Vehicular Thermoelectric Applications

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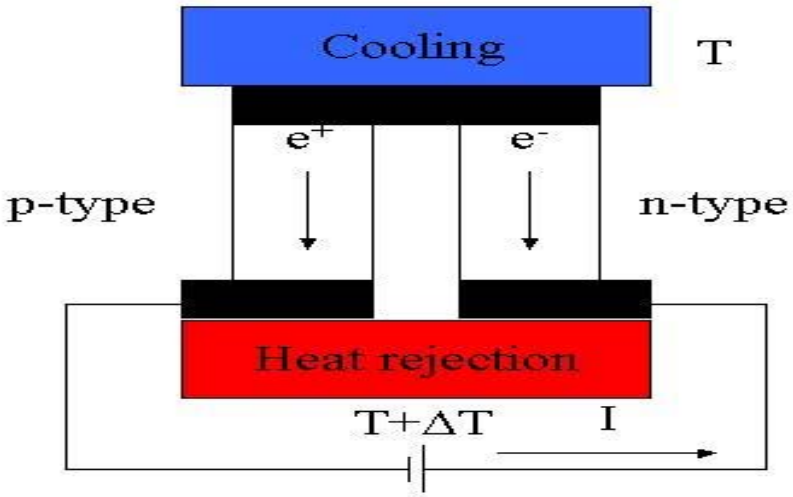
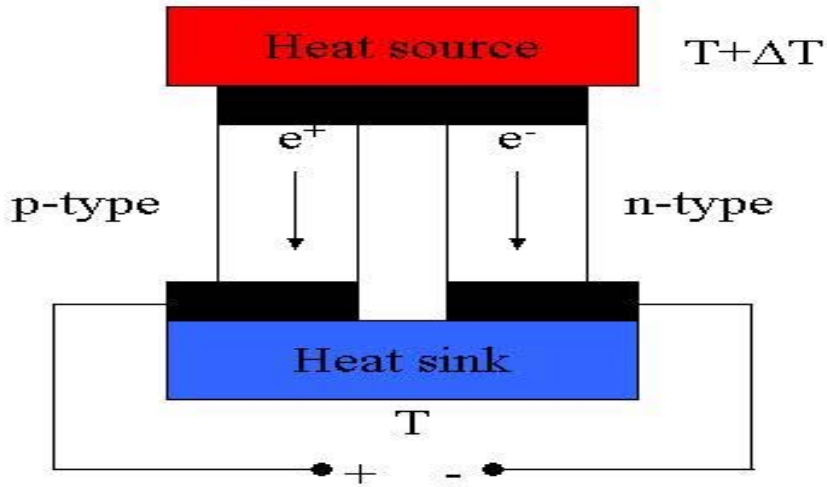
Thermoelectrics

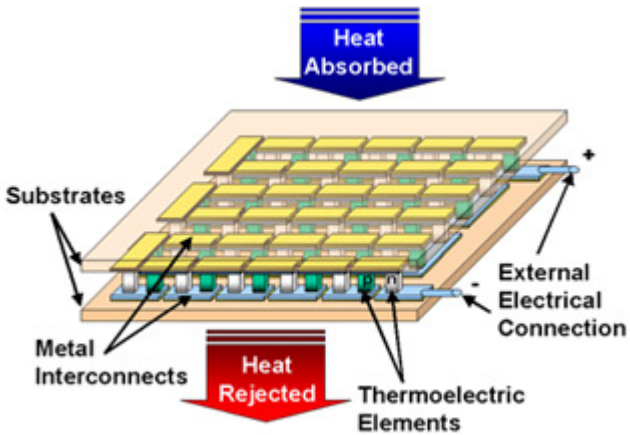
Thermoelectric Modules



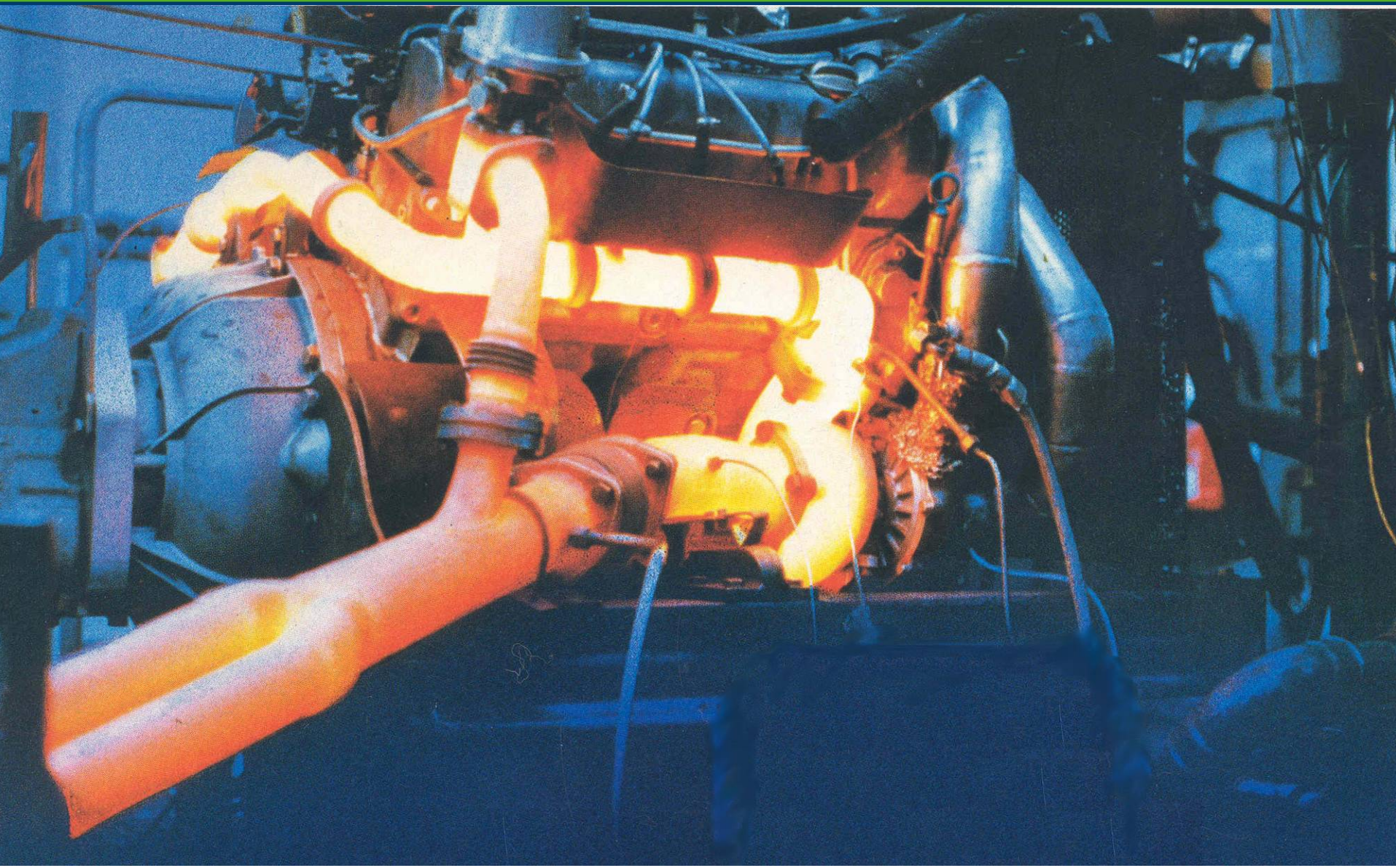
Refrigeration



Power generation

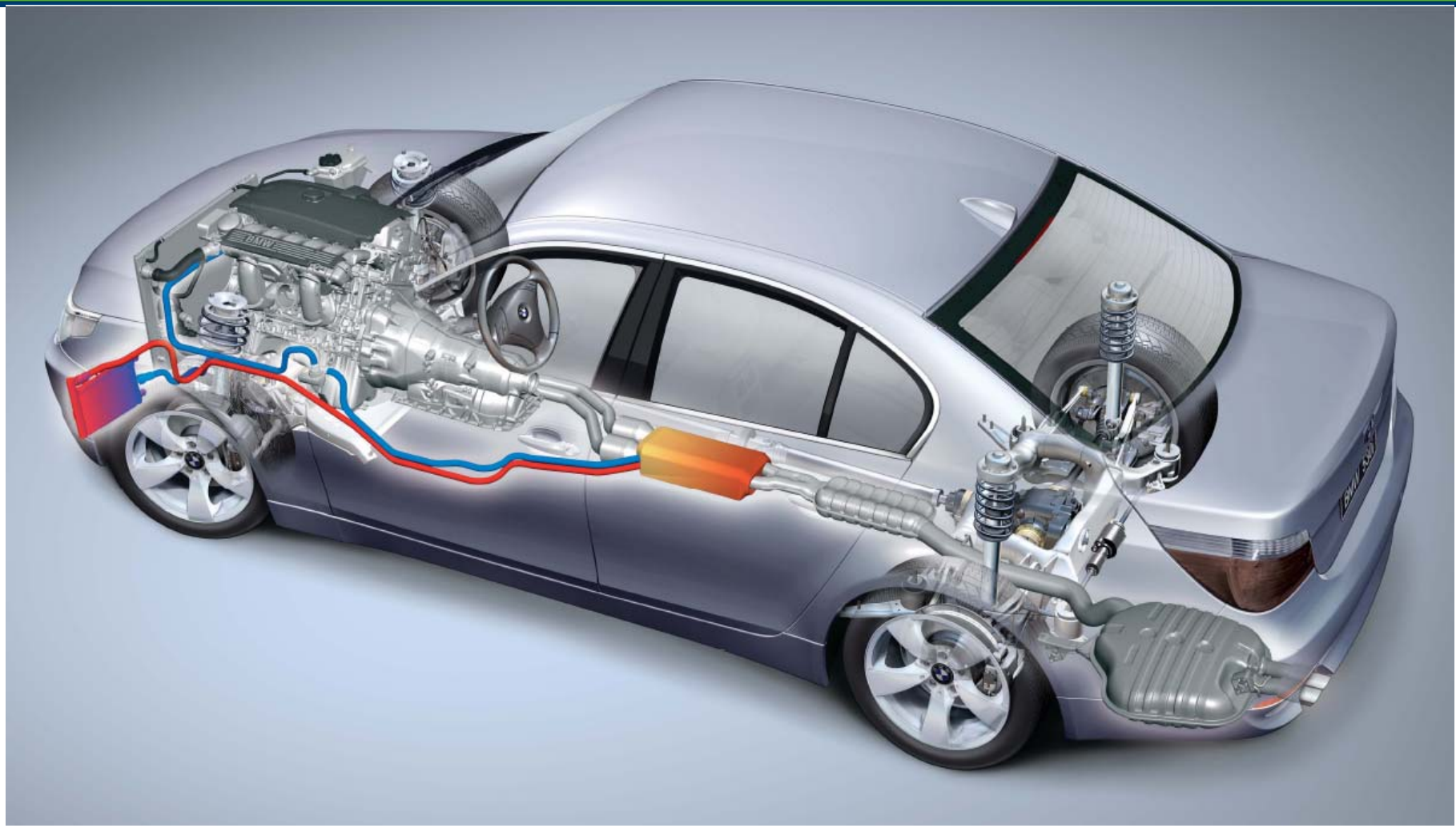


Available Energy in Engine Exhaust



U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

BMW Series 5 , Model Year 2011, 3.0 Liter Gasoline Engine w/ Thermoelectric Generator



FreedomCAR & Fuel Partnership

Visteon

BSST innovative solutions in temperature control

BMW

MINI

- Current Vehicular Air Conditioner uses Compressed R134-a Refrigerant Gas
  - > Vehicles leak 33-70 g/year R134-a
  - > R134-a Has 1300 times Greenhouse Gas Effect as Carbon Dioxide (CO_2)
  - > EU is proscribing use of R134-a
  - > Thermoelectric Heating, Ventilation and Air Conditioning (HVAC) is Candidate Replacement

Automotive Greenhouse Gases from Operating Air Conditioning

- 69.5 Million Metric Tons/Year of CO_2e Released from Personal Vehicles in the US as a Result of Using Air Conditioning

- Additional significant amounts CO_2e released due to accidents and end of life vehicle salvage releasing R134-a

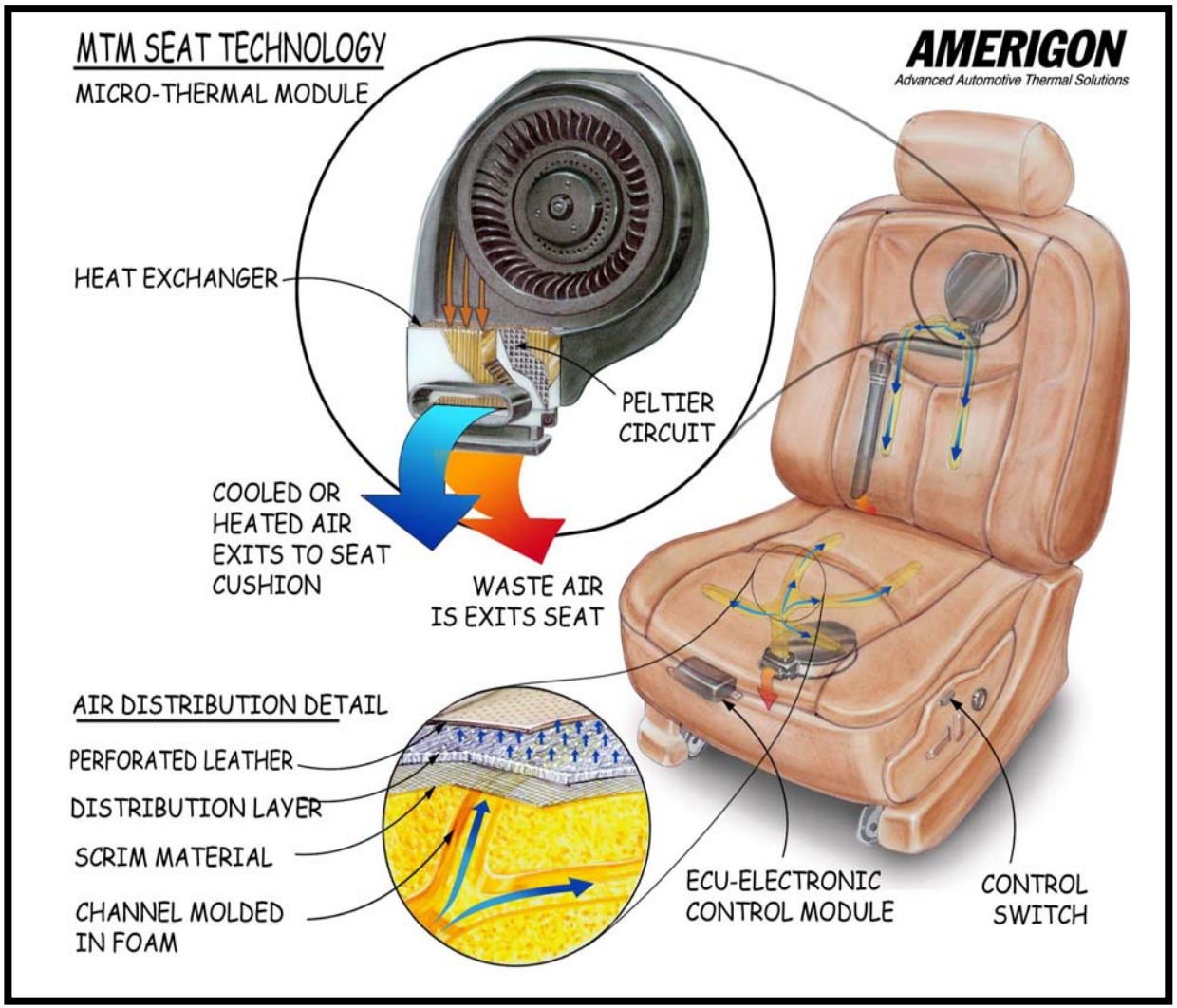
Vehicular Solid State Thermoelectric HVAC Development Program

- Approach: Develop Zonal Thermoelectric based heating and cooling systems for cars, light trucks (SUV's, Pick-ups, Mini vans) and Heavy Duty Class 7 &8 Trucks which provides :

  - Reduced fuel consumption
  - Reduced Greenhouse Gases
  - Reduced toxic emissions (NOx & Particulates)
  - Increased engine-off comfort
  - Faster heating and cooling to comfort at start-up
  - Reduced maintenance costs
    - No moving parts

      (Except for fans and heat transfer fluid circulating pump)
    - No refrigerant gas recharging

Climate Control Seat™



Zonal HVAC System

Zonal TE devices located in the dashboard, headliner, A&B pillars and seats / seatbacks

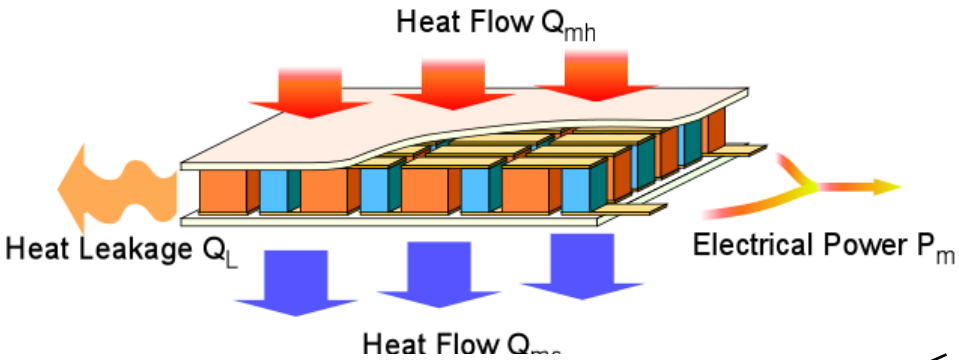
Thermoelectric HVAC Advantages for Plug-in Hybrids

- Occupant Heating During Battery Propulsion
  (No Engine Heat)
  – Resistance Heating Inefficient

  Occupant Cooling
  – Electric Compressor Refrigerant Gases
  > Need R134-a Replacement

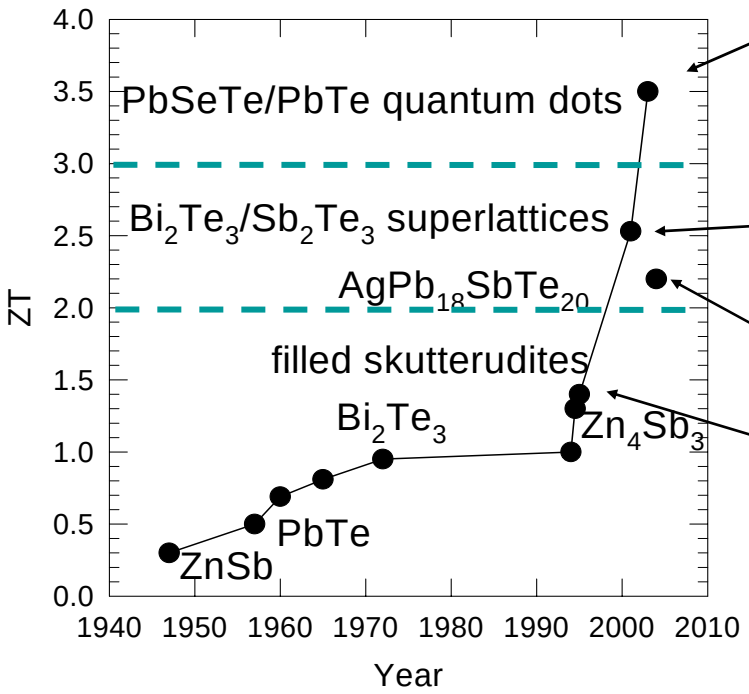
  Thermoelectric HVAC Zonal Concept
  > Cooling COP 1.5
  Augment or Replace Compressed Gas Unit
  > Heating COP 2.5
  Replace Resistive Heater

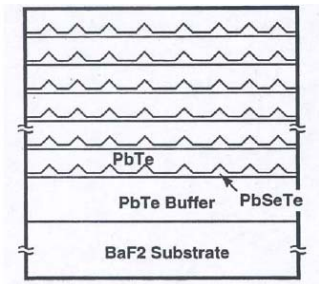
Recent Advances in Efficiency of Thermoelectric Materials

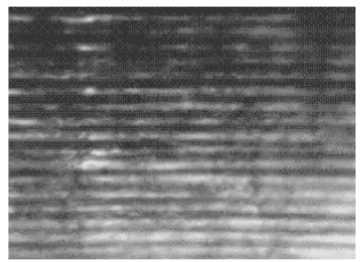


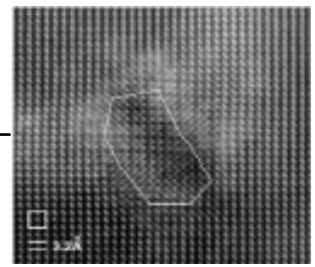
Efficiency:

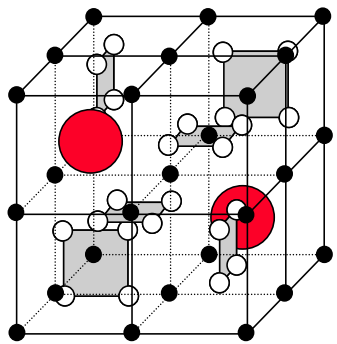
$$\varepsilon = \frac{T_H - T_C}{T_H} \frac{\sqrt{1 + ZT} - 1}{\sqrt{1 + ZT} + \frac{T_C}{T_H}}$$









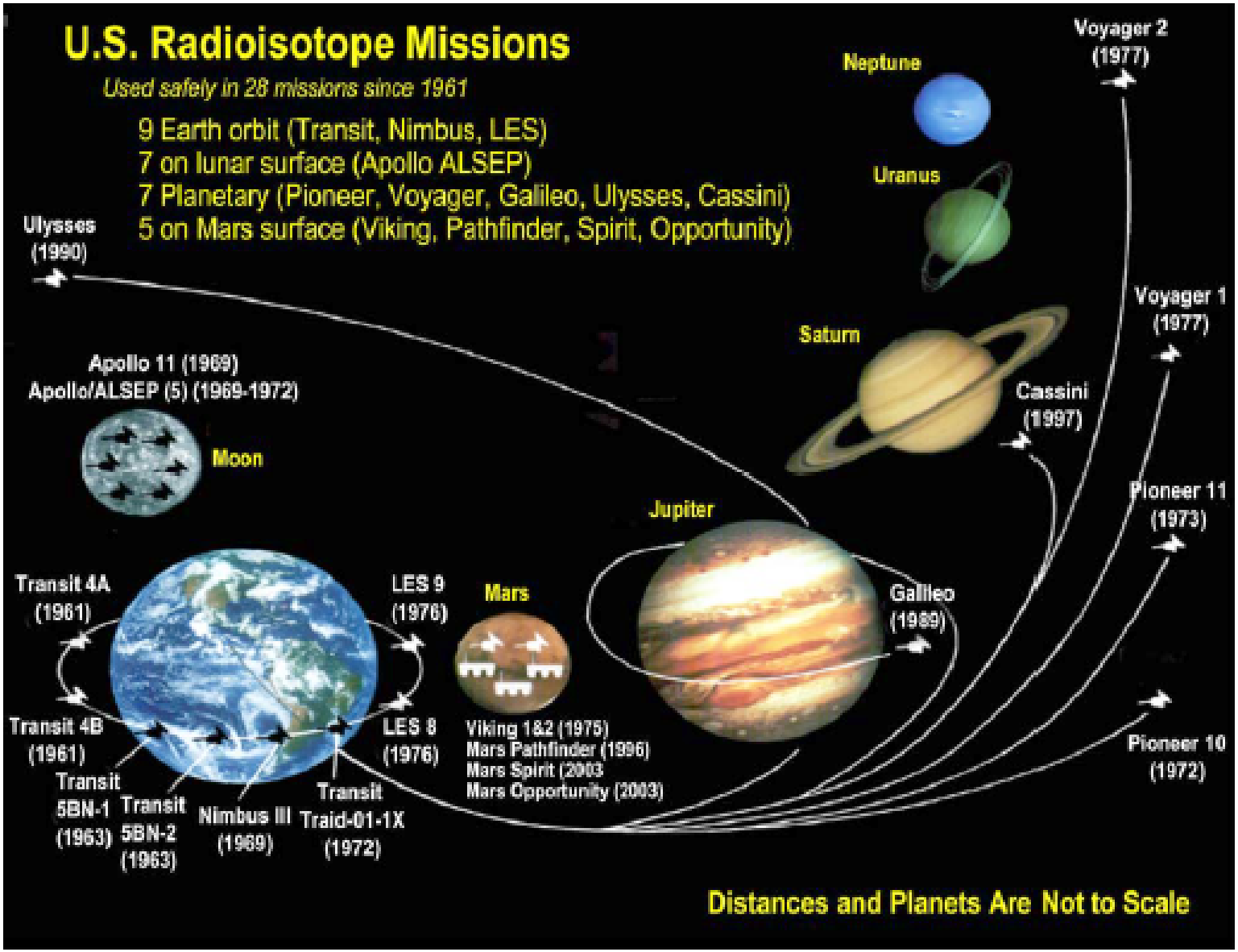


» Many recent thermoelectric material advances are nano-based

Thermoelectric Growth Potential

- Materials emerging in labs > 300 % more efficient than 1st generation thermoelectric generators
- > Major Challenges scaling up to commercially viable modules
- When 30 percent efficient cells available
  - > Replace automotive gasoline engine
  - > Dedicated combustor – burn virtually any fuel
    - Liquid, gas, pulverized solid (corn, wood etc)
  - ➢ Low combustion temperature – essentially no NOx
- End of Century
  - > Solar concentrators and encapsulated thermoelectric generators Charge battery packs for electric cars
  - > RTG + Thermoelectric Generator Powertrains cars & buses
    - Expensive but 30 – 40 years life
    - Change vehicle body every 5 to 10 years

Spacecraft Using Radioisotope Thermoelectric Generators



Next……..

- 1st generation thermoelectric generators