Today: Tech II Breakout

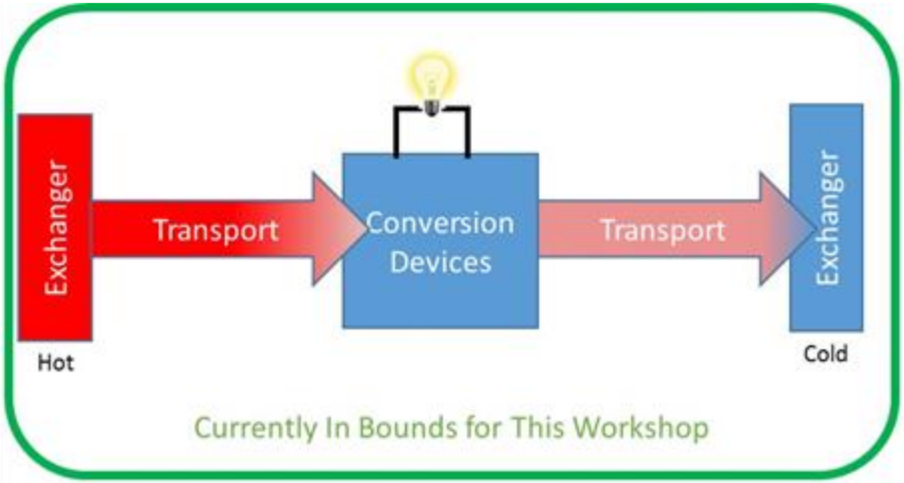
arpa·e
CHANGING WHAT'S POSSIBLE

Lower Grade Waste Heat Recovery Workshop
December 13-14, 2016
Hilton San Francisco Union Square
333 O'Farrell St, San Francisco, CA 94102

Wednesday, 12/14

Time	Event
7:00 – 8:00 AM	Breakfast
8:00 - 8:10 AM	**Day 1 Summary/Readout and Day 2 Objectives** *Dr. Joseph King, ARPA-E*
8:10 – 8:35 AM	**Thermoelectric Generators and Thermionics** *Guest Speaker: Prof. Mona Zebarjadi, University of Virginia*
8:35 – 9:00 AM	**Heat Transport – Capture and Rejection** *Guest Speaker: Prof. Gang Chen, Massachusetts Institute of Technology*
9:00 – 9:25 AM	**Mechanical Systems** *Guest Speaker: Prof. Todd Bandhauer, Colorado State University*
9:25 – 9:30 AM	**Breakout 2 Overview** *Dr. Joseph King, ARPA-E*
9:30 – 9:50 AM	Break/Networking
9:50 – 11:45 AM	**Breakout Session 2**
11:45 - 11:50 AM	Wrap-up
12:00 – 1:00 PM	Individual meetings with Dr. Joseph King and his technical team

Breakout Session Goals - Identify and Capture



Keep Focused on "Lower"-grade Waste Heat:
-Discuss Thermal Interfaces
-Discuss Transport, rejection, and concentration methodologies
-Discuss novel Temperature to Energy conversion devices

1. What is the current state-of-the-art?
2. What are the three biggest performance limitations in the field?
3. If solved, what would be the biggest break though or quantum leap forward for this technology?
4. Are there challenging but reasonable approaches to address the limitations?
5. What is the biggest opportunity/application for this technology were the limitations to be surmounted?

Preview: Seed Questions

Mechanical Systems:

Q_1: Are there any new energy conversion cycles?

Q_2: Are there advantages to expanding the types of working fluid selection to improve availability, costs, GHG impact, corrosion reduction, *etc*.?

Q_3: Are there novel, yet untried, devices (*e.g.* compressors, turbines or expanders) which might lead to improved efficiency at low cost if developed?

Q_4: Are there any new mechanical systems other than ORC for transportation applications that could lead to significant size/weight reductions at a competitive cost?

Q_5: Are there potential opportunities for weight reduction and efficient heat capture using highly conductive polymers?

Q_6: What would it take to obtain efficiencies above 50%? Are there untried designs which might achieve this?

Seed Questions By Area

Thermophotovoltaics:

- High temperature device: 700 – 1500^{+}K
- Higher temperatures yield higher power (∞T^4) and efficiency
- Near field requires sub-100nm separation
- PV cell bandgap energy between 0.4 – 0.6 eV (*e.g.* $In_{1-x}Ga_xAs$)
- 8 - 12% efficient

Q_1: What are the challenges to achieving a near-field emitter-PV cell separation of <100nm? Are there feasible designs possible which might achieve this spacing?

Q_2: Alternatively, is there a way to loosen the emitter cell spacing requirements for efficiency? Are there topological and/or material systems which might enable this?

Q_3: What would need to be true to get a system energy efficiency above 20 – 25%? Would it be possible to do so below 400-500^{o}C?

Q_4: Can a far-field blackbody limited device ever yield a high conversion efficiency?

Seed Questions By Area

Thermionics:

- Cathode: High Heat Distortion Temp. (900^{o}C-2,000^{+o}C)
- Maximum cathode-anode $\Delta_{\text{work function}}$
- Narrow Cathode –anode spacing (< 10 µm)
- Surface sensitization (*e.g*. Cs)
- 6 – 10% efficient

Q_1: What would need to be true to operate efficiently below 600 – 700^{o}C?

Q_2: Are there stable alloys that results in a lower work function than any of the individual elements work functions:

- *e.g.* eutectic materials?

Q_3: What would need to be true to get a system energy efficiency above 20-25%?

Q_3: Is there a topology approach to design a lower cathode work function w/wo sensitization?

Seed Questions: Thermoelectrics

Thermoelectrics: ("Phonon Glass-Electric Crystal")

- High electrical conductivity (ion mobility)
- Low thermal conductivity (limited phonon mobility)
- Brittle materials (*e.g*. highly doped semiconductors)
- Thermal shock tolerance
- 6 – 10% efficient

Q_1: Are there semiconductor classes/structures predicted to be effective (ZT>2; $\eta \geq$ 10-12%) but are unexplored?

Q_2: What can be done with module designs which would make the system more resilient (*e.g*. to thermal cycling/shock) and/or at lower cost (<$1/W)?

Q_3: What would need to be true to get a system energy efficiency above 20 – 25% operating below 400-500^{o}C?

Q_4: The Lorenz ration between electrical and thermal conductivity is a property that varies only over a factor of two range. Are there any material classes or material engineering strategies which can exhibit a Lorenz number below 2.44 x 10^{-8} W/(Ohm-K)?