Solar Refrigeration

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Introduction

• Need refrigeration in areas not connected to power grid
• Need to minimize environmental impact and fuel cost
• Evaluate potential of solar energy to meet these needs
• Evaluate efficiencies of three types of solar refrigeration
Conventional Refrigeration
Vapor Compression Cycle

\[ \dot{W}_{\text{min}} = m \int_{P_1}^{P_2} v dP \]

Figure 1a: Schematic of a vapor compression refrigeration system.
Types of Solar Refrigeration

• Photovoltaic Operated Refrigeration Cycle
• Solar Mechanical Refrigeration
• Absorption Refrigeration

Efficiency metric: \[ COP = \frac{Q_{ref}}{E_{rad}} \]
PV Refrigeration

• Vapor compression cycle with power input from Photovoltaic cells
• DC electric power output from PV runs the compressor of a conventional cycle
• Considerations
  – Must match voltage imposed on PV array to the motor characteristics and power requirements of the refrigeration cycle
PV (cont)

- For given operating condition (solar radiation and module temperature), single voltage provides maximum power output
- Must find compressor motor closely matched to the electric characteristics of the PV module
Solar Mechanical Refrigeration

• Vapor compression cycle with power input from solar Rankine cycle
• Considerations
  – Efficiency optimization based on delivery temperature

Figure 4: Solar driven mechanical power cycle.
Solar Mechanical (cont)

- Efficiency of Rankine cycle increases with increased heat exchanger temperature
- Efficiency of solar collector decreases with increase in temperature

*Figure 5: Approximate efficiencies for a Rankine cycle (bold line) and evacuated solar collectors (fine lines) at 30°C (86°F) ambient and differing solar radiation values.*
Absorption Refrigeration

• Condenser, throttle, evaporator function exactly the same way

• Replaces compressor with “thermal compression system”
  – Ammonia is working fluid
  – Minimal mechanical power input (pump instead of compressor)
  – In this regard, significantly different and less intuitive than other forms of solar cooling
Absorption (cont)
Thermal Compression System

- Absorption into water solution allows it to be pumped
- Desorbed in generator (rectifier required to separate out water)
- Heat into generator provided by solar collectors
- This system greatly increases complexity
Conclusion

• COP for solar refrigeration systems is low
  – Better metrics: size, cost
  – Complexity of solar ref. systems requires more size, bulkiness
  – Low operating costs do not outweigh high initial investment

• Advantage is that they don’t rely on power grid (PV is most practical for small scale)