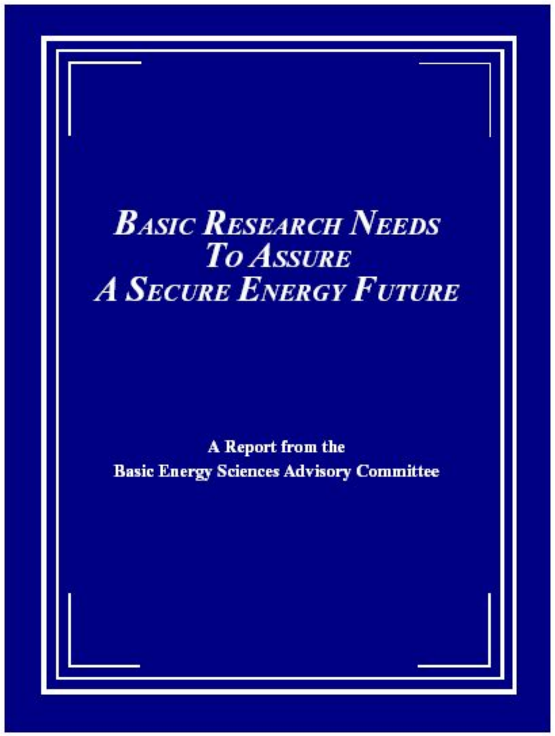
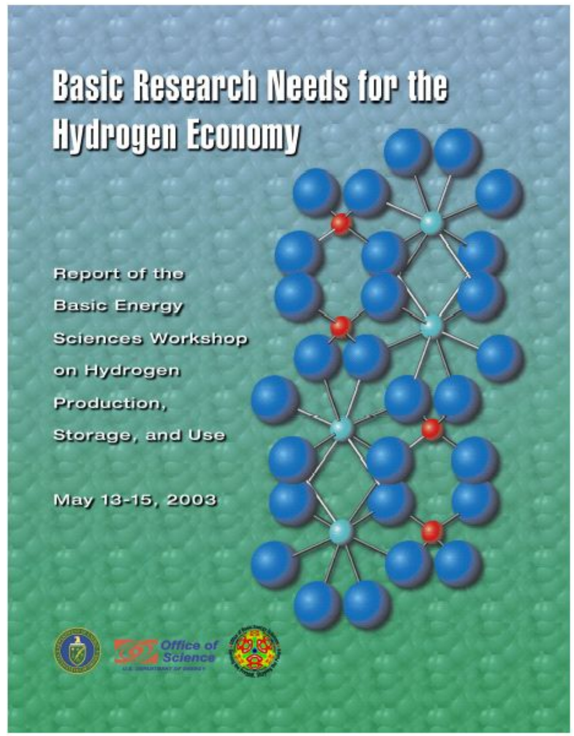
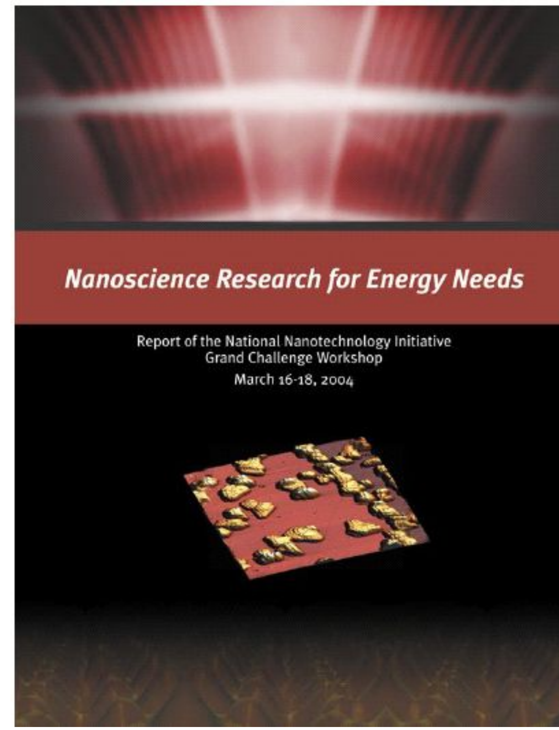
Energy and Nanotechnology

Sources



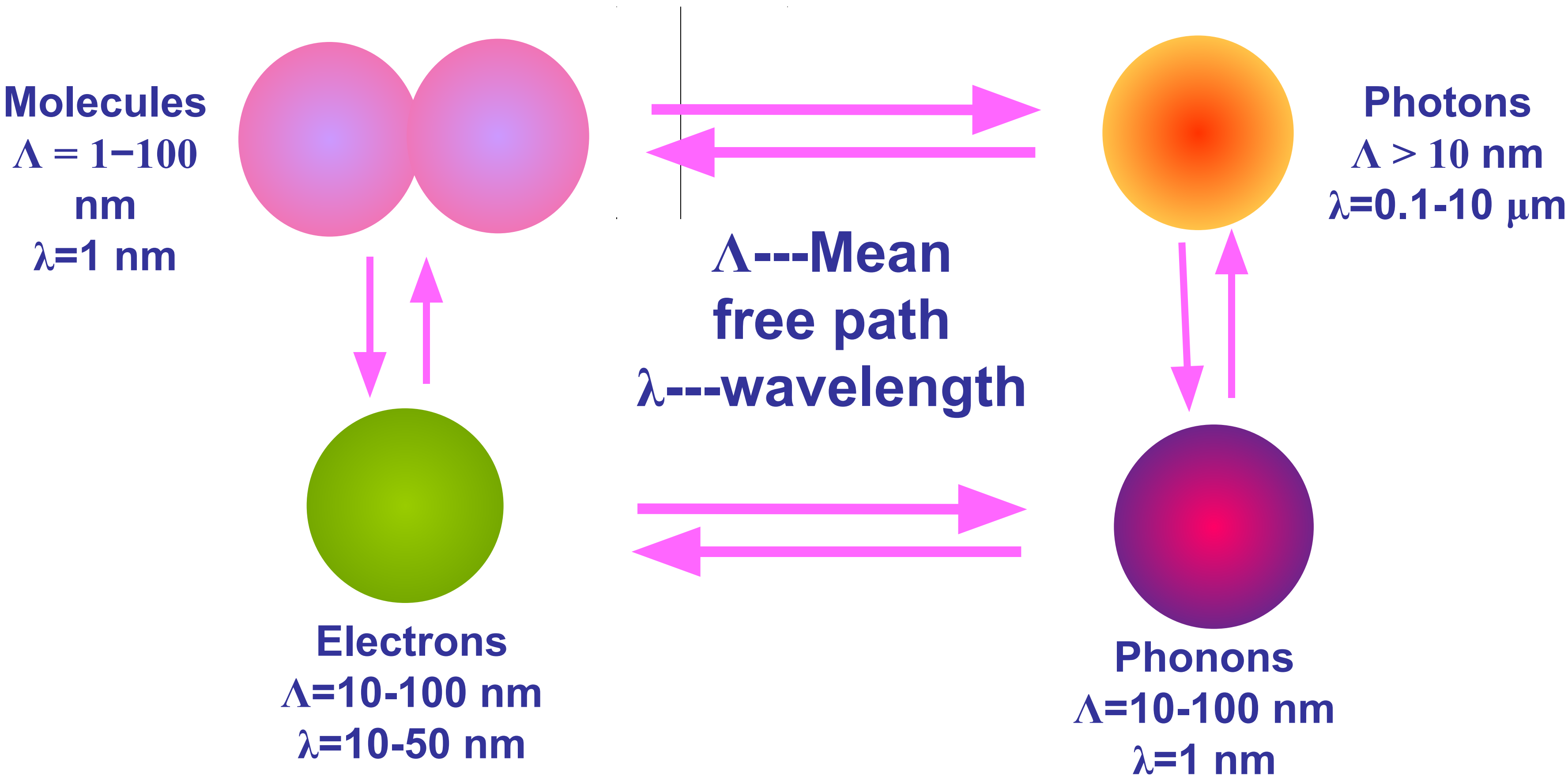




http://www.sc.doe.gov

Nano for Energy

- Increased surface area
- Interface and size effects

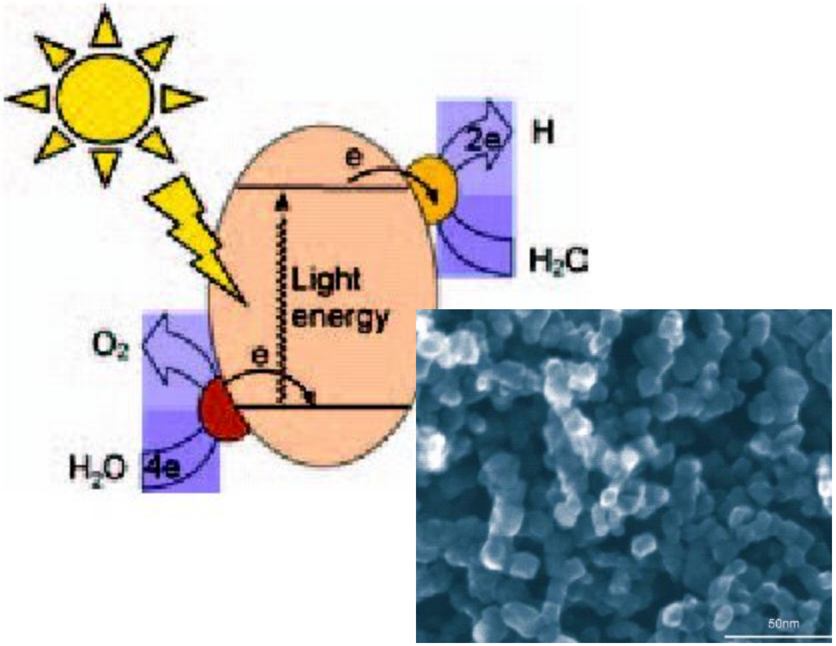


Nanoscience Research for Energy Needs

- Catalysis by nanoscale materials
- Using interfaces to manipulate energy carriers
- Linking structures and function at the nanoscale
- Assembly and architecture of nanoscale structures
- Theory, modeling, and simulation for energy nanosciences
- Scalable synthesis methods

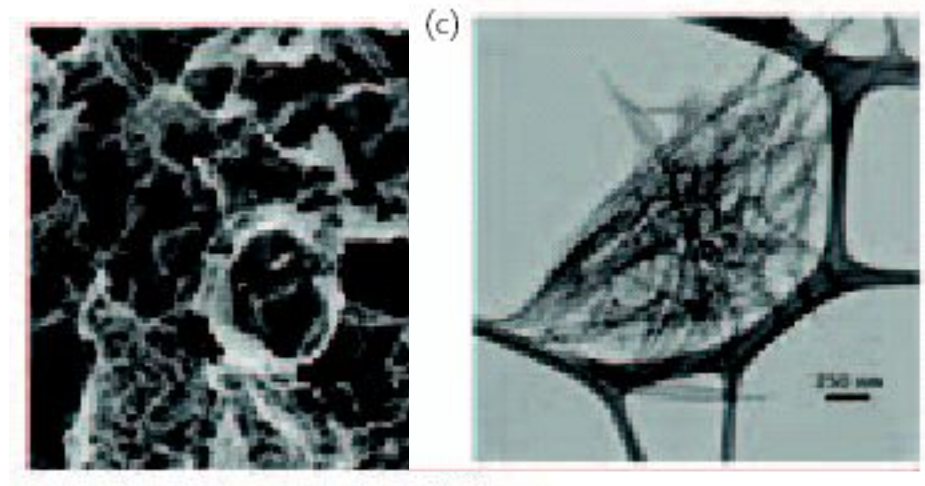
National Nanotechnology Initiative Grand Challenge Workshop, March, 2004

Examples



Grätzel cell for photovoltaic generation and water splitting

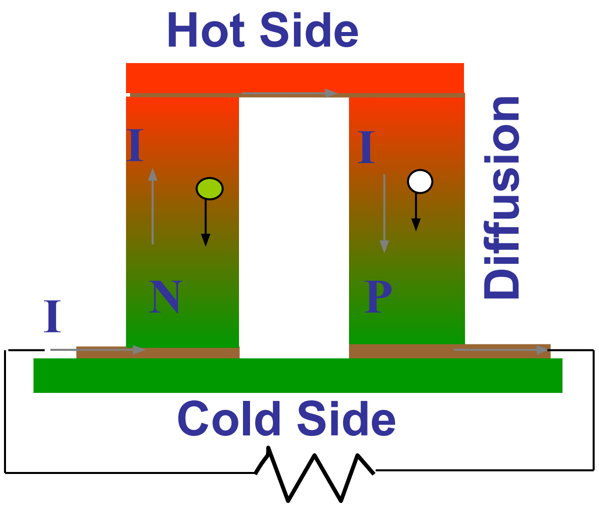
- Radiation transport to maximize absorption
- Two phase flow
- Electrochemical transport
- Multiscale, multiphysics transport



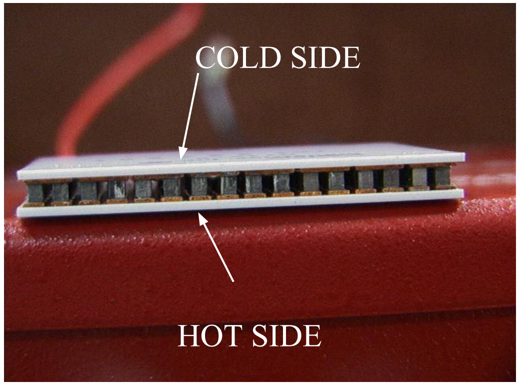
Catalytic nanostructured hydrogen storage materials

- Mass transport
- Heat transfer (intake and release)
- Small scale thermodynamics
- Two phase flow
- Multiscale and multiphysics

Thermoelectrics Devices



Power Generation



Media Clip

Figure of Merit:

Electrical Conductivity — Seebeck Coefficient

$$ZT = \frac{\sigma S^2 T}{k_e + k_p}$$

Electron — Phonon
Thermal Conductivity

- **Refrigeration**
- **Power Generation:**

  T(hot)=500 C, T (cold)=50 C

  ZT=1, Efficiency = 8 %

  ZT=3, Efficiency =17 %

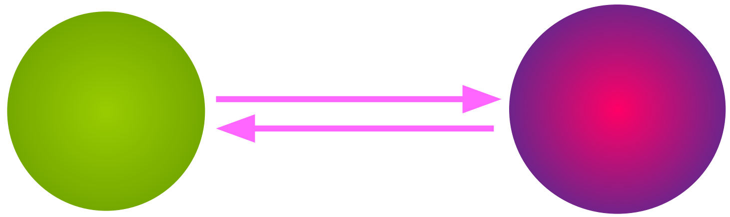
  ZT=5, Efficiency =22 %

- **Critical Challenges:**

  Reduce phonon heat conduction while maintaining or enhancing electron transport

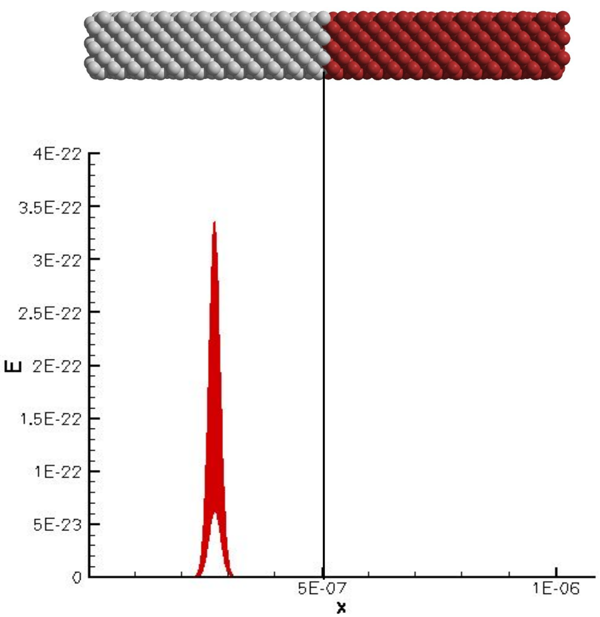
Nanoscale Effects for Thermoelectrics

Interfaces that Scatter Phonons but not Electrons

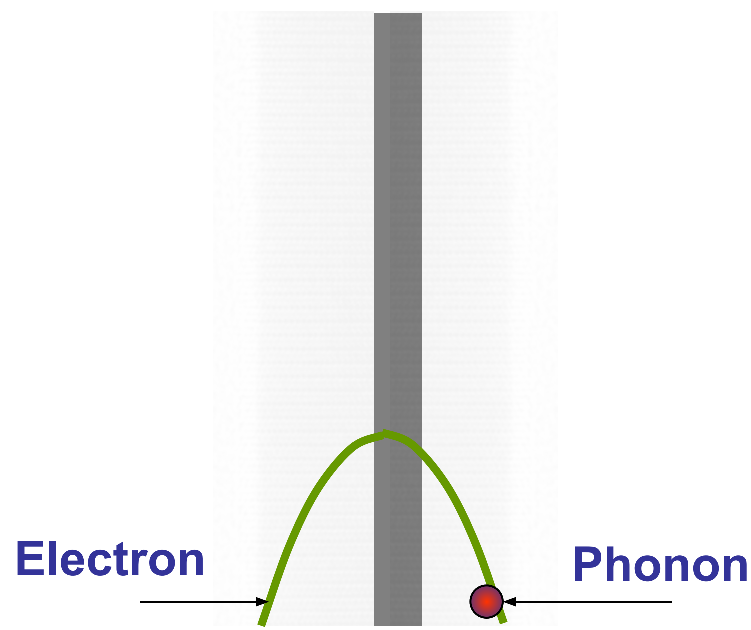


Electrons
Λ=10-100 nm
λ=10-50 nm

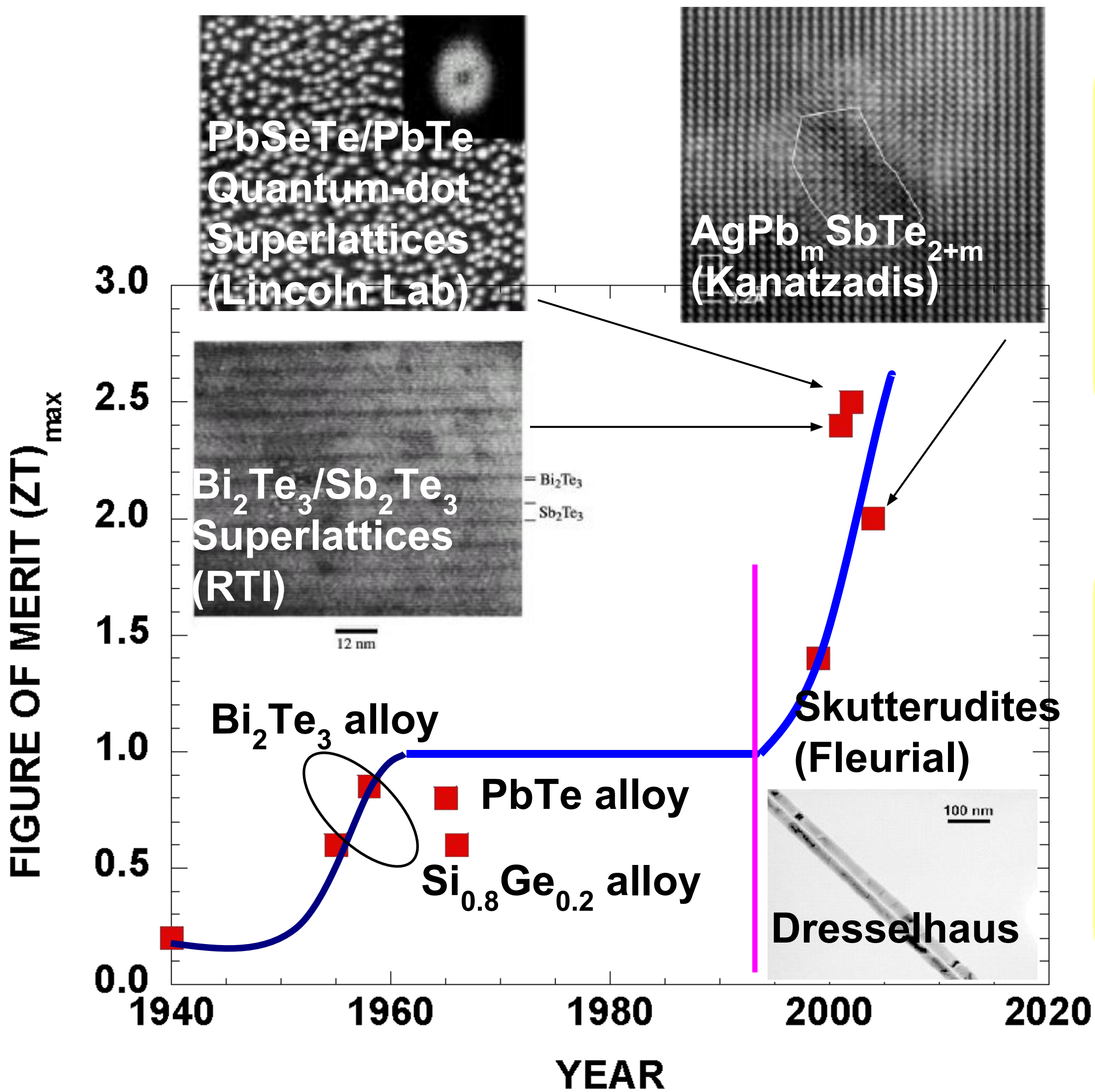
Phonons
Λ=10-100 nm
λ=1 nm



Molecular Dynamics (Freund)



State-of-the-Art in Thermoelectrics



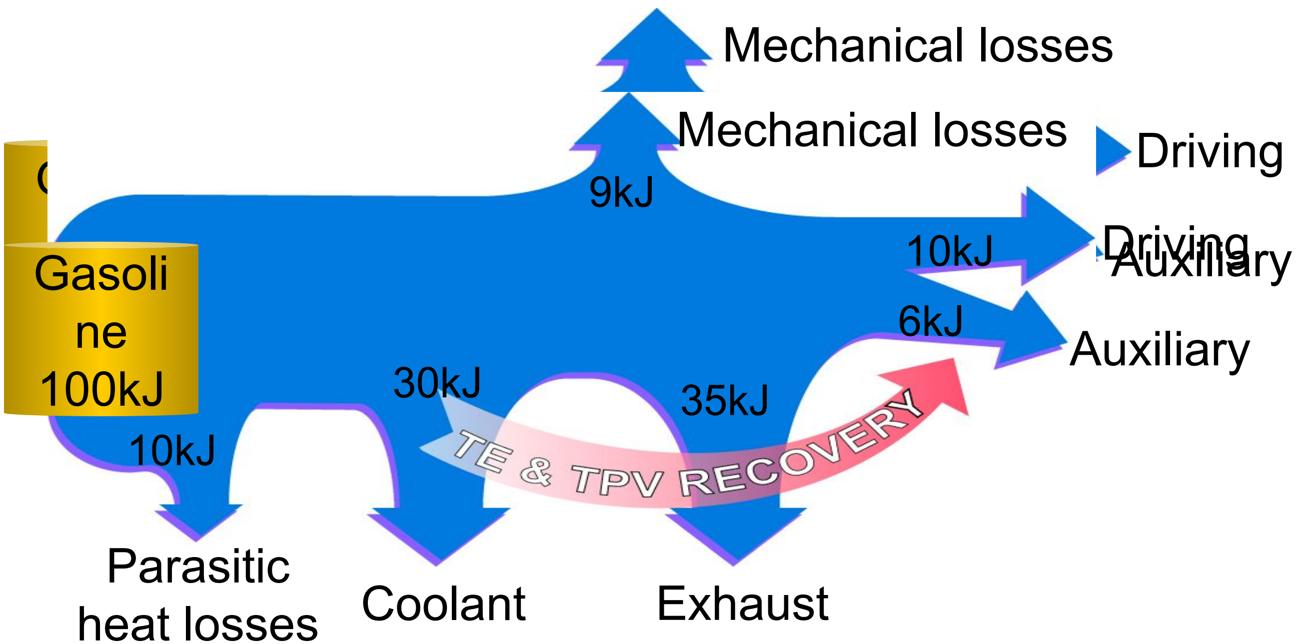
PbTe/PbSeTe	Nano	Bulk
$S^2\sigma$ (μW/cmK^2)	32	28
k (W/mK)	0.6	2.5
ZT (T=300K)	1.6	0.3

Harman et al., Science (2003)

Bi_2Te_3/Sb_2Te_3	Nano	Bulk
$S^2\sigma$ (μW/cmK^2)	40	50.9
k (W/mK)	0.6	1.45
ZT (T=300K)	2.4	1.0

Venkatasubramanian et al.,
Nature, 2002.

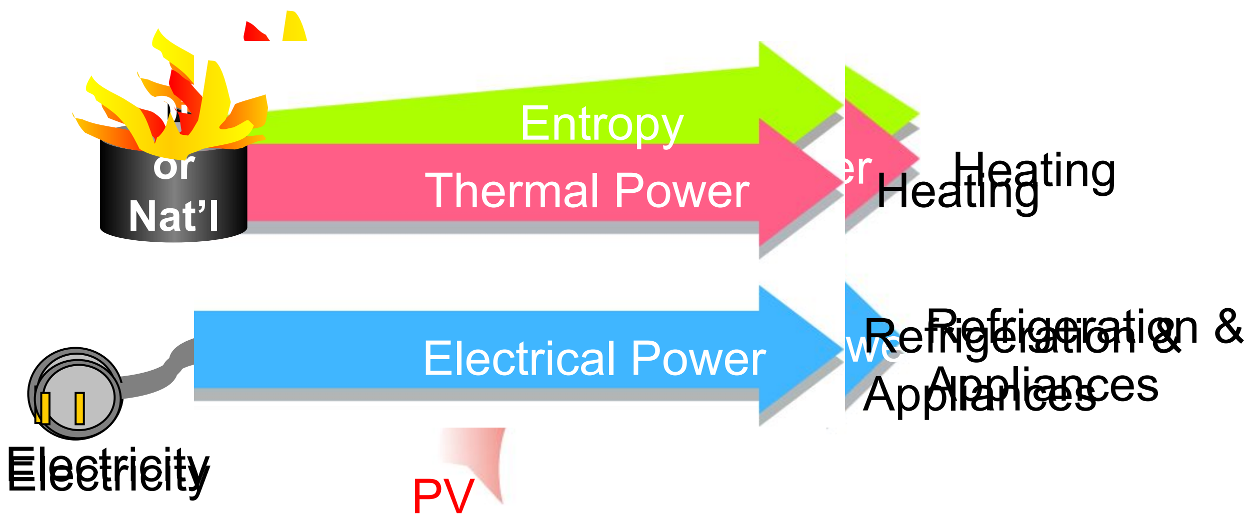
Potential Applications



Transportation

In US, transportation uses ~26% of total energy.

10% energy conversion efficiency = 26% increase in useful energy



Residential

In US, residential and commercial buildings consume ~35% energy supply

Challenges and Opportunities

- Mass production of nanomaterials
- Energy systems: high heat flux

- Nanomaterials are trans-boundary
- Basic energy research leads to breakthroughs
- Transports (molecular, continuum) are crucial
- Inter-departmental collaborations