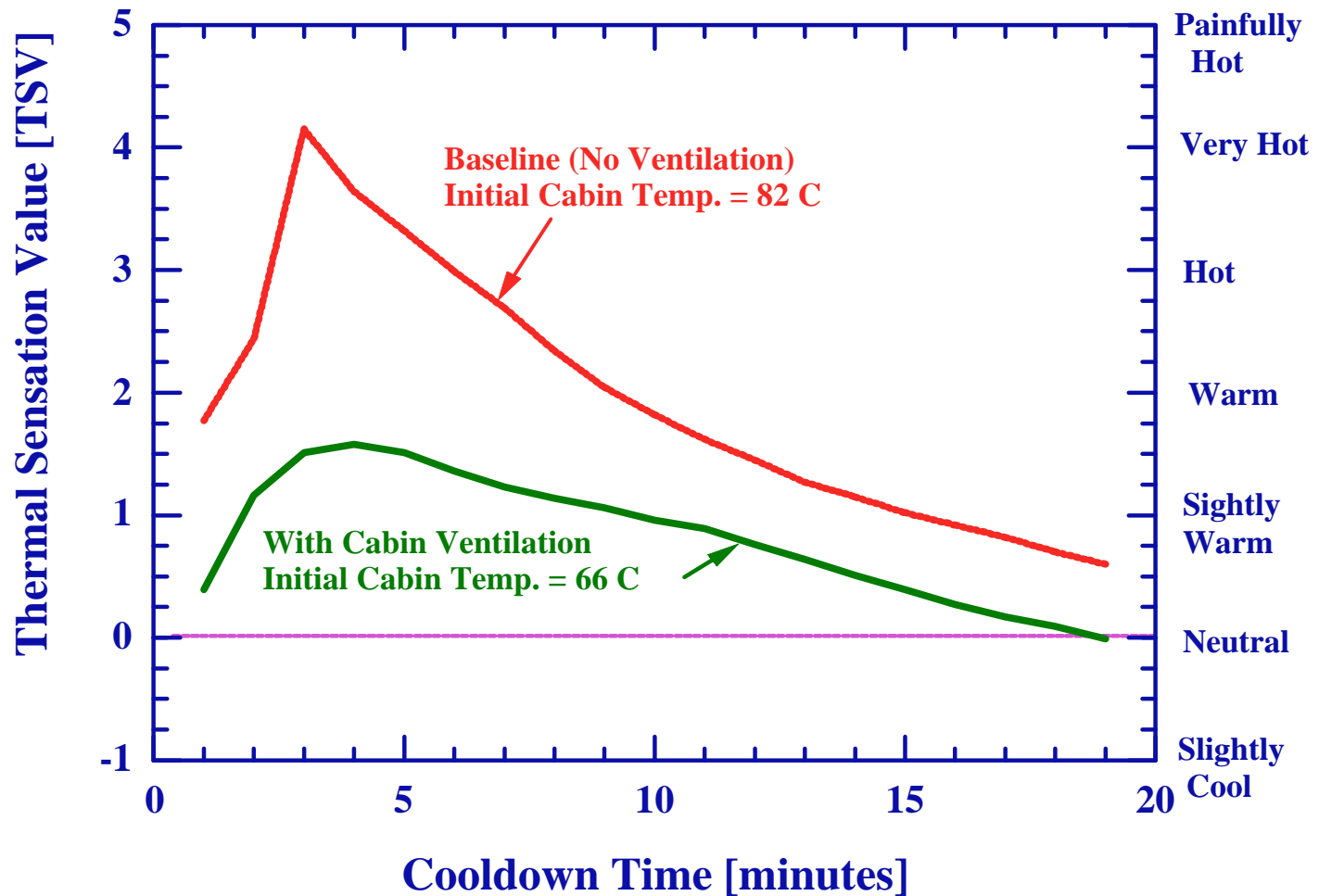


# Infrared Image of Heated Seat

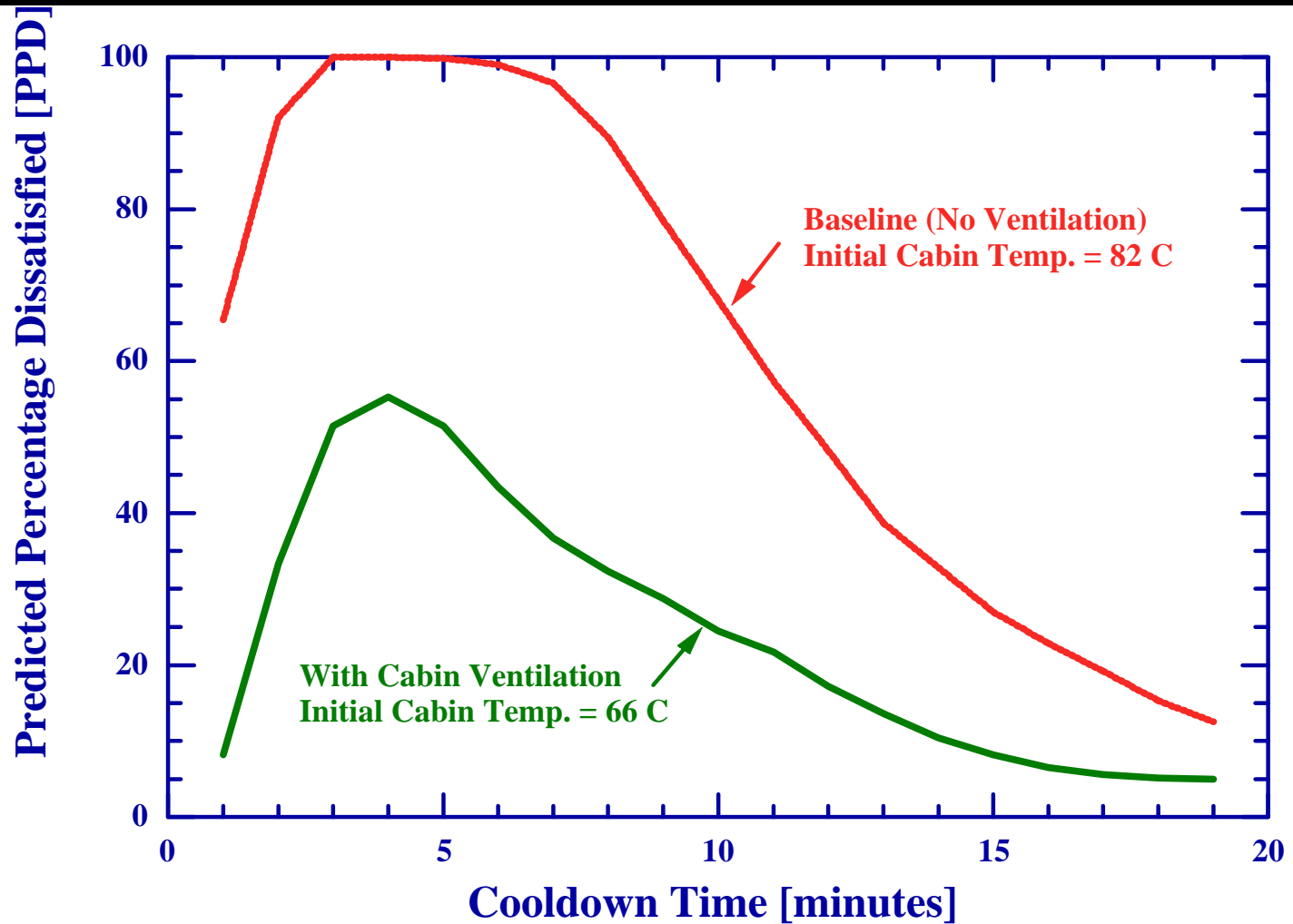


*CENTER FOR TRANSPORTATION TECHNOLOGIES AND SYSTEMS*

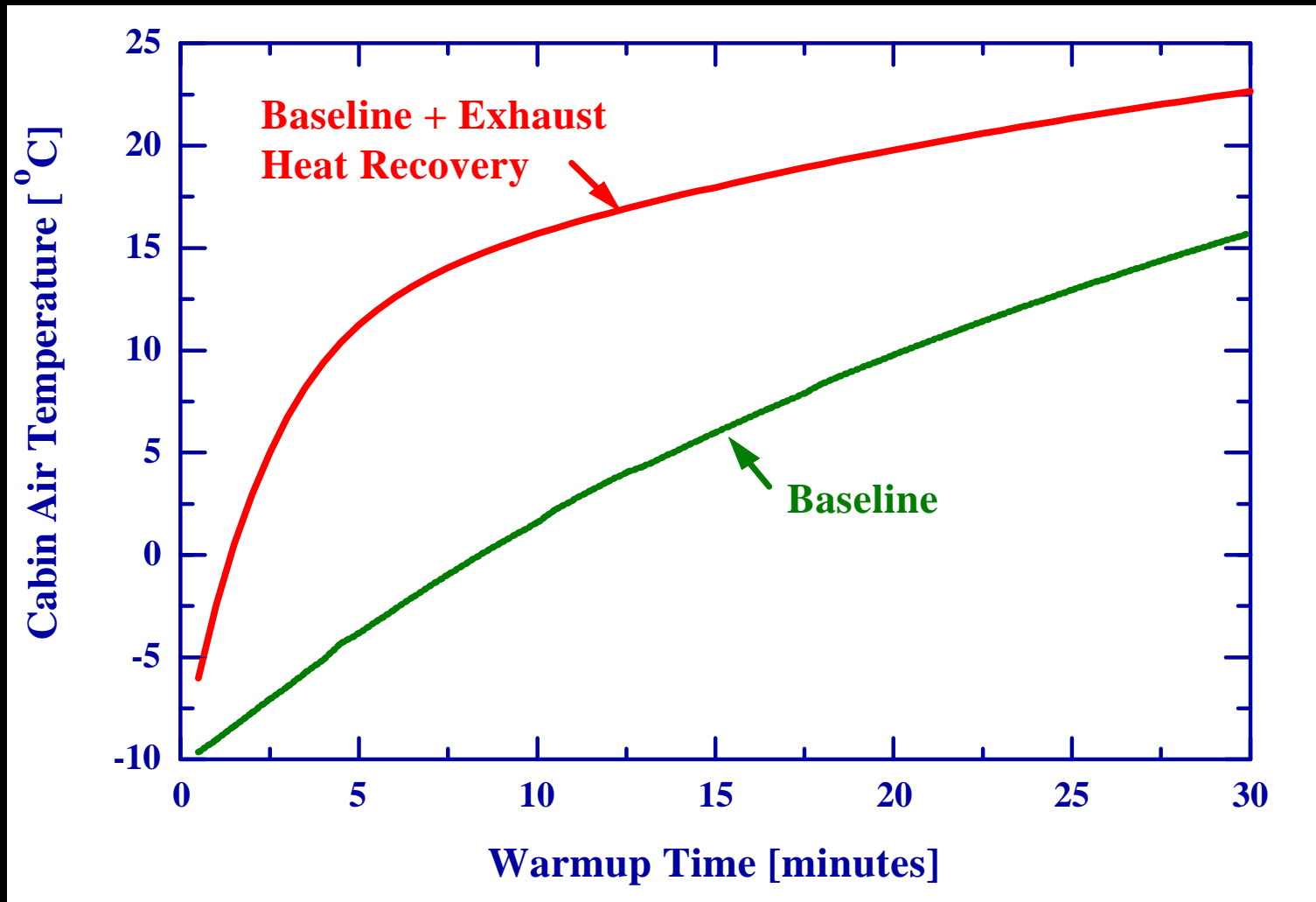
# Thermal Comfort - TSV



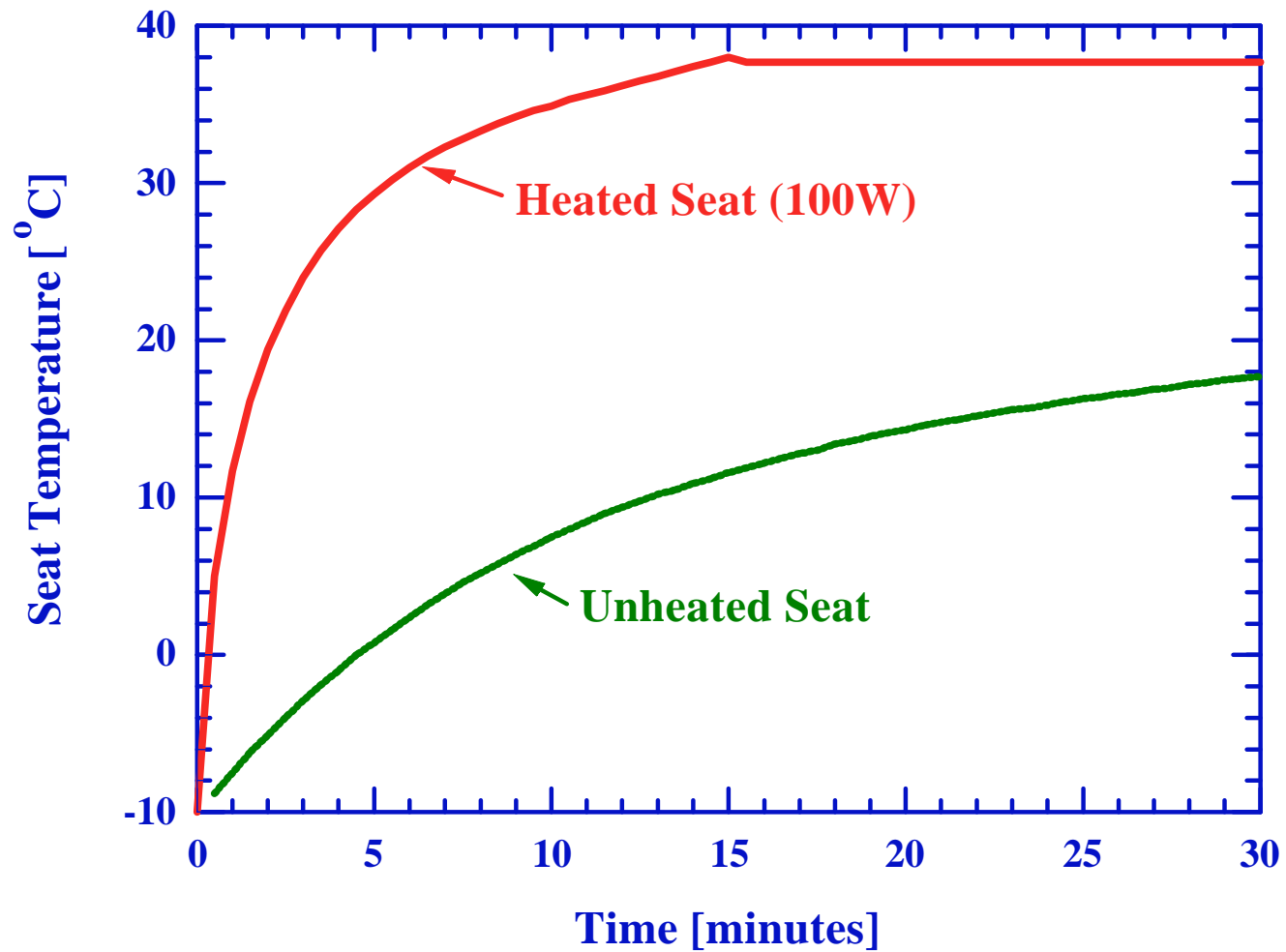
# Thermal Comfort - PPD



# Cabin Warm-up: Exhaust Heat

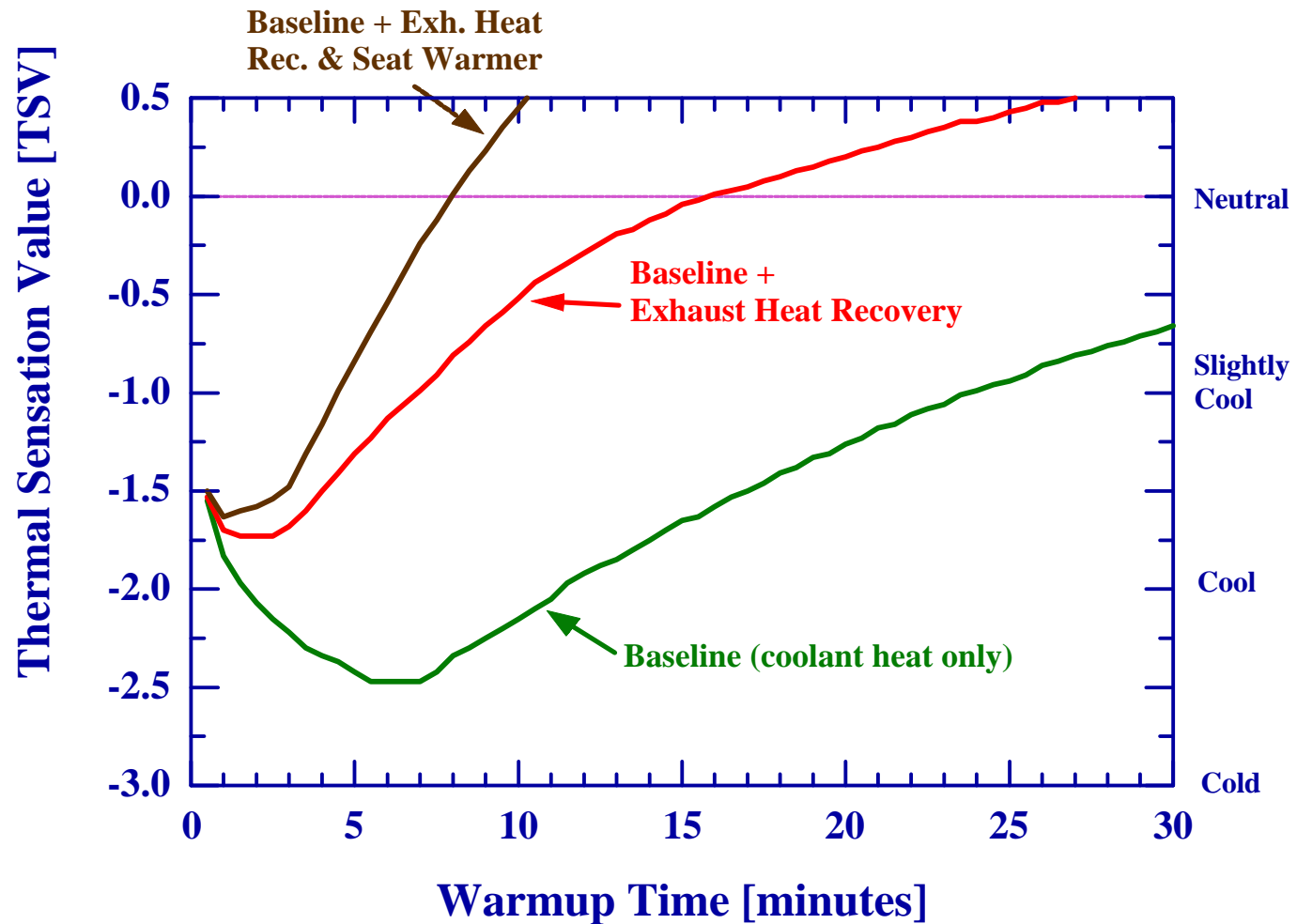


# Cabin Warm-up: Heated Seat





# Cabin Warm-up: TSV





# Cabin Air Cleaning Options

- ▶ Ventilation
- ▶ Activated carbon unit (requires regeneration or periodic replacement)
- ▶ Photocatalytic device (alone or in combination with activated carbon)
- ▶ Other chemical or photochemical treatment methods (ozone, catalytic oxidation, etc.)



# Objectives for Integrating Photocatalytic Oxidation (PCO) Unit into a Vehicle

- ▶ Simple unit that can be integrated into the HVAC assembly
- ▶ Power consumption less than 10 watts
- ▶ Unit cost less than \$10
- ▶ Capable of removing VOC's from fuels, vehicle emissions, odors, and interior materials
- ▶ Can increase use of recirculated air



# Advantages of PCO System

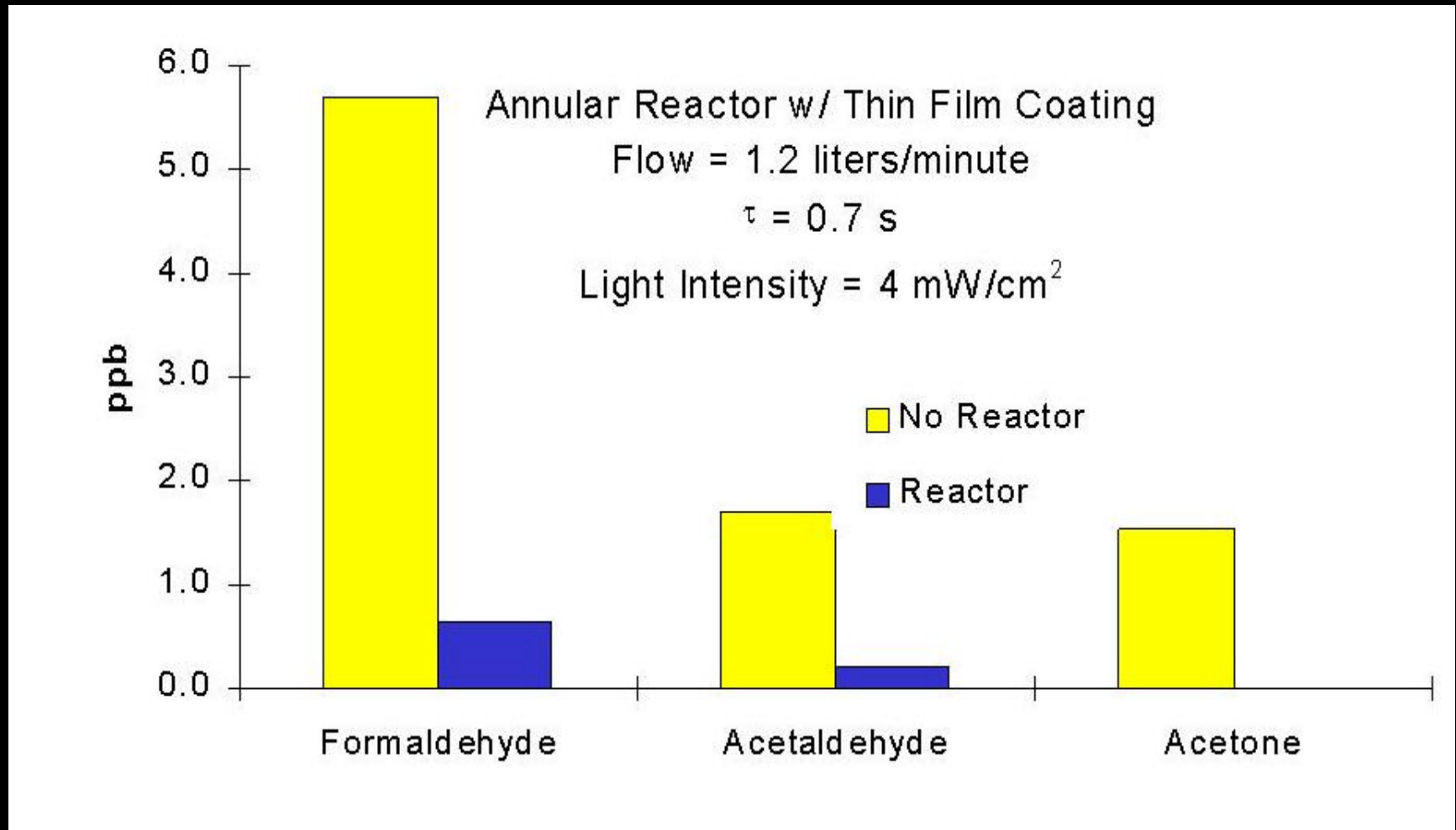
- ▶ Acts as a self cleaning filter for VOCs and bioaerosols
- ▶ Low maintenance - light bulb and catalyst/filter media (project long life unless it becomes contaminated with inorganic matter)
- ▶ Operates at ambient conditions - insensitive to temperature, 0 - 82 C

# NREL's PCO Device

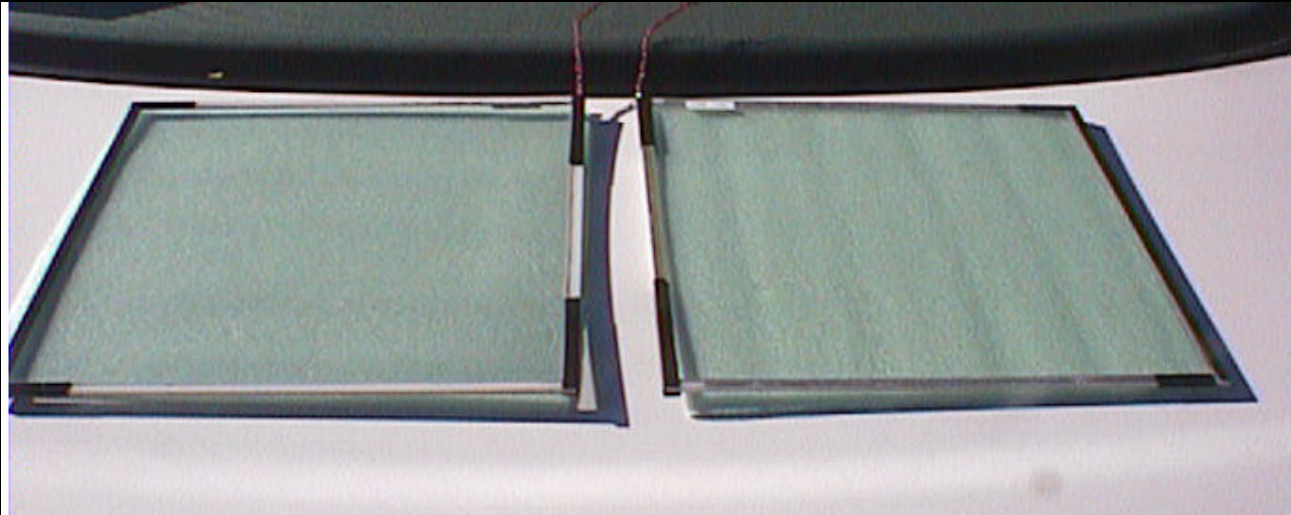


*CENTER FOR TRANSPORTATION TECHNOLOGIES AND SYSTEMS*

# PCO Performance



# Electrochromic Sunroof



*CENTER FOR TRANSPORTATION TECHNOLOGIES AND SYSTEMS*

# PV Sunroof - Trunk Mounted

- ▶ Aperture Area =  $.37 \text{ m}^2$
- ▶  $P_{\text{max}} = 30\text{W}$
- ▶ Efficiency = 8%







# Desiccant-Assisted A/C

## ➤ Advantages

- Efficient latent load removal
- Improved cabin comfort because of lower humidity
- Potential for reducing AC components size (30% less compressor power required)
- Use of waste heat, lower overall fuel consumption
- Potential for more efficient defrost/defog

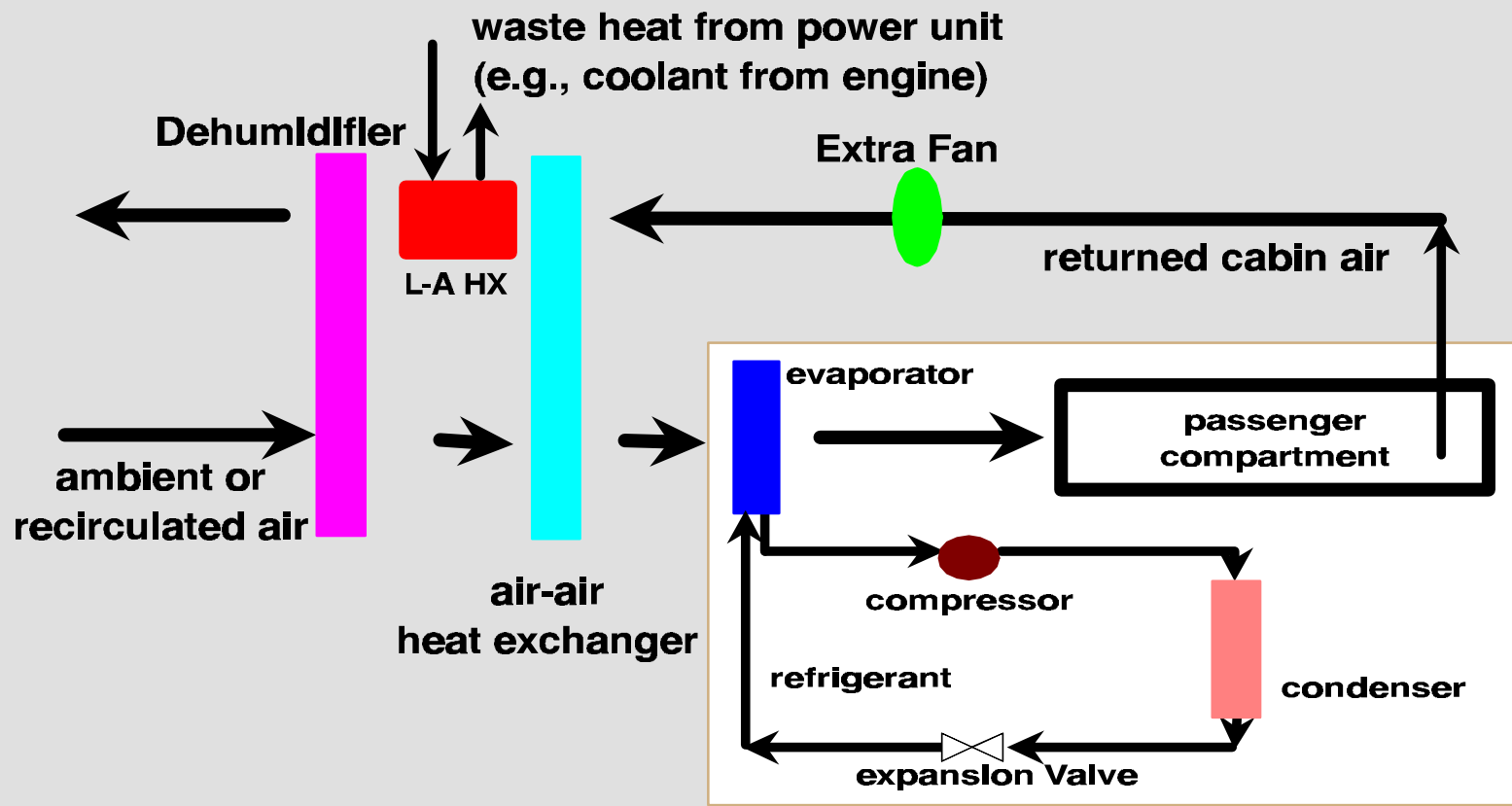


# Desiccant-Assisted A/C

- ▶ Disadvantages
  - ▶ More components
  - ▶ Increased mass (about 3 kg)
  - ▶ Complexity in packaging and control

# Desiccant-Assisted A/C Schematic

## NREL Desiccant-Assisted Air Conditioner Concept for Vehicles



# NREL's Cool Car Web Site

To learn about NREL's Vehicle Auxiliary Load Reduction Program, go to the "cool car" Web site.

The address is:

<http://www.ctts.nrel.gov/auxload.html>

Or contact Rob Farrington, project manager, at  
(303) 275-4448





# Acknowledgments

- ▶ Ren Anderson, Thermal Analysis and Testing
- ▶ Dave Benson, Electrochromic Windows and Energy Storage
- ▶ Dan Blake, Photocatalysis
- ▶ Jay Burch, Thermal Modeling
- ▶ Nick Chornet, Photocatalysis
- ▶ Matt Cuddy, Thermal Analysis and Modeling
- ▶ Sara Farrar, Thermal Comfort Modeling
- ▶ Bill Jacoby, Photocatalysis
- ▶ Terry Penney, Industry Liaison
- ▶ Ahmad Pesaran, Desiccant Technology
- ▶ Cassie Quaintance, Cabin Thermal Modeling
- ▶ Lorenzo Roybal, Photovoltaics
- ▶ Tom Thoensen, Vehicle and Subsystem Testing

*CENTER FOR TRANSPORTATION TECHNOLOGIES AND SYSTEMS*