Impact of Glass Variations on MAC Loads

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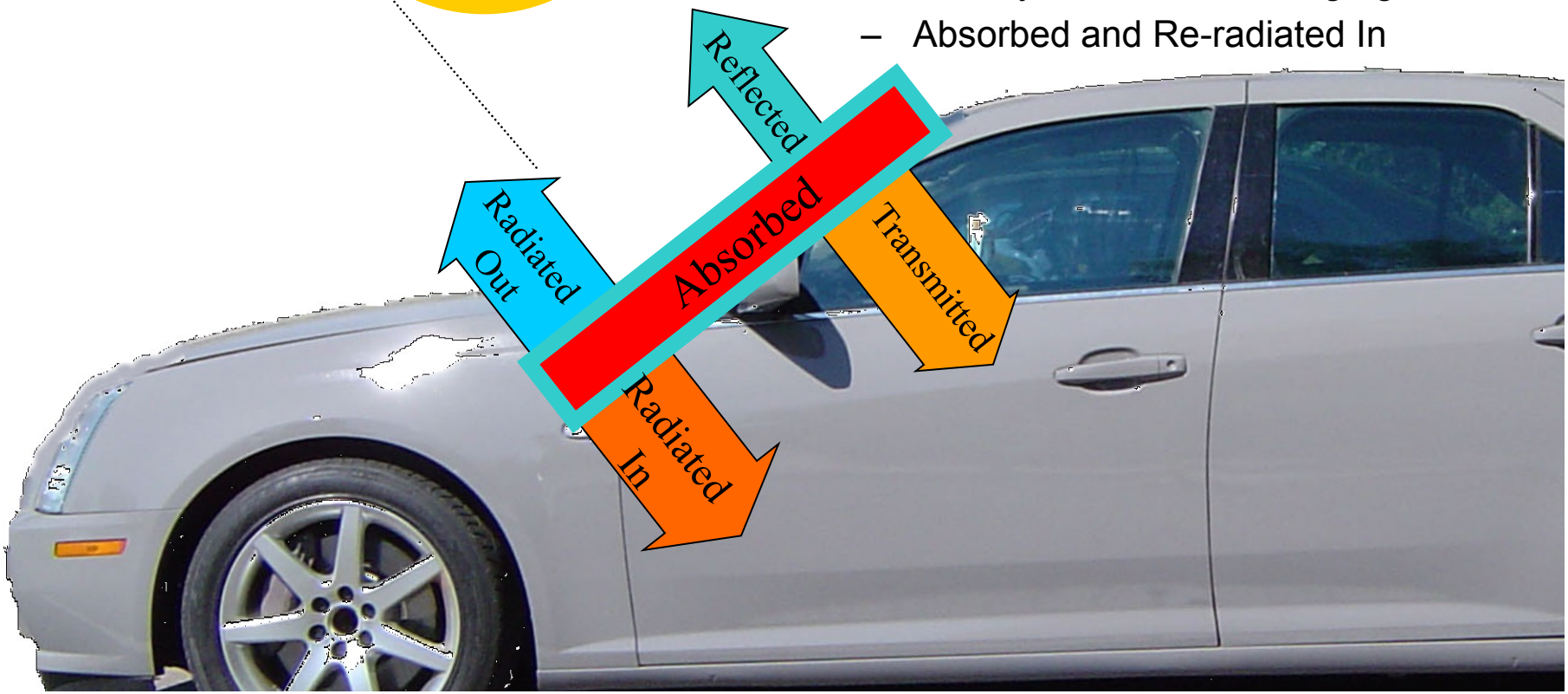
Agenda

- Glazing impact on thermal load
- Glazing impact on fuel consumption and CO_2 emissions
- Impact on ICE, HEV, PHEV, and EV
- How to measure impact of glazing
- Glazing impact and test procedures
- Conclusions

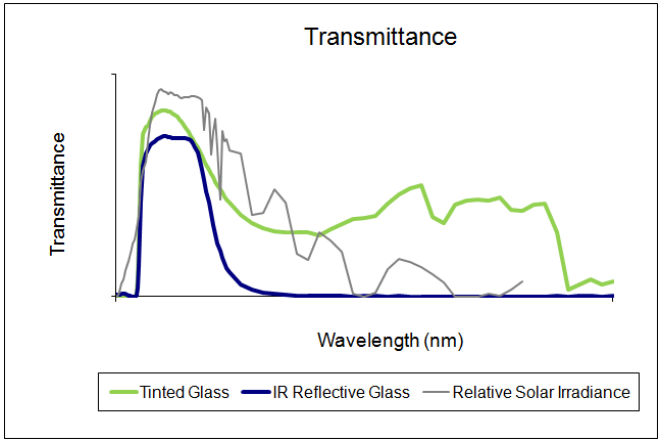
Glazing Impact on Thermal Load

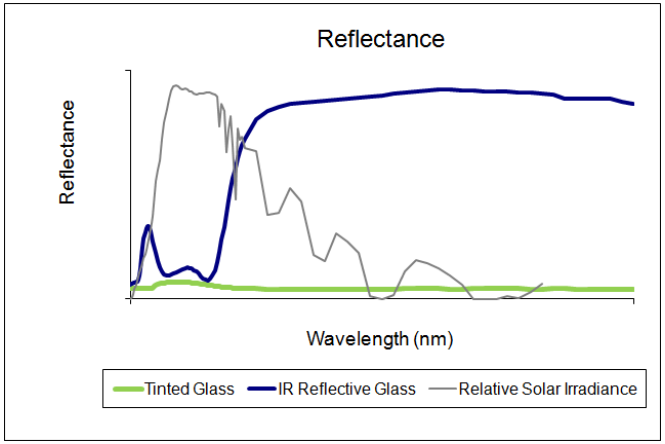
- 50% to 75% of the Thermal Energy entering the vehicle comes through the glazing
  - Directly transmitted through glass
  - Absorbed and Re-radiated In



Glazing reduces heat load in vehicle

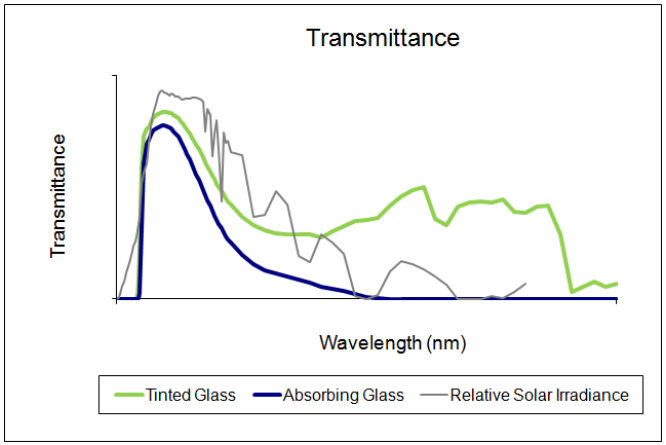
- Various technologies available
  - Reflective Glazing
    - Reflects Infra-Red energy
      - Reduces transmitted energy
      - Reduces energy absorbed by glass
      - Reduces total energy entering vehicle
    - Very effective for parked/slow moving vehicle
    - Meets all FMVSS requirements
    - Is commercial
    - Is not a “tint”

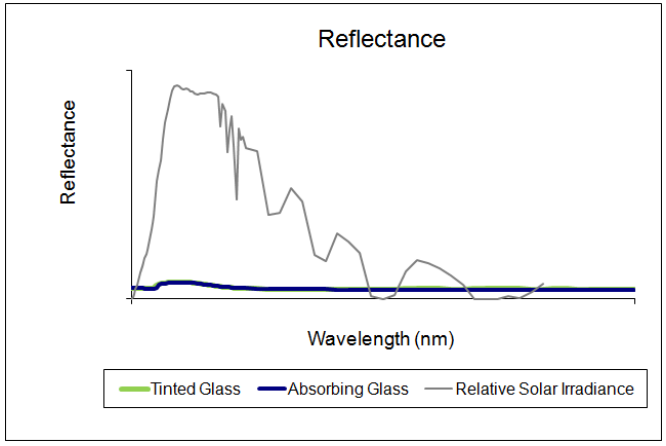




Glazing reduces heat load in vehicle

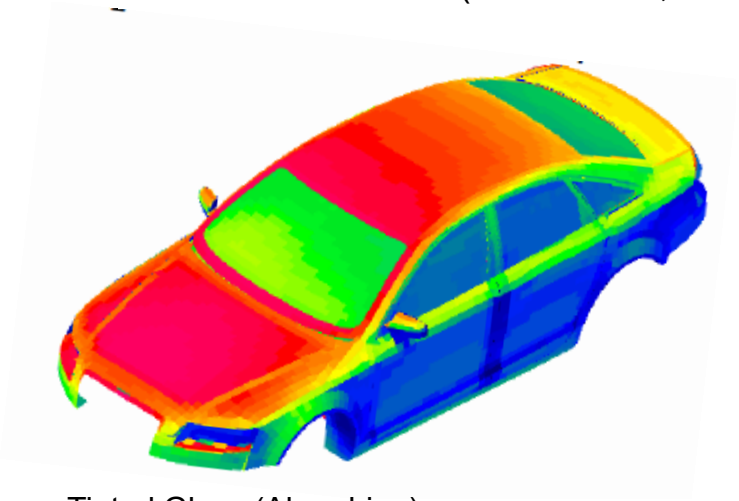
- Various technologies available
  - Absorbing Glazing
    - Absorbs energy into glass
      - Reduces transmitted energy
      - Glass composition and/or laminated construction
    - Convection removes absorbed energy at higher winds/speeds
    - Meets all FMVSS requirements
    - Is commercial
    - Can be tinted



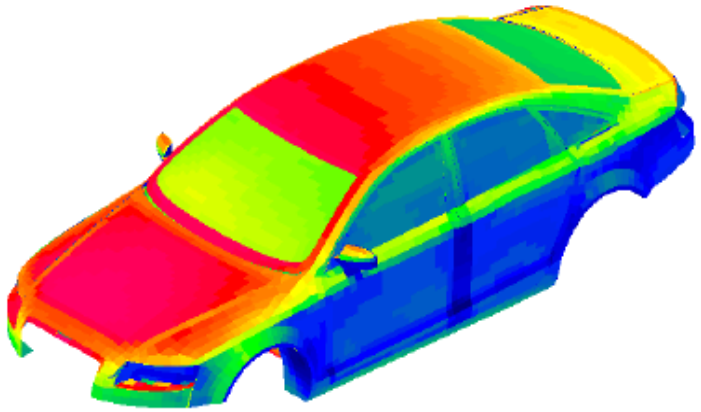


Glass impact on exterior temperatures

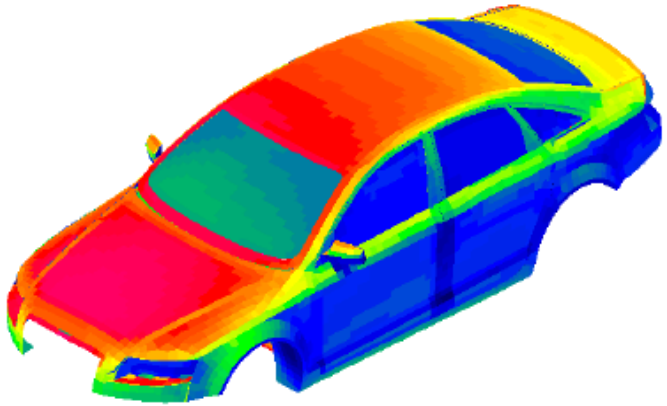
(Parked Car, Phoenix, 1:00 pm)



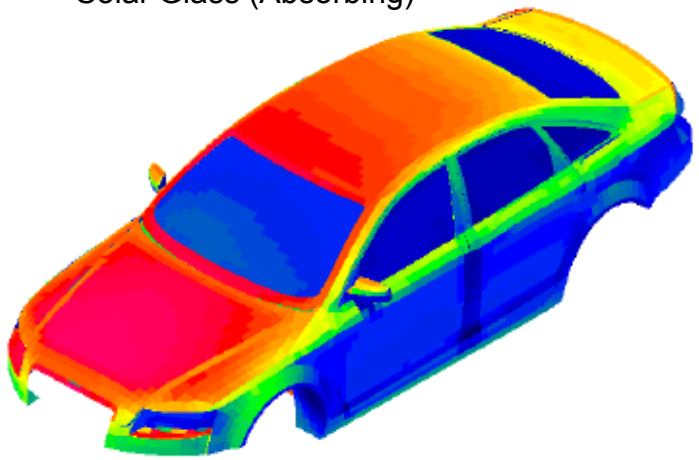
Tinted Glass (Absorbing)



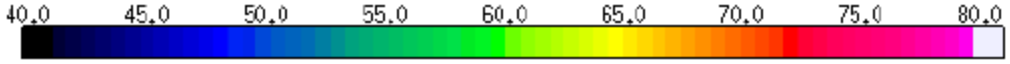
Solar Glass (Absorbing)



IR Reflecting Glass



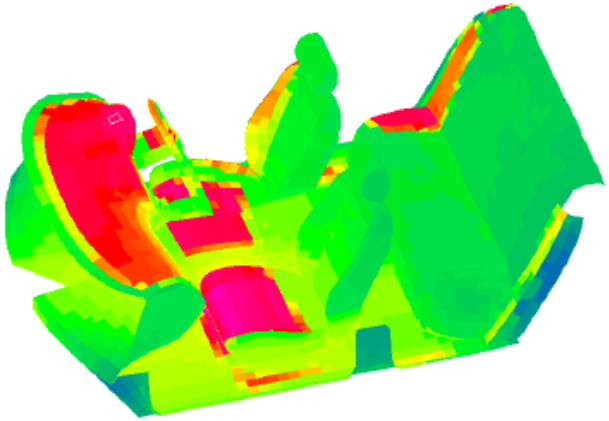
Super IR Reflecting Glass



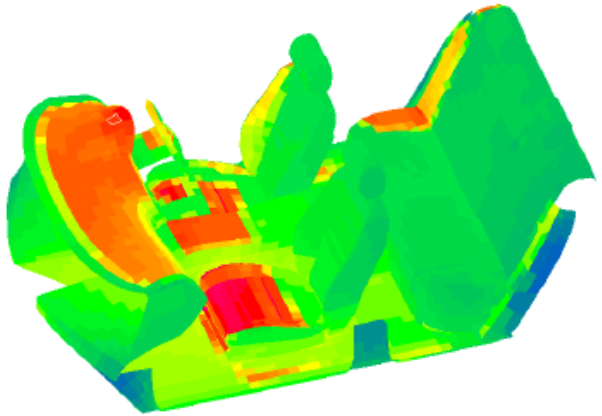
Source: Thermal modeling, PGW data

Glass impact on interior temperatures

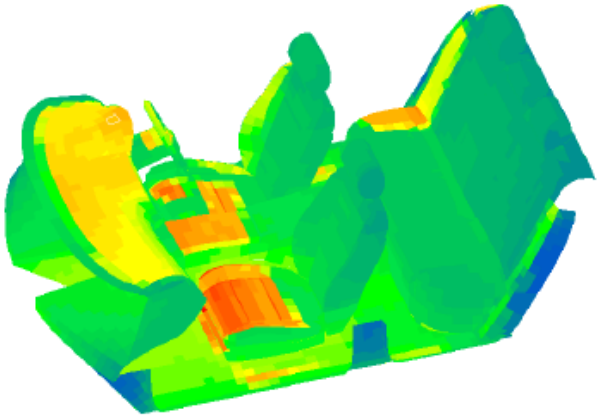
(Parked Car, Phoenix, 1:00 pm)



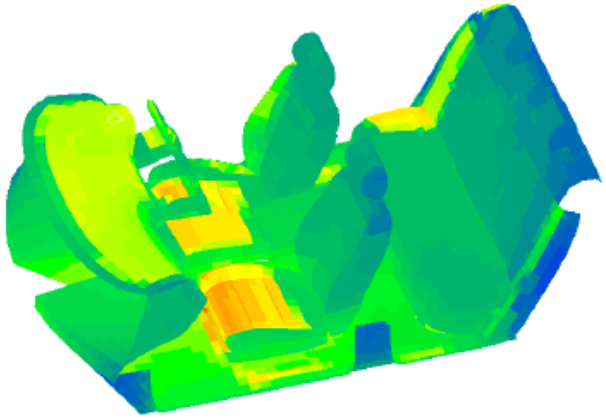
Tinted Glass (Absorbing)



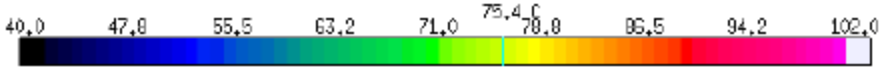
Solar Glass (Highly Absorbing)



IR Reflecting Glass



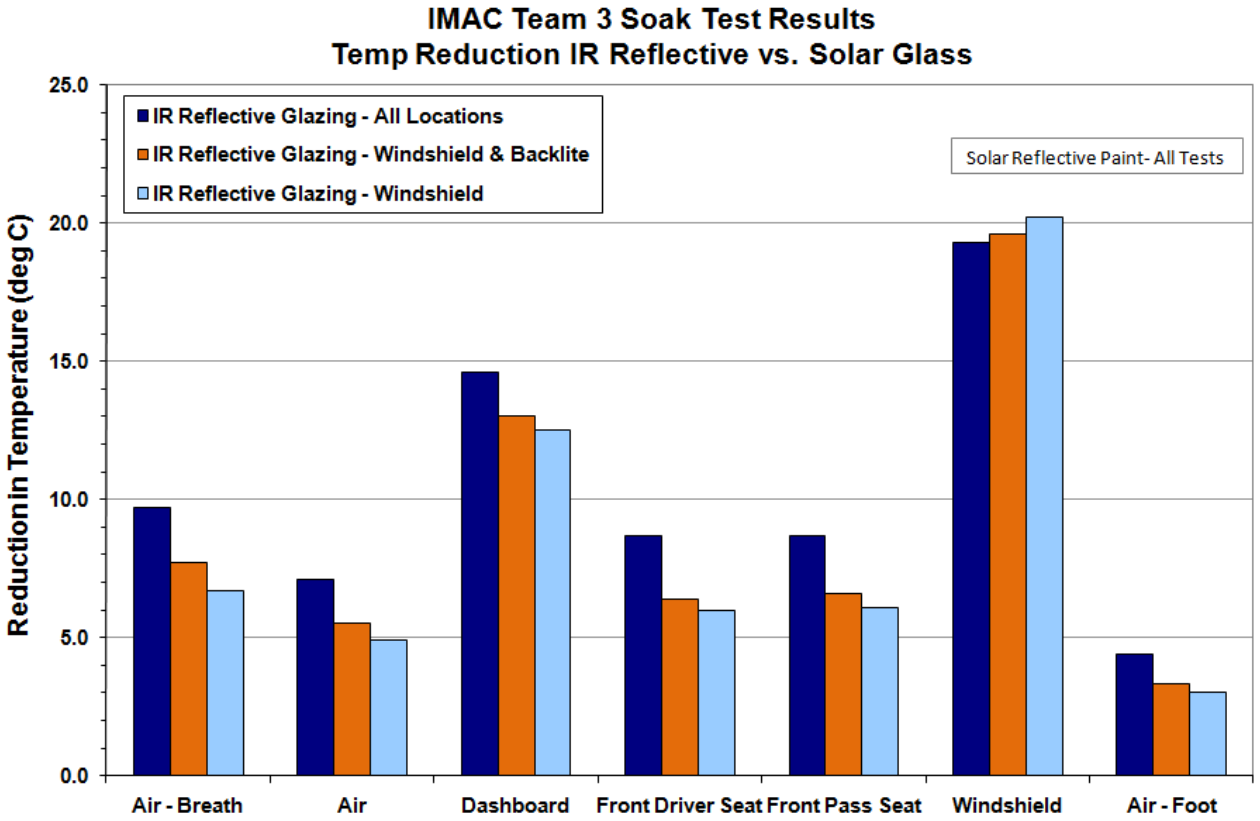
Super IR Reflecting Glass



Source: Thermal modeling, PGW data

Actual Soak Temperature Difference

- SAE/IMAC project showed temperature reductions from glazing can be very significant. Temperature difference would be even greater when compared to tinted glass.



Glazing impact on fuel consumption and CO_2 emissions

- NREL analysis shows 1.2% AC Fuel Reduction per 1 deg F reduction in interior (breath air) temperature
  - AC Fuel reduction of as much as 33% possible over a base case of tinted glass (even higher over clear glass)
  - AC Fuel reduction of 27% possible over current mix of glass (per CARB calculations)

Impact on ICE, HEV, PHEV, EV

- Impact on ICE well researched
- Recent studies show glazing has significant impact on HEV, PHEV, and EV
  - Fuel consumption improvement > 8% over composite UDDS/US06 drive cycles (55/45), e.g. 41.6 mpg vs. 38.4 mpg (source: NREL/PGW)
  - Other benefits
    - Consumer comfort
    - Stop/Start performance improvement
    - Enhanced battery life

How to measure impact of glazing

- Measure spectral performance of glazing
  - International standards exist
- Use model to determine heat load into vehicle
  - Several models exist (NREL's VSOLE, Radtherm, etc.)
- Use Fuel Consumption Model
  - Models exist (NREL's ADVISOR)
- Apply to national average
  - As developed by EPA/NREL

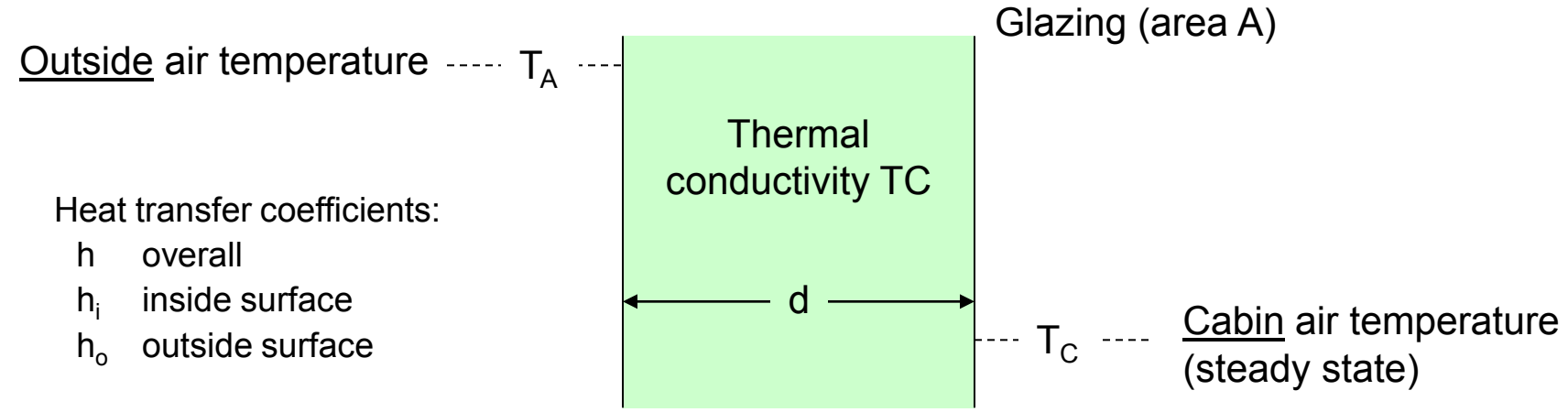
Glazing impact and test procedures

- Test procedures, when devised, have to account for real-world conditions
  - Indoor testing has to replicate solar spectrum
    - Glazing is specifically designed for real-world conditions
  - Sufficient heat soak to represent real-world conditions
  - Account for solar movement within the day
  - Include impact during drive cycle (including wind speed)
  - Account for “shoulder” months – AC use could be mitigated with glazing completely
  - Glazing to be credited with AC weight reduction due to efficiency
  - Start/Stop functionality enhancement
  - Battery efficiency and long term impact on battery

Conclusions

- Glazing has significant impact on cabin temperature and AC system
  - Breath air temperatures can be lowered by as much as 14 deg C
  - Cool down times are reduced
  - Reduced heat load → Lower AC Fuel Usage
  - Lower AC Fuel Use → Lower CO_2 emissions

Reduced glazing thermal conductivity reduces steady state MAC indirect emissions



Total heat transfer = Conduction + Radiation

$= h \cdot A \cdot (T_A - T_C)$ + Radiation

where $1/h = 1/h_o + d/TC + 1/h_i$

Fix d, Radiation to isolate TC effect

Reduced thermal conductivity means

- → **reduced Total heat transfer**
- → **reduced HVAC cooling load**
- → **reduced MAC indirect emissions**

Computational Fluid Dynamics case study:

Phoenix, mid-day, Apr - Oct, 100 kmph vehicle speed

Reduced roof & backlite thermal conductivity from 1 W/m-°K (glass) to 0.2 W/m-°K (polycarbonate)

→ 5.5% reduction HVAC load (kW)

→ 4.5 gCO_2 /mile reduction MAC indirect emissions

Reduced thermal conductivity glazing materials like polycarbonate can help reduce MAC indirect emissions … 5.5% load reduction achievable