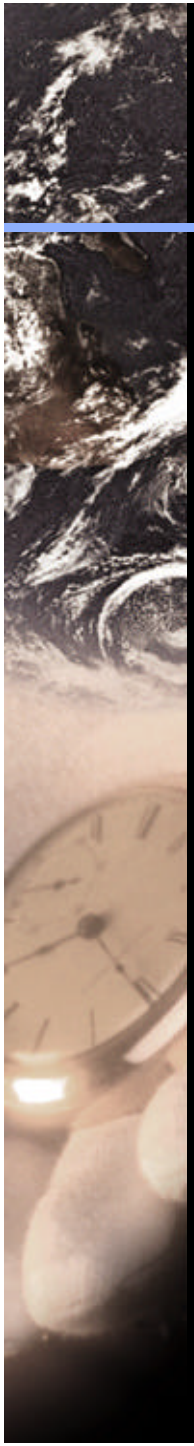


Opportunities to Reduce Vehicle Climate Control Loads

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

NREL Background

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

NREL Facilities

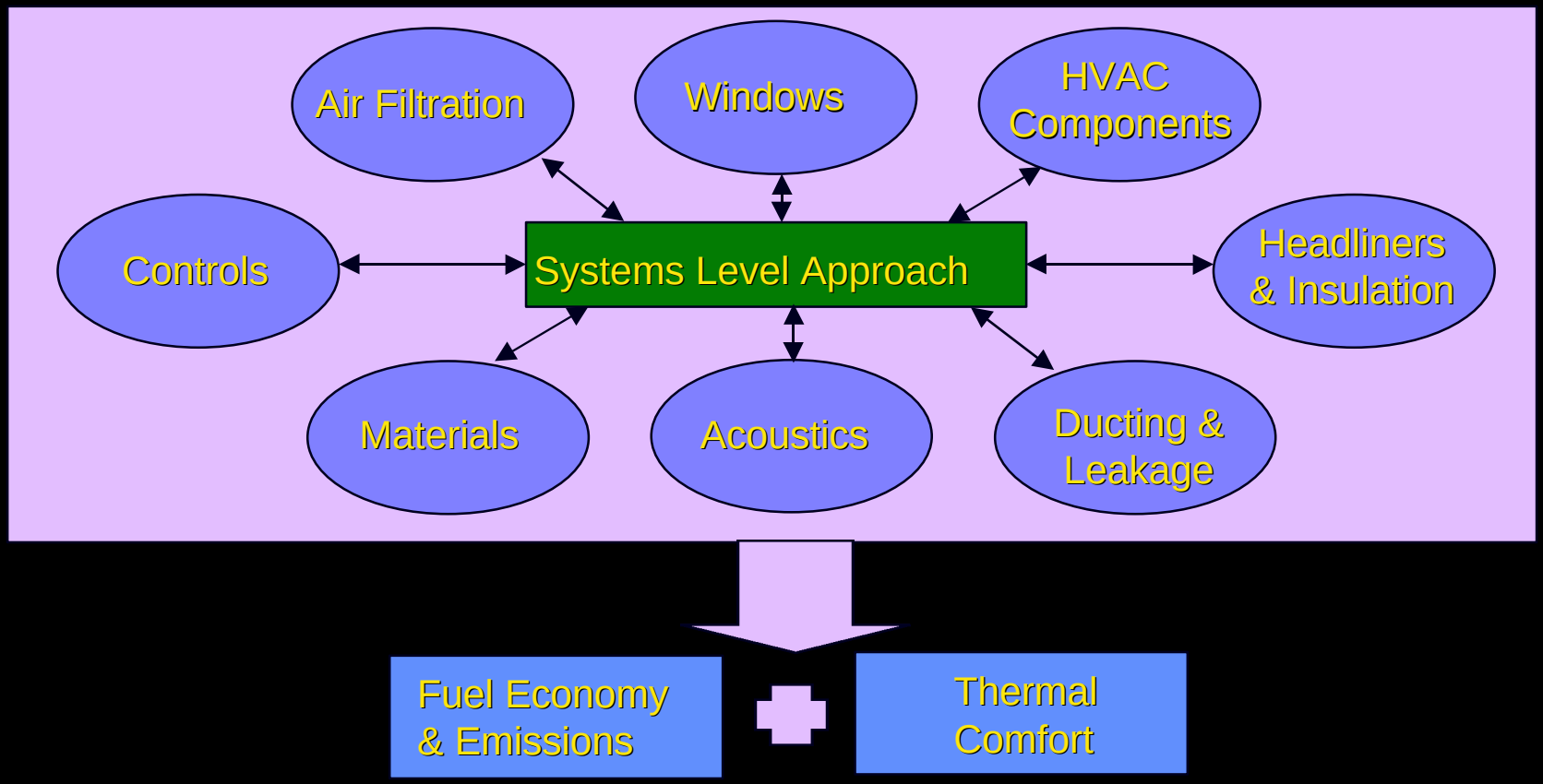
Center for Transportation Technologies and Systems

Cool Car Goal

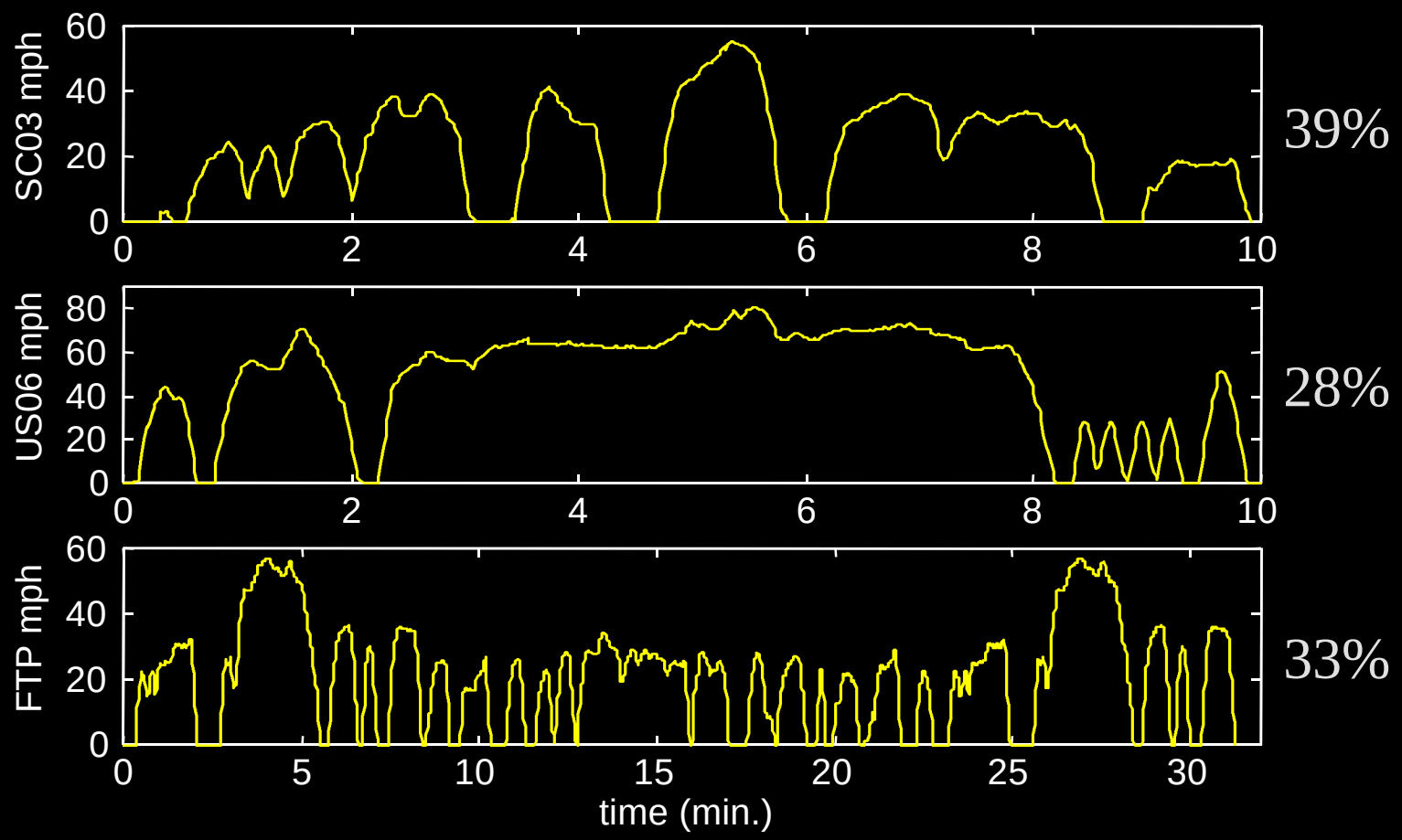
To reduce energy use for vehicle climate control by 50% while maintaining passenger thermal comfort and safety.

Our Approach

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



Supplemental Federal Test Procedure: Velocity Profiles



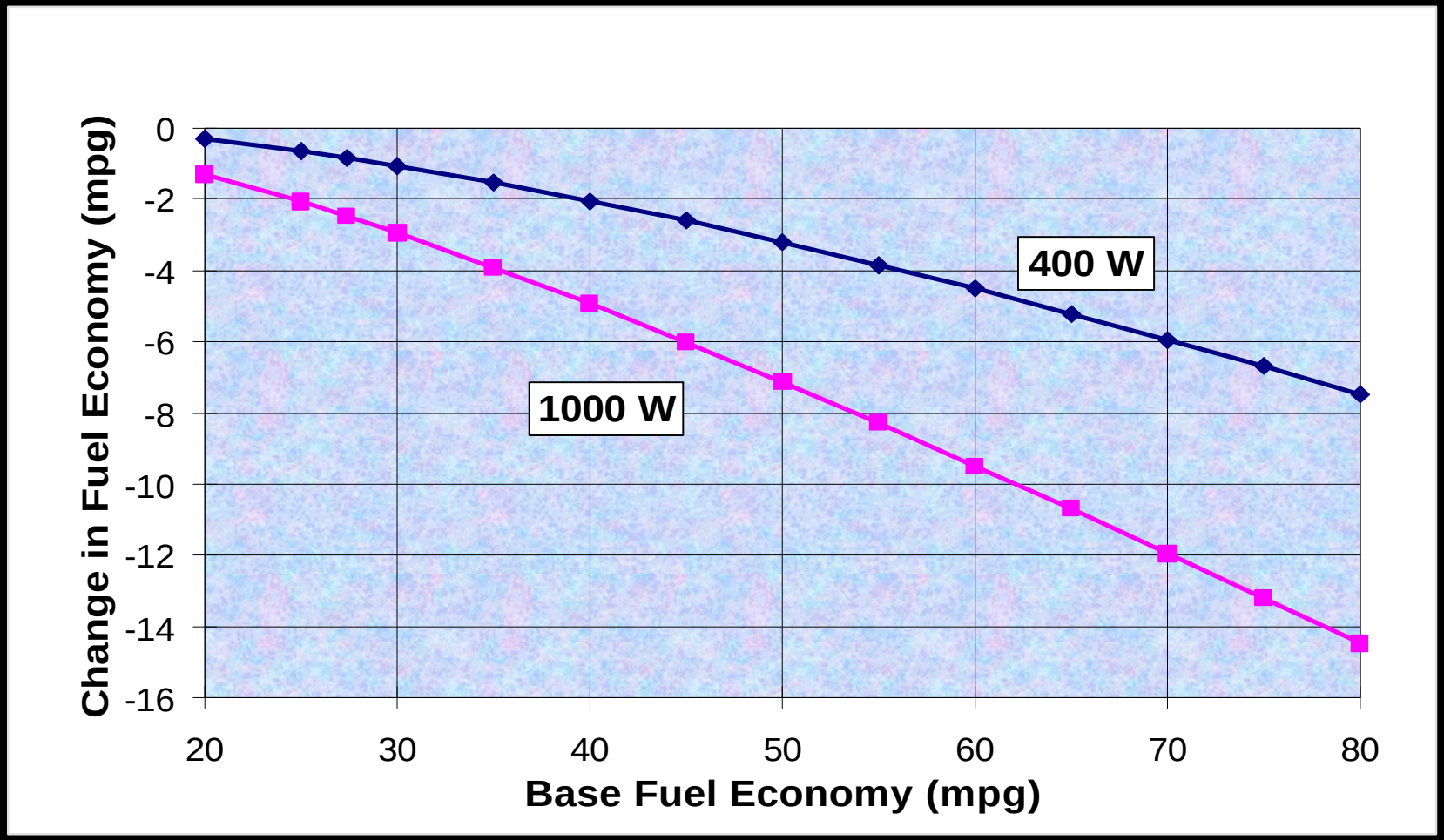
Supplemental Federal Test Procedure: Timeline

- 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)

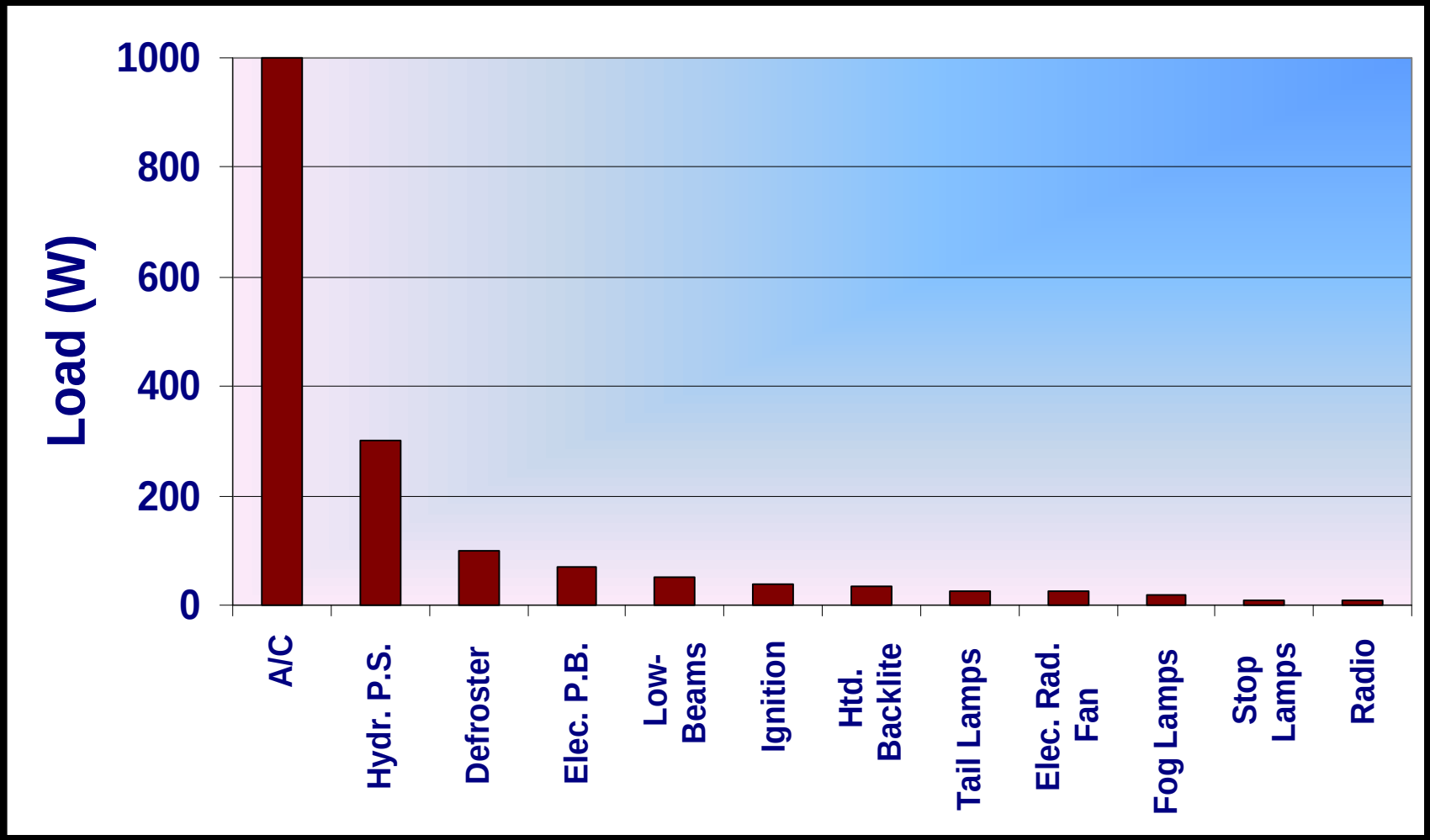
Fuel Economy Penalties From Auxiliary Loads



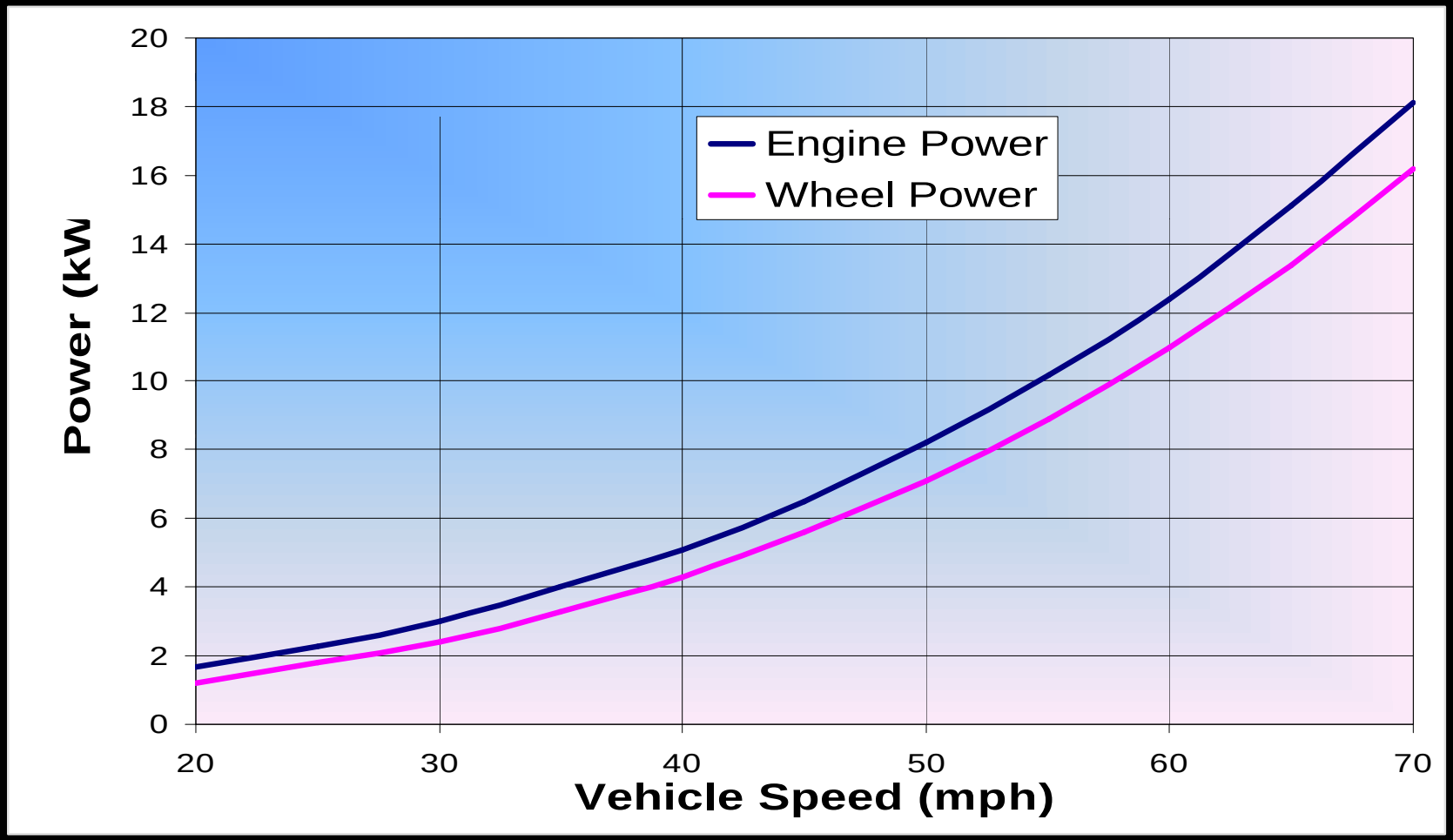
Reducing Vehicle Auxiliary Loads Saves Energy and Money

- 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

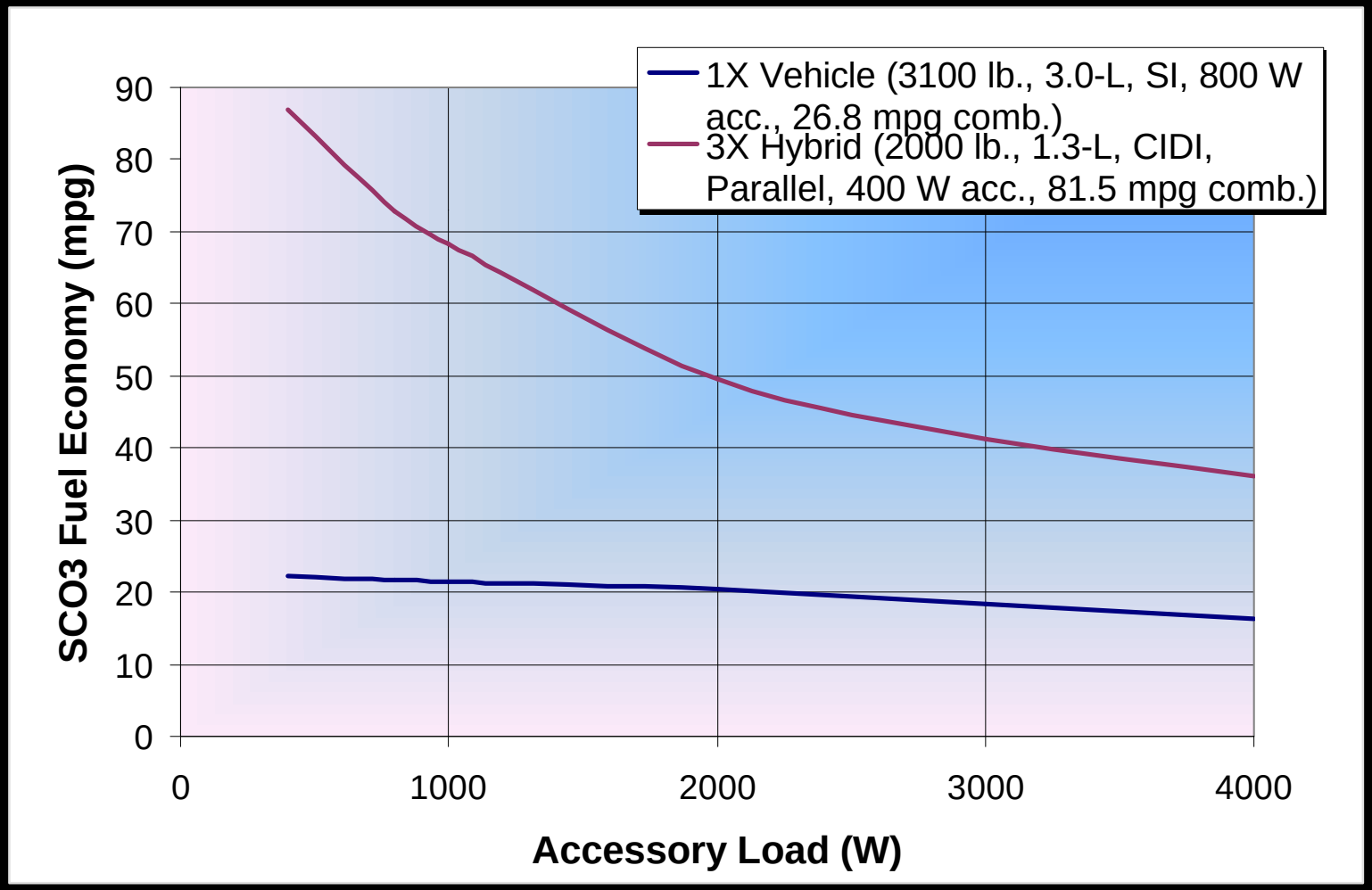


Power vs. Vehicle Speed



A/C Increases Engine Loading

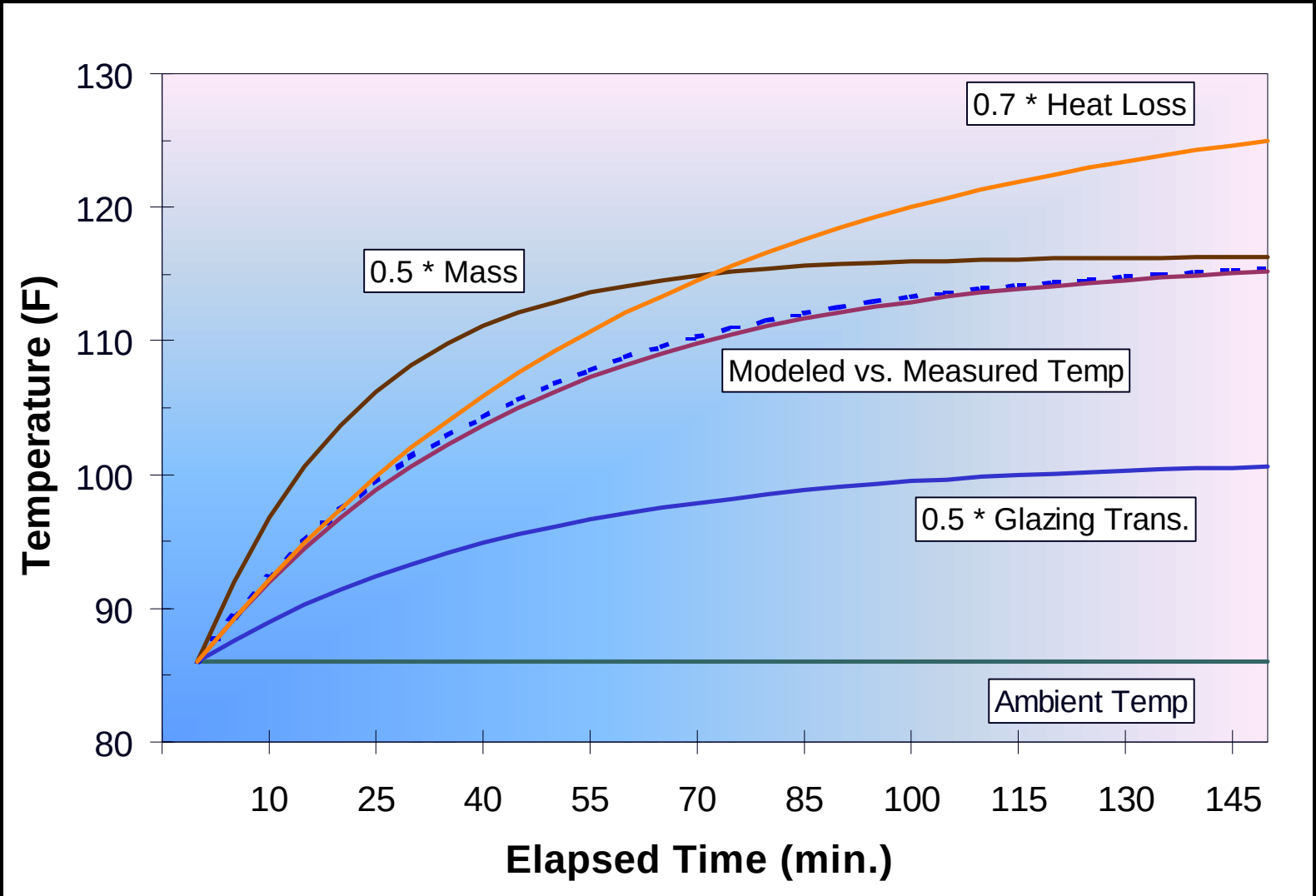
Fuel Economy Impact



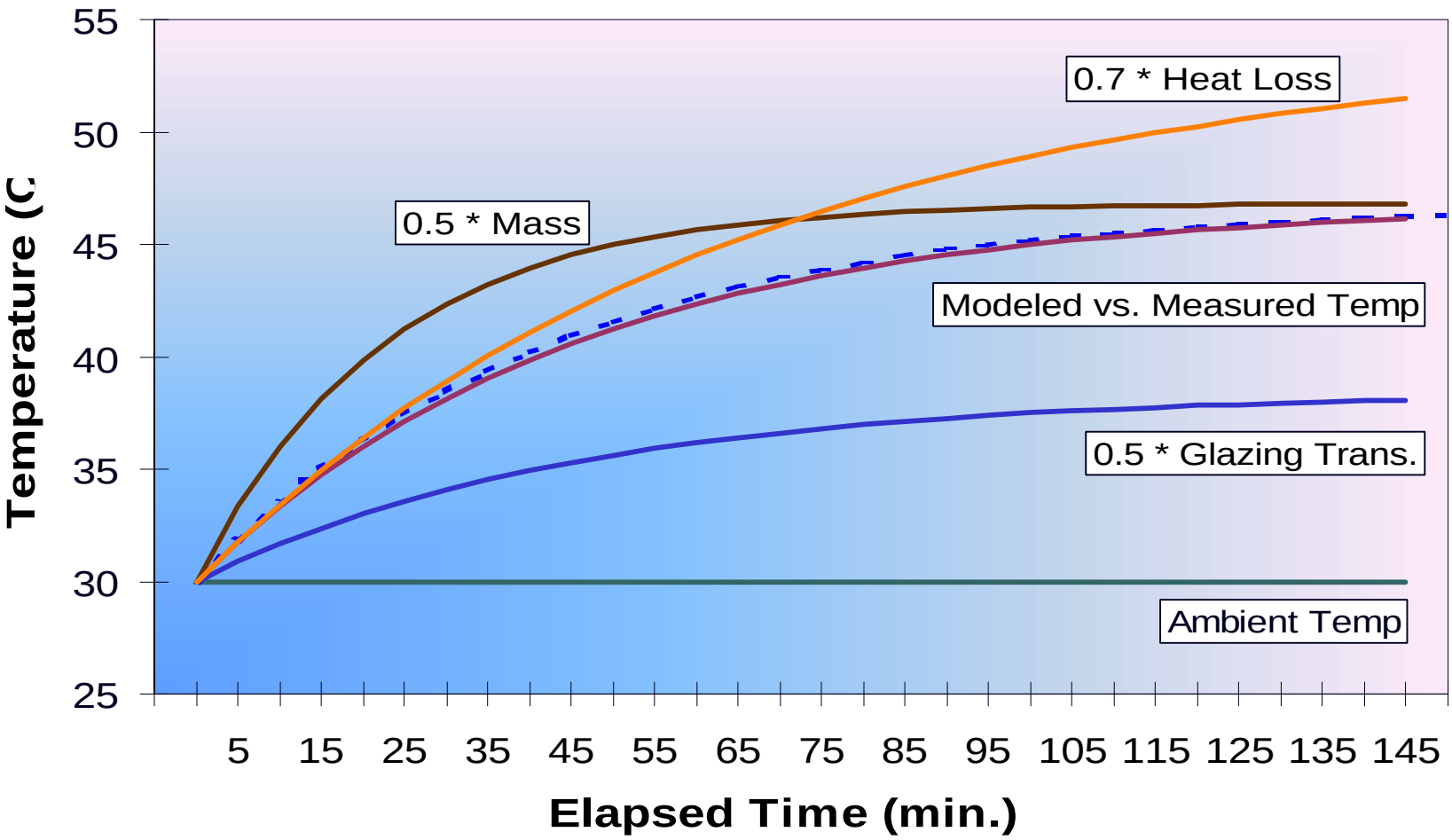
Benefits of Cool Interiors

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

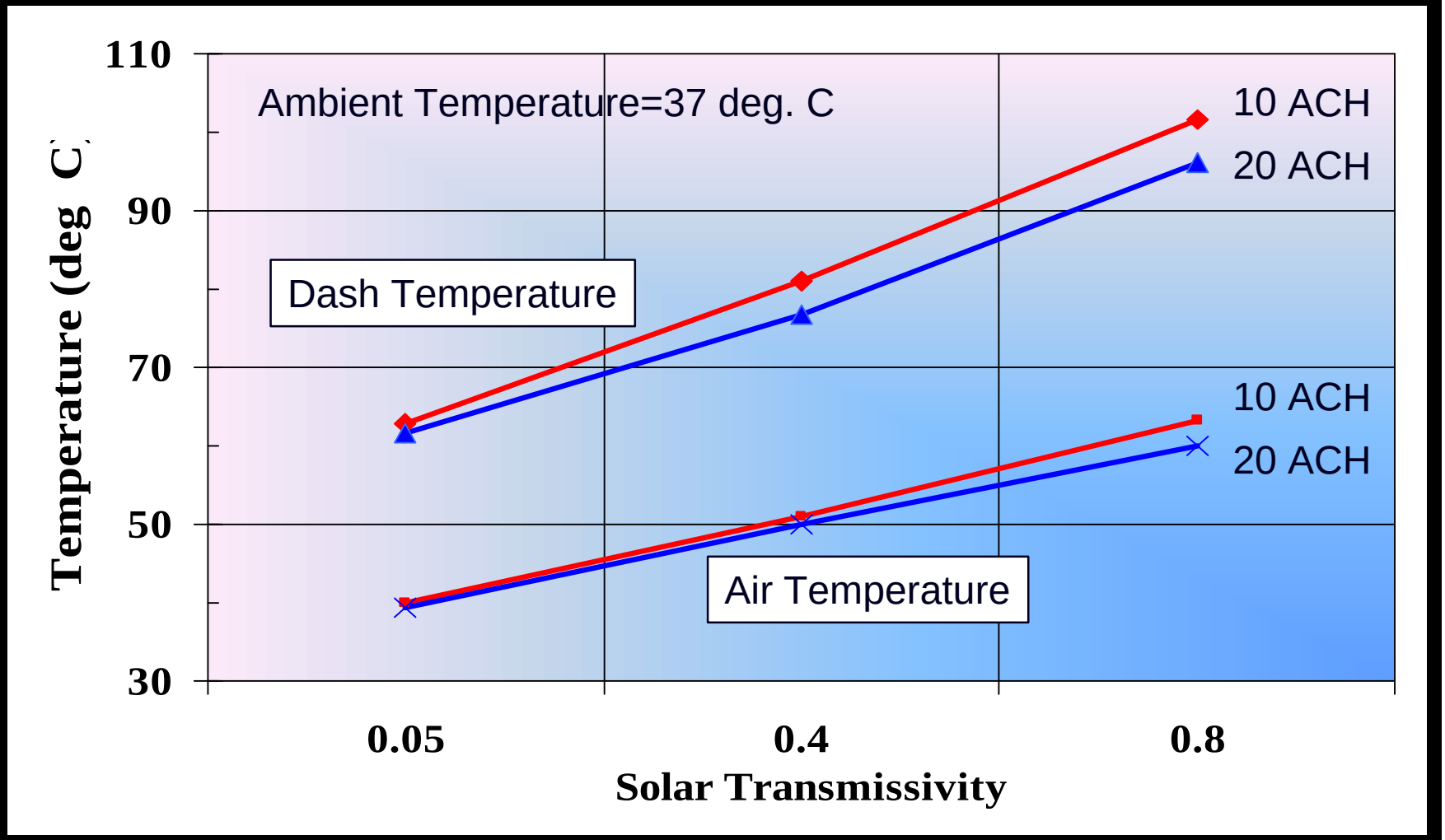
Soak Temperature Sensitivity



Soak Temperature Sensitivity



Predicted Peak Dash/Air Temps.



NREL's Breeze Test Vehicle

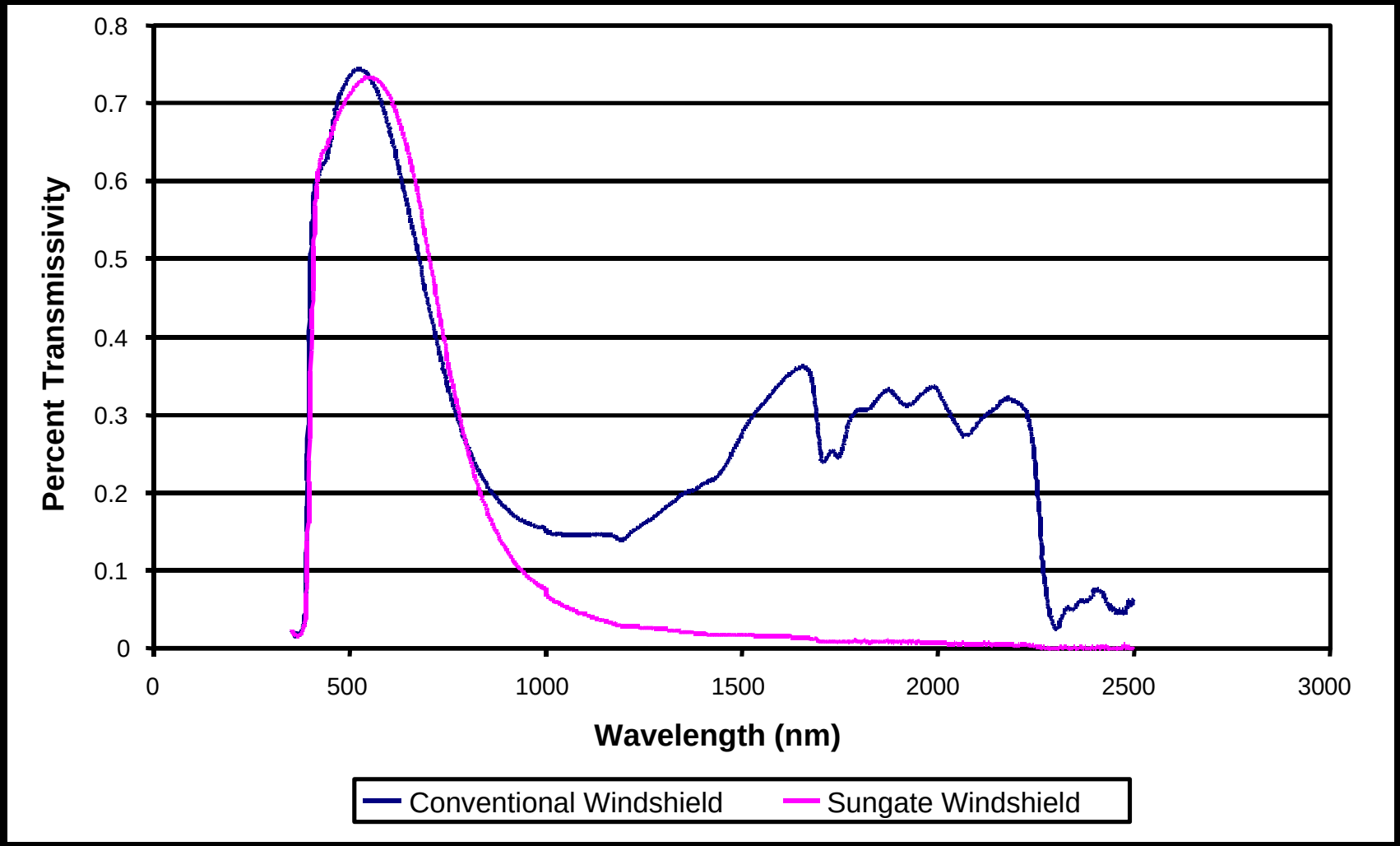
Solar Gain Reducing Windshields

NREL tested 3 different windshields:

- Sungate
- Solex
- Solar green

Sungate Windshield Description

Solar Reflective Windshield

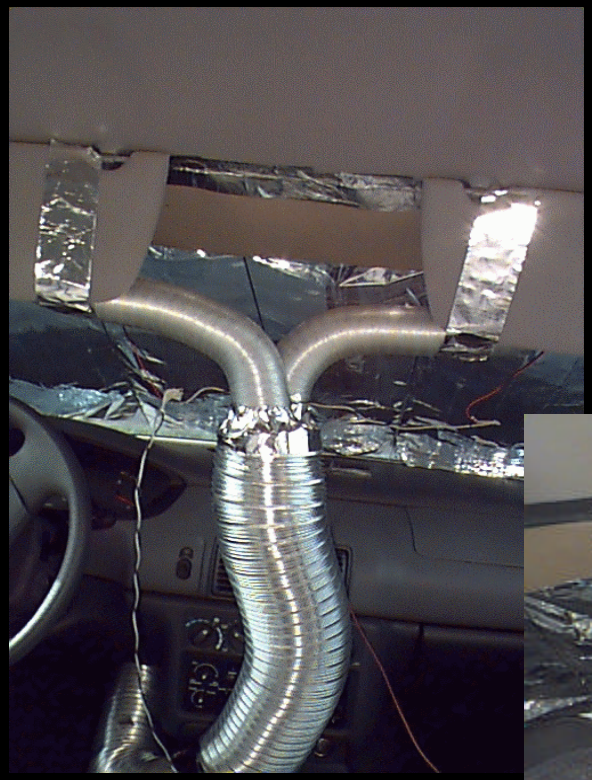


Fuel Economy Results

(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

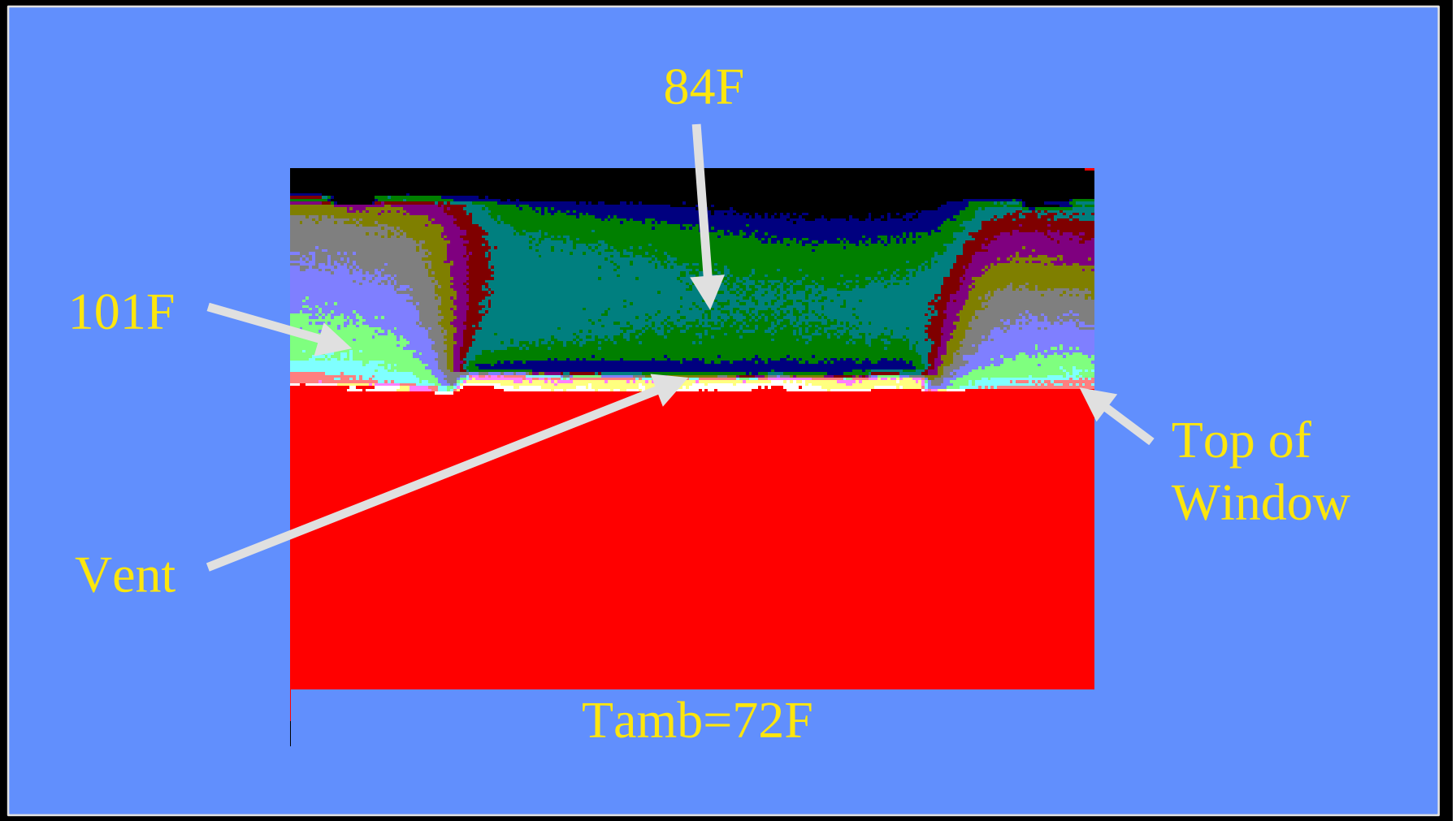


Testing set-up inside the Neon

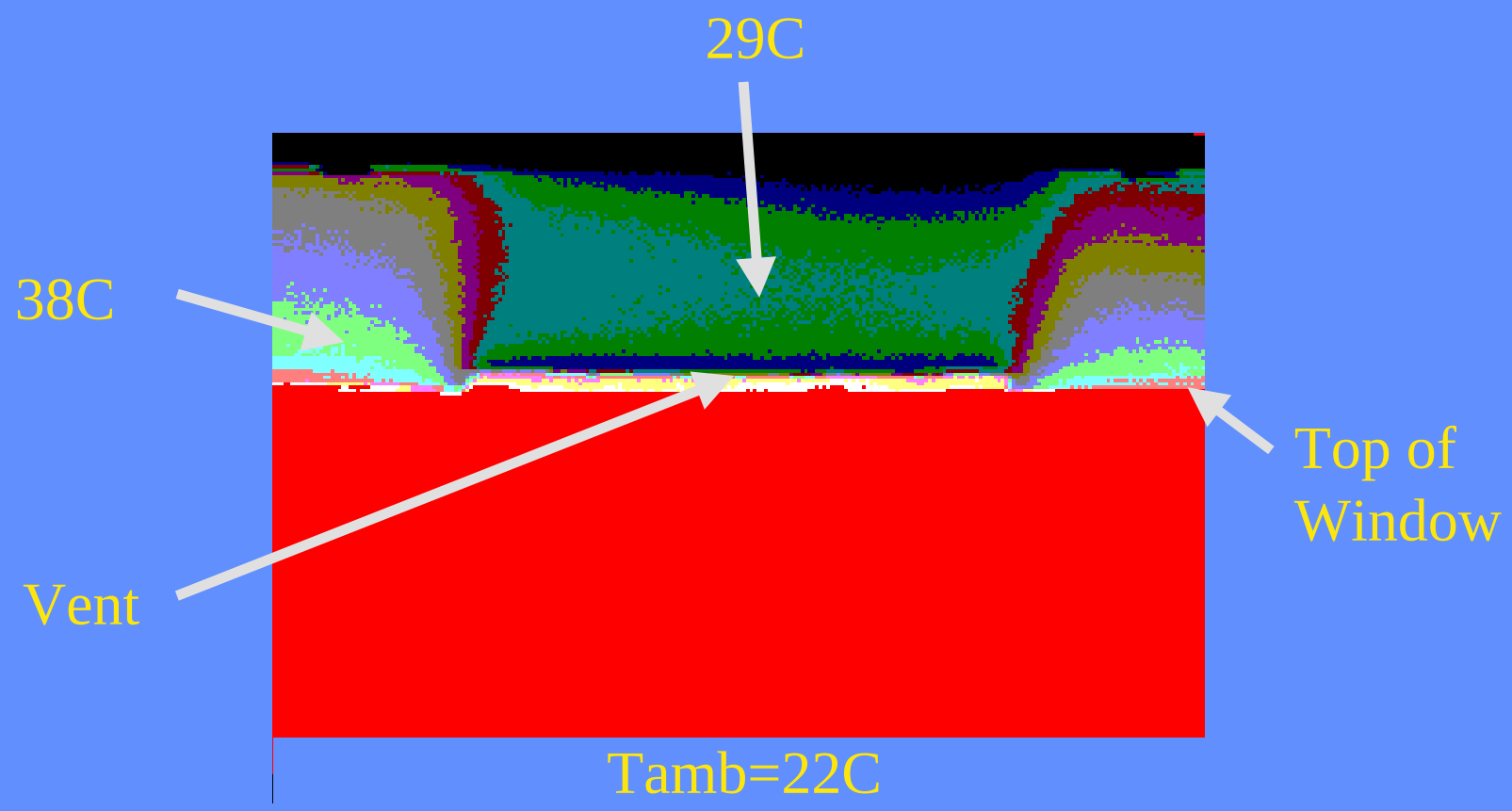
NREL is evaluating how the hot boundary layer that forms along windows inside a vehicle can be effectively removed.

Boundary Layer Mockup

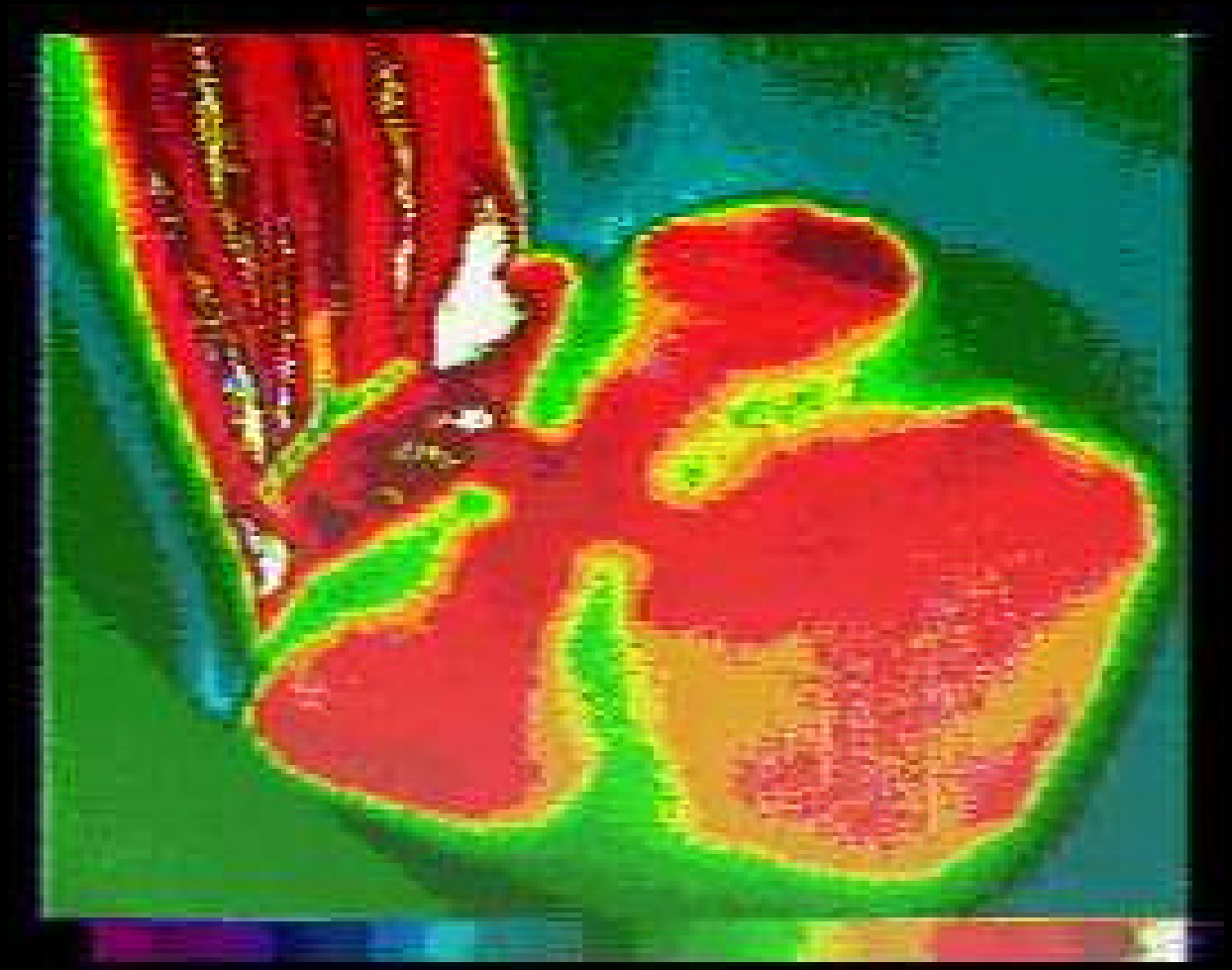
Impact of BL Control on Local Surface Temperature



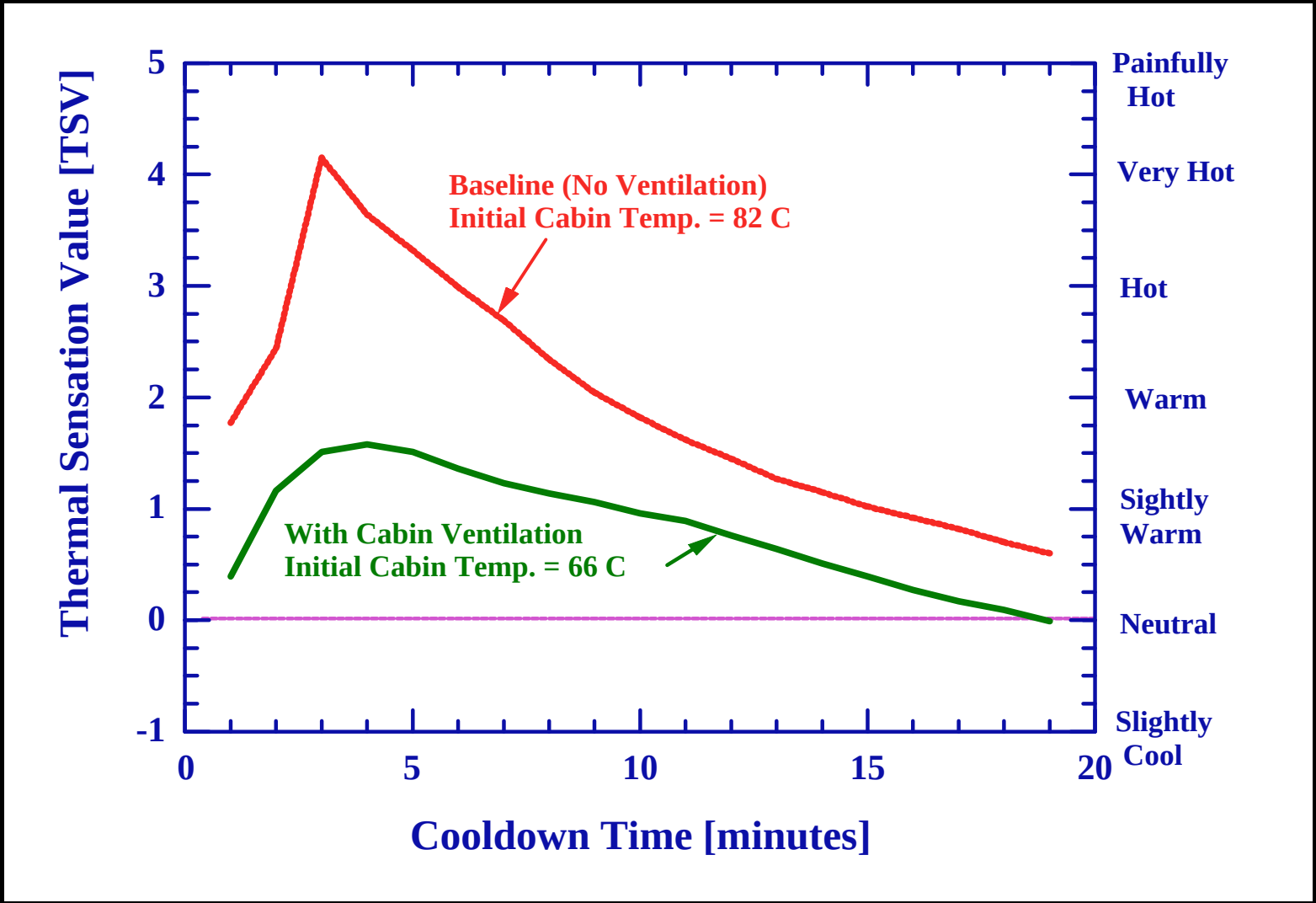
Impact of BL Control on Local Surface Temperature



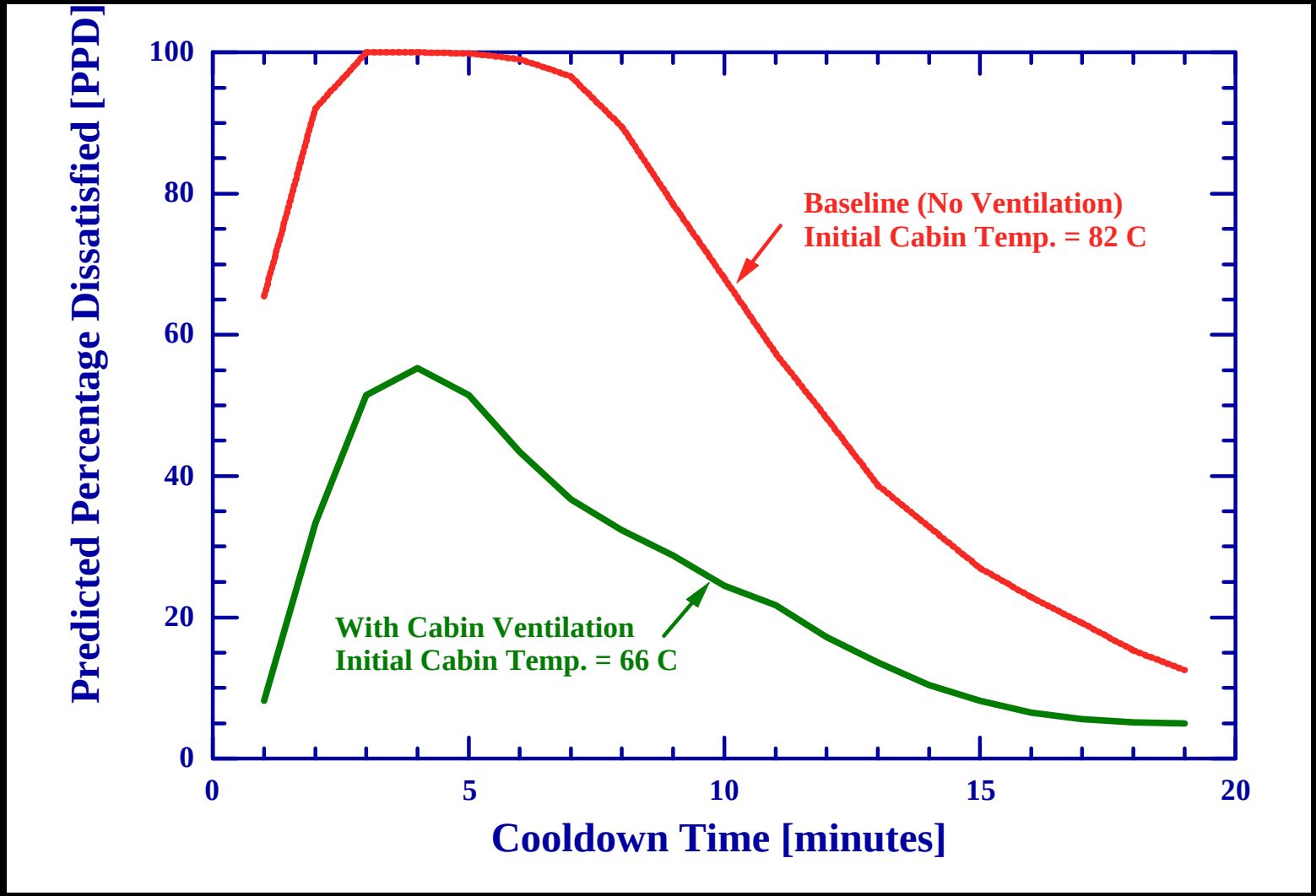
Infrared Image of Heated Seat



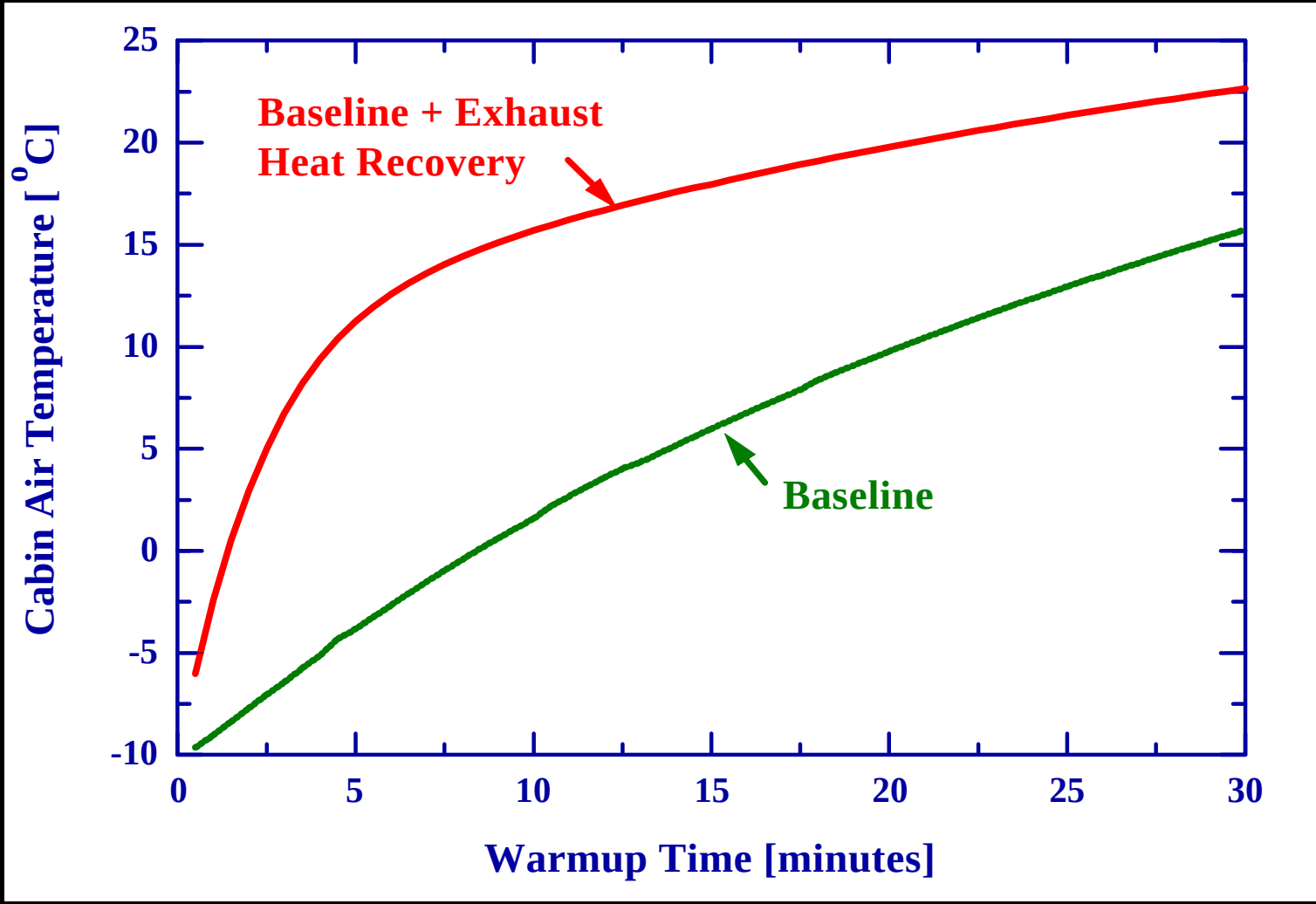
Thermal Comfort - TSV



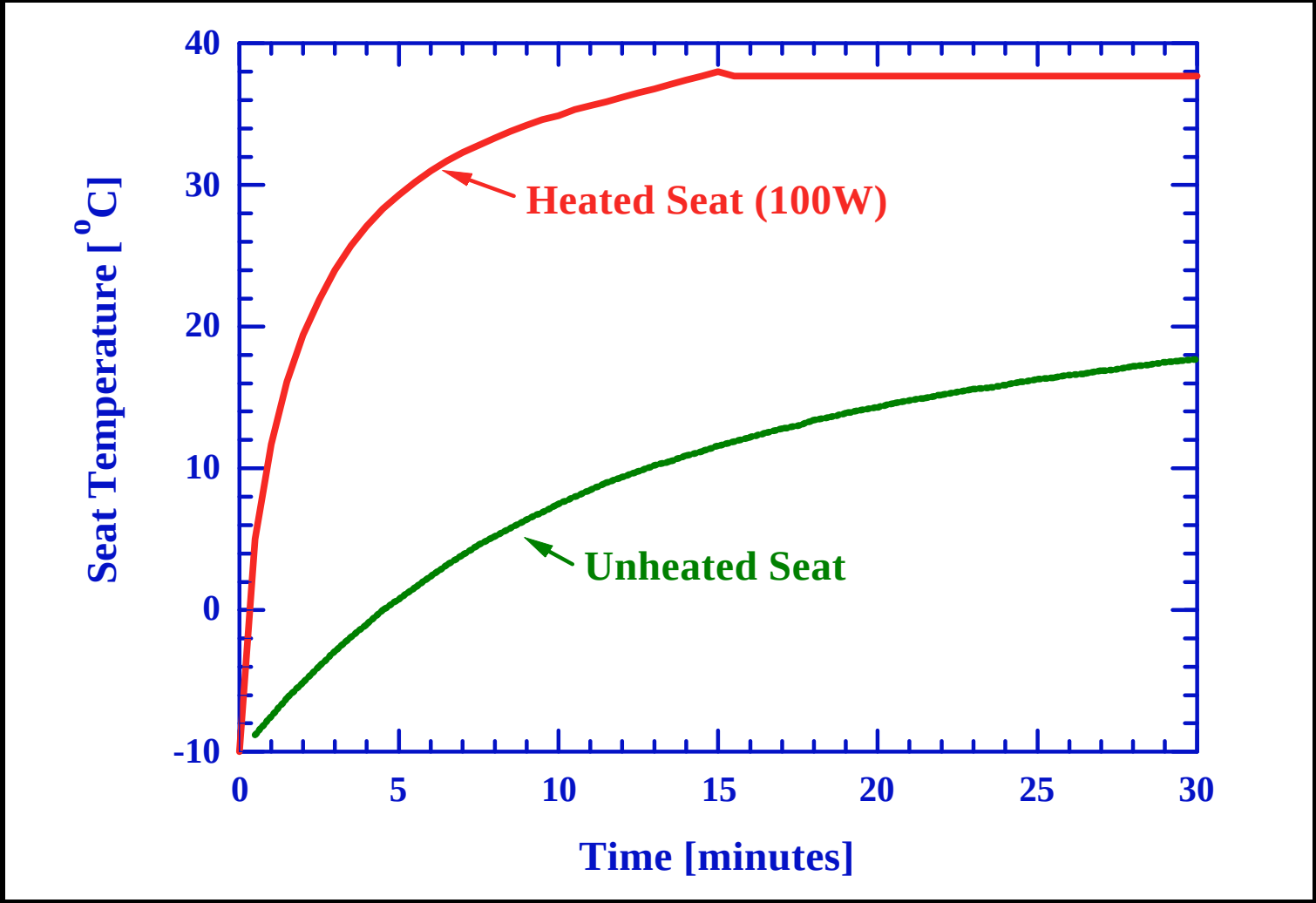
Thermal Comfort - PPD



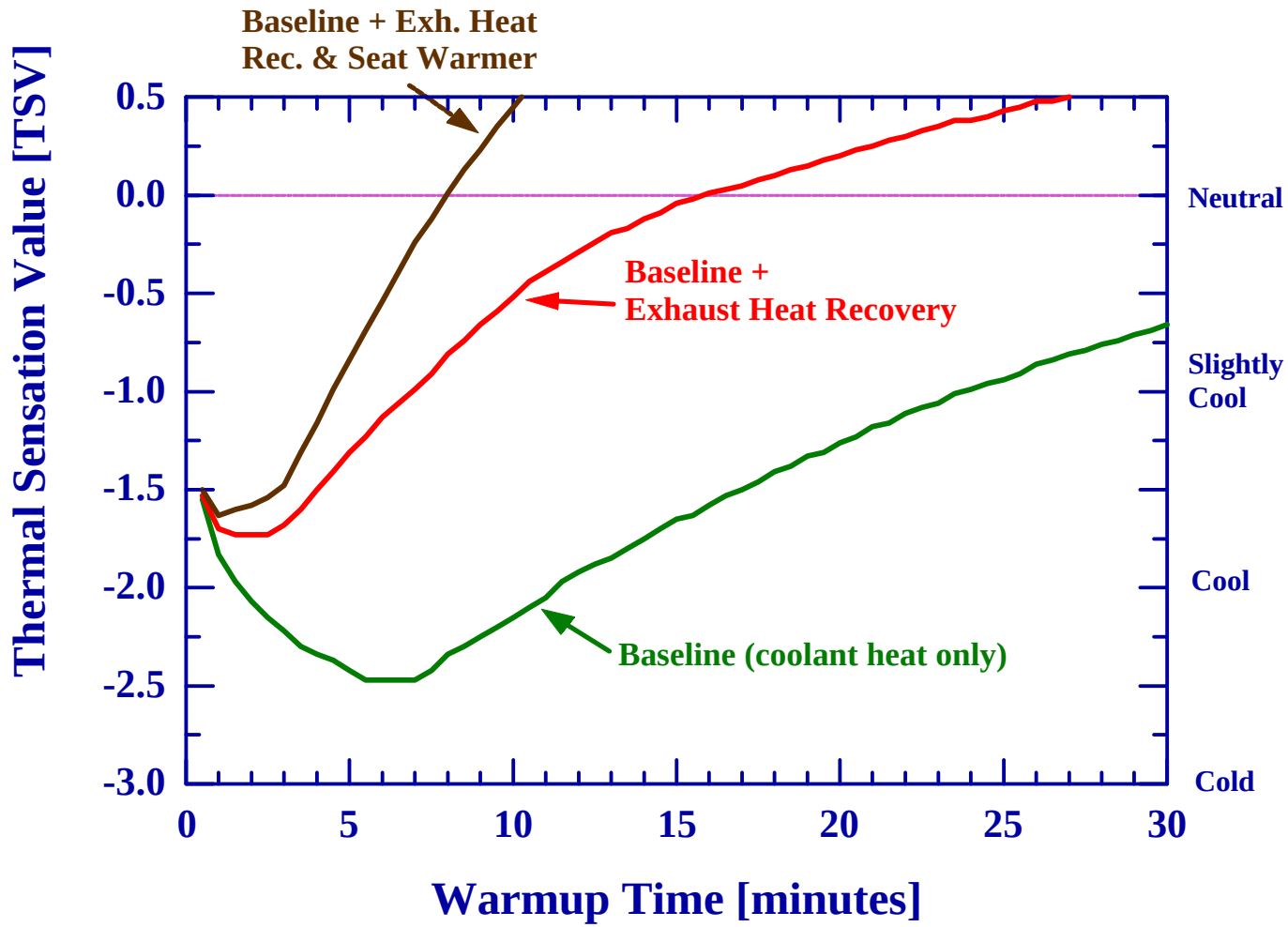
Cabin Warm-up: Exhaust Heat



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

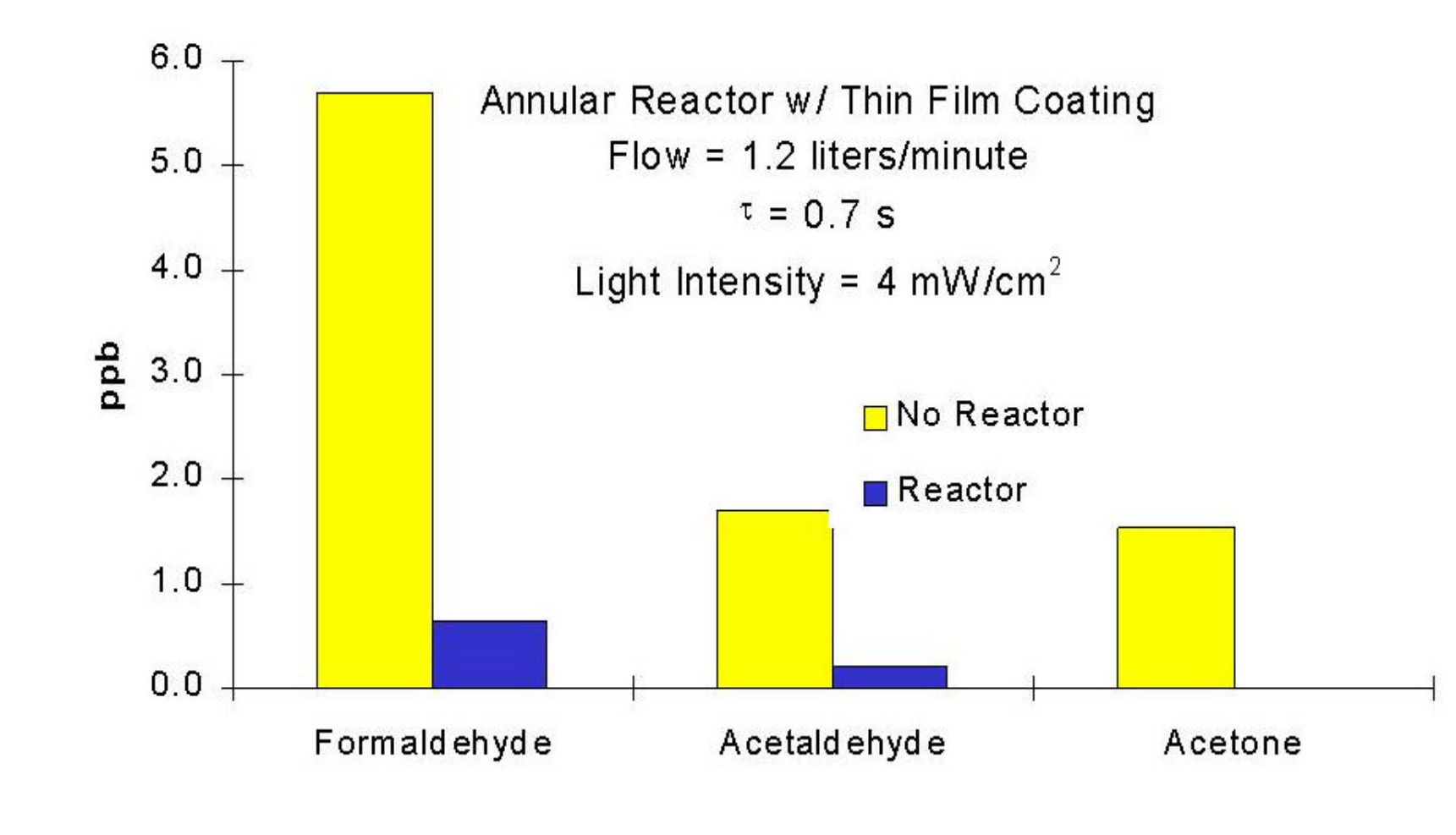
- Simple unit that can be integrated into the HVAC assembly
- Power consumption less than 10 watts
- Unit cost less than $10
- Capable of removing VOC's from fuels, vehicle emissions, odors, and interior materials
- Can increase use of recirculated air

Advantages of PCO System

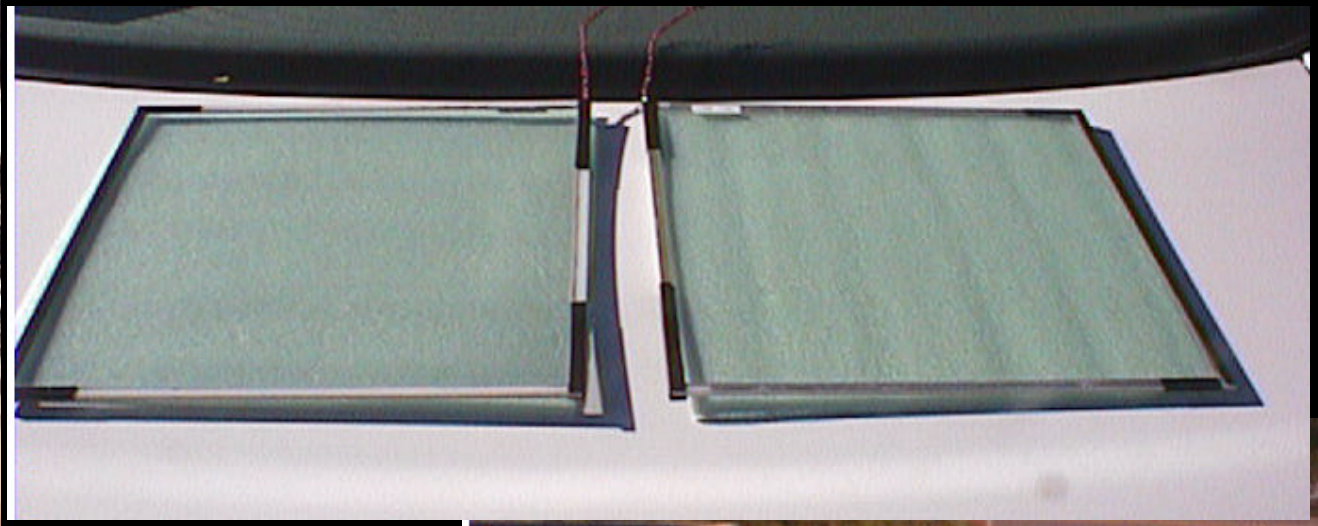
- Acts as a self cleaning filter for VOCs and bioaerosols
- Low maintenance - light bulb and catalyst/filter media (project long life unless it becomes contaminated with inorganic matter)
- Operates at ambient conditions - insensitive to temperature, 0 - 82 C

NREL's PCO Device

PCO Performance



Electrochromic Sunroof



PV Sunroof - Trunk Mounted

- Aperture Area = .37 m^2
- Pmax = 30W
- Efficiency = 8%

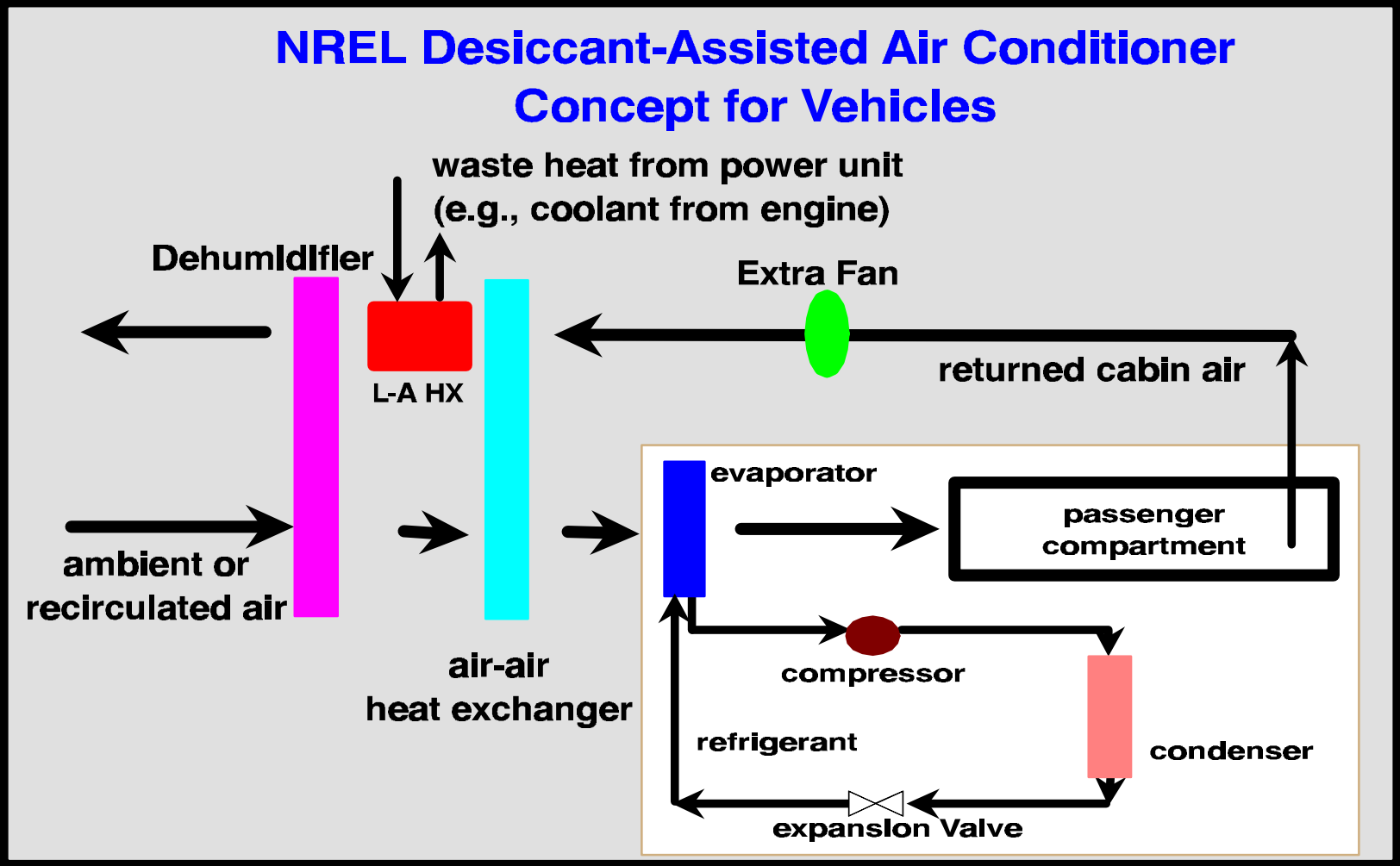
Desiccant-Assisted A/C

- **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

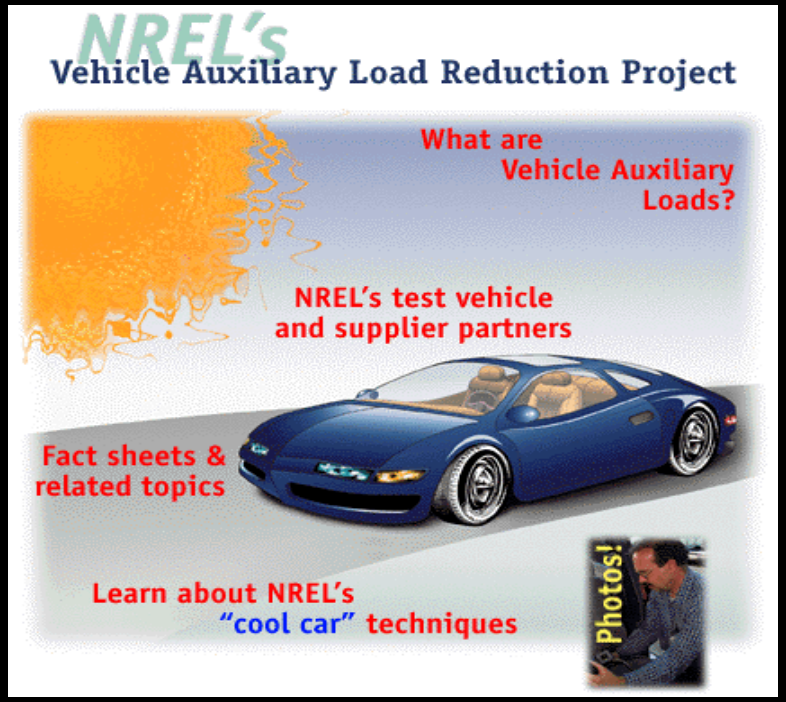
Desiccant-Assisted A/C

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

Desiccant-Assisted A/C Schematic



NREL'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

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- Ahmad Pesaran, Desiccant Technology
- Cassie Quaintance, Cabin Thermal Modeling
- Loreno Roybal, Photovoltaics
- Tom Thoensen, Vehicle and Subsystem Testing