Panel 2 - R&D Opportunities in thermal efficiency, generation, and storage

Panelists

- Andy Hooper, Brewmaster, Seismic Brewing
- Tom Maulhardt, Campbell Soup Supply Company
- Alan Rossiter, University of Houston
- Kevin Uy, CA Energy Commission
- Joel Zimmer, Salt Lake City Energy Management Engineer, Chevron

Moderator

Vinod Narayanan
Associate Director, WCEC
Professor, Mechanical and Aerospace Eng.
Thermal Efficiency
- Heat exchangers
- Waste heat recovery
- Insulation
- Controls
- Pre-cooling
- Evaporative cooling
- Building envelope efficiency
- Refrigeration efficiency
- HVAC efficiency
- Multi-effect evaporators

Thermal Generation
- High efficiency boilers; low NOx combustion
- Combined cooling heat and power (CCHP)
- Power cycles that use waste heat
- Solar thermal
- Solar PV + thermal

Thermal Storage
- Hot storage
- Cold storage
- Sensible vs latent storage
- Phase change materials
- Ice storage
- Thermochemical storage
US manufacturing section annual primary and process energy flow

Industrial Process Heating Energy Use

Table 8. U.S. natural gas consumption for direct process heating and conventional boiler use in high-use industry sectors

<table>
<thead>
<tr>
<th>MECS Code</th>
<th>MECS subsector</th>
<th>Natural Gas Consumed per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>311</td>
<td>Food</td>
<td>Trillion Btu: 339, GWh\textsubscript{th}: 99,400</td>
</tr>
<tr>
<td>322</td>
<td>Paper</td>
<td>Trillion Btu: 170, GWh\textsubscript{th}: 49,800</td>
</tr>
<tr>
<td>324</td>
<td>Petroleum and Coal Products</td>
<td>Trillion Btu: 618, GWh\textsubscript{th}: 181,000</td>
</tr>
<tr>
<td>325</td>
<td>Chemical</td>
<td>Trillion Btu: 722, GWh\textsubscript{th}: 212,000</td>
</tr>
<tr>
<td>331</td>
<td>Primary Metals</td>
<td>Trillion Btu: 289, GWh\textsubscript{th}: 84,700</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>Trillion Btu: 627,000, GWh\textsubscript{th}: 627,000</td>
</tr>
</tbody>
</table>

Table 10. Estimated natural gas consumption for direct process heating and boiler use in California for select MECS industries

<table>
<thead>
<tr>
<th>NAICS Code</th>
<th>MECS sector</th>
<th>Natural Gas Consumption for Process Heating (GWh\textsubscript{th}/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>311</td>
<td>Food Manufacturing</td>
<td>10,200</td>
</tr>
<tr>
<td>322</td>
<td>Paper Manufacturing</td>
<td>1,244</td>
</tr>
<tr>
<td>324</td>
<td>Petroleum and Coal Products	Manufacturing</td>
<td>31,211</td>
</tr>
<tr>
<td>325</td>
<td>Chemical manufacturing</td>
<td>3,526</td>
</tr>
<tr>
<td>331</td>
<td>Primary Metal	Manufacturing</td>
<td>2,134</td>
</tr>
</tbody>
</table>
## US Industry Waste Heat Profile

### Table 4 - Temperature Classification of Waste Heat Sources and Related Recovery Opportunity

<table>
<thead>
<tr>
<th>Temp Range</th>
<th>Example Sources</th>
<th>Temp (°F)</th>
<th>Temp (°C)</th>
<th>Advantages</th>
<th>Disadvantages/Barriers</th>
<th>Typical Recovery Methods/Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium</td>
<td>Steam boiler exhaust</td>
<td>450-900</td>
<td>230-480</td>
<td>More compatible with heat exchanger materials</td>
<td></td>
<td>Combustion air preheat</td>
</tr>
<tr>
<td></td>
<td>Gas turbine exhaust</td>
<td>700-1,000</td>
<td>370-540</td>
<td>Practical for power generation</td>
<td></td>
<td>Steam/power generation</td>
</tr>
<tr>
<td></td>
<td>Reciprocating engine exhaust</td>
<td>600-1,100</td>
<td>320-590</td>
<td></td>
<td></td>
<td>Organic Rankine cycle for power generation</td>
</tr>
<tr>
<td></td>
<td>Heat treating furnace</td>
<td>800-1,200</td>
<td>430-650</td>
<td></td>
<td></td>
<td>Furnace load preheating, feedwater preheating</td>
</tr>
<tr>
<td></td>
<td>Drying &amp; baking ovens</td>
<td>450-1,100</td>
<td>230-590</td>
<td></td>
<td></td>
<td>Transfer to low-temperature processes</td>
</tr>
<tr>
<td></td>
<td>Cement kiln</td>
<td>840-1,150</td>
<td>450-620</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>Exhaust gases exiting recovery devices in gas-fired boilers, ethylene furnaces, etc.</td>
<td>150-450</td>
<td>70-230</td>
<td>Large quantities of low-temperature heat contained in numerous product streams.</td>
<td>Few end uses for low temperature heat</td>
<td>Space heating</td>
</tr>
<tr>
<td></td>
<td>Process steam condensate</td>
<td>130-190</td>
<td>50-90</td>
<td></td>
<td>Low-efficiency power generation</td>
<td>Domestic water heating</td>
</tr>
<tr>
<td></td>
<td>Cooling water from:</td>
<td></td>
<td></td>
<td></td>
<td>For combustion exhausts, low-temperature heat recovery is impractical due to acidic condensation and heat exchanger corrosion</td>
<td></td>
</tr>
<tr>
<td></td>
<td>furnace doors</td>
<td>90-130</td>
<td>30-50</td>
<td></td>
<td></td>
<td>Organic Rankine cycle</td>
</tr>
<tr>
<td></td>
<td>annealing furnaces</td>
<td>150-450</td>
<td>70-230</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>air compressors</td>
<td>80-120</td>
<td>30-50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>internal combustion engines</td>
<td>150-250</td>
<td>70-120</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>air conditioning and refrigeration condensers</td>
<td>90-110</td>
<td>30-40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drying, baking, and curing ovens</td>
<td>200-450</td>
<td>90-230</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hot processed liquids/solids</td>
<td>90-450</td>
<td>30-230</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Panelists

- What is the current status of process heating, generation and storage in your industry?
- Where do you see bottlenecks? Room for improvement in (a) near term, (b) medium term and (c) long term?
- What are the potential barriers to adoption of above improvements?
- Does a collaborative effort in addressing needs make sense? What do you envision a collaboration looking like?
  - Are there sufficient common areas between food and petrochemical processing to pursue joint projects?
  - Are there things that UCD faculty and researchers can help with to bridge the knowledge or technology translation gap?
Oil & Gas Industry Energy Collaboration with the Food & Beverage Sector

Panel Discussion Talking Points

UC Davis, July 31, 2019

Joel Zimmer
Energy Management Engineer
Chevron
Salt Lake City Refinery
Thermal Efficiency

• Furnace Efficiency & Emissions
  ➢ Minimizing excess O2
  ➢ Tuning & controls
  ➢ Performance monitoring
    ➢ Track KPIs: O2, CO, stack temperature, fired duty intensity

• Heat Exchanger Performance
  ➢ Heat exchanger design
    ➢ Conventional shell & tube; shell & tube with extended surfaces; plate & frame
    ➢ Pinch analysis for heat exchanger networks within complex process units
  ➢ Performance monitoring
    ➢ Track KPIs: approach temperature, U-value
  ➢ Connection between heat exchangers and furnaces
    ➢ Performance of key heat exchangers dictates process unit heat integration
    ➢ Heat integration dictates furnace fuel consumption and emissions (CO2 & NOx)
Oil & Gas Industry Energy Collaboration with the Food & Beverage Sector

Panel Discussion Talking Points

UC Davis, July 31, 2019

Alan Rossiter
Executive Director, External Relations
UH Energy, University of Houston
## Oil & Gas and Food & Beverage Industries – A Quick Comparison

<table>
<thead>
<tr>
<th></th>
<th>Food &amp; Beverages</th>
<th>Oil &amp; Gas (inc. Downstream)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edible</td>
<td>Yes (mostly)</td>
<td>No (mostly)</td>
</tr>
<tr>
<td>Equipment</td>
<td>heat exchangers, heaters, refrigerators, vessels, filters &amp; centrifuges, pumps, compressors, piping</td>
<td>heat exchangers, heaters, refrigerators, vessels, filters &amp; centrifuges, pumps, compressors, piping</td>
</tr>
<tr>
<td>Size, tpa</td>
<td>1-1,000,000</td>
<td>10-30,000,000</td>
</tr>
<tr>
<td>Typical Operating Mode</td>
<td>Batch</td>
<td>Continuous</td>
</tr>
<tr>
<td>Process Temperatures, °F</td>
<td>-10 to 500</td>
<td>-400 to 1400</td>
</tr>
<tr>
<td>Process Pressures, psia</td>
<td>0.1-30</td>
<td>0.1-45,000</td>
</tr>
</tbody>
</table>
Thermal Efficiency, Generation, and Storage Themes

• Boiler & Furnace Efficiency
  ➢ Low temperature stack heat recovery

• Heat Integration
  ➢ Simple vs. complex systems

• Utility Systems
  ➢ Integration of renewables

• Thermal Storage
  ➢ Appropriate applications
Process Optimization Themes

• Design Optimization
  ➢ Technologies – e.g., new catalysts
  ➢ Equipment – e.g., separations, saturators
  ➢ Systems – e.g., heat integration

• Real-time Optimization
  ➢ IIoT
  ➢ Smart Manufacturing

• Process Intensification

• Electrification
Real food matters for life's moments

Thermal Processes in the Tomato Processing Industry
Global Tomato Processing in 2017: 37.47 million mT

- California: 9,492
- Canada: 430
- Other US: 408
- Dom. Rep: 220
- Brazil: 1,450
- Argentina: 488
- Chile: 1,080
- Portugal: 1,554
- Spain: 3,300
- France: 195
- Poland: 175
- Italy: 5,200
- UK: 650
- Russia: 400
- Iran: 1,000
- Israel: 200
- Egypt: 300
- Tunisia: 643
- Sth Africa: 160
- Greece: 400
- Turkey: 1,900
- India: 130
- Thailand: 260
- Australia: 185
The processes that produce tomato products, like tomato paste and diced tomatoes, use heat in many steps.

That heat is supplied by steam, which is created by combusting natural gas in large boilers (at least in our facilities).

Making tomato paste requires evaporating water from tomato juice to concentrate the amount of solids from an initial 5% to 30% or more.

Most tomato processing is aseptic, and steam is used to create a sterile environment. Aseptic products don’t require refrigeration during storage and won’t spoil, which makes them more economical to produce.
Focus on Energy Efficiency - Boilers

- Boilers are tuned prior to each season to deliver maximum efficiency across a wide range of firing rates.
- Feedwater economizers preheat water entering the boilers with the residual heat from exhaust gases, increasing overall efficiency.
- Returning hot condensate, and even hot tomato evaporate water, to the boilers reduces the need to preheat boiler feedwater.
- Virtually all steam pipes and heat exchangers are insulated to prevent heat loss.
Focus on Energy Efficiency - Evaporators

• Evaporation of water from tomatoes to create tomato paste is a critical process that is also very energy intensive.

• Steam from the boilers is used to drive turbines coupled to large evaporator circulation pumps and vapor compressors. The exhaust steam from these turbines is used to heat the tomato paste in the evaporators, effectively using a large % of the overall energy contained in the natural gas fuel.

• Multiple effect evaporators and Mechanical Vapor Recompression (MVR) evaporators are used to increase the amount of water evaporated for each pound of steam.
Triple Effect Evaporator
Current Tomato Processing Practices

• Tomato ingredient production uses processes that have been fine-tuned to maximize efficiency, throughput, reliability, and food safety. These are all key factors in controlling the cost of production.

• Current alternatives to using natural gas to create the steam for process heat are either much too expensive, or not able to operate at sufficient capacity to be implemented commercially.

• Electrification of steam generation would require major investments in electrical infrastructure and electricity costs that are an order of magnitude lower than what they are currently to be competitive.
Near Term Opportunities

• More efficiency improvements and better process control
• Economies of scale from greater capacity
• Growing tomatoes with higher initial solids
• Waste heat recovery
• High pressure processing
• Solar thermal
Mid to Long Term Opportunities

• Concentration without evaporation
• Renewable fuels as affordable as fossil fuels and identical in function
• Extremely cheap renewable electricity for electrification
• Something else???