Report on the

Technology Forum:

Low Temperature Waste Energy Recovery in Chemical Plants and Refineries

Held May 16, 2012 in Houston, TX

Prepared by Texas Industries of the Future
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Background

Recovery of low temperature waste energy is the holy grail of industrial energy efficiency. In general, the chemical and refining industries have successfully recovered the energy from streams above approximately 400 °F. The Texas Industries of the Future Chemical and Refining Sectors Advisory Committee identified the need for a better understanding of the technologies available to recover energy from streams that are below 400 °F. A Technology Forum was held on May 16, 2012 in Houston, Texas, to address this issue. Texas IOF organized the event with the sponsorship of the Institute for Industrial Productivity.

The purpose of the Technology Forum was to accelerate the adoption of waste energy recovery technologies by:

- Educating end-users on the technologies available for low temperature waste energy recovery, and
- Educating technology developers on the potential market and needs at chemical plants and refineries.

Forty attendees from 17 chemical and refining companies, 5 technology developers, and 7 interested organizations attended the “Technology Forum: Low Temperature Waste Energy Recovery at Chemical Plants and Refineries” held at Brady’s Landing in Houston, Texas. Table 1 lists the organizations participating in the Technology Forum. During the morning session, attendees from industry characterized their waste energy streams. The notes from this discussion are found in Appendix 1. There clearly is a significant opportunity for energy recovery below 400 °F at both refineries and chemical plants. However, it was also clear that at today’s energy prices in the US, there was not a strong economic driver for recovery of low temperature heat to generate power in the US. Some end-users were familiar with the organic rankine cycle technology, which was developed for geothermal

Table 1: Participating Organizations

- BASF Corporation
- Braskem
- Chevron Phillips Chemical Company LP
- CITGO
- Eastman Chemical Company
- Energy Concepts Company
- ExxonMobil Chemical Company
- FuelCell Energy, Inc.
- GE Oil &Gas
- Goodyear Tire and Rubber
- Houston Advanced Research Center
- Hudson Technologies
- Huntsman Chemical
- Idaho National Laboratory
- Institute for Industrial Productivity
- Integral Power, LLC
- LyondellBasell
- Ormat Technologies, Inc.
- Phillips 66
- PPG
- Sasol North America Inc.
- Shell
- SI Group
- Texas State Energy Conservation Office
- TAS Energy
- Tesoro Refining & Marketing
- Texas A&M University
- Texas Industries of the Future
- The Dow Chemical Co.
- Total Petrochemicals and Refining USA, INC
power production. Prior to the Forum, end-users had less familiarity with the absorption chilling or fuel cell technologies.

Technology developers of organic rankine cycle, absorption chilling, and fuel cells presented a 10 minute overview of their technology, its capabilities, similar installations and costs. All of the Forum presentations are posted at https://TexasIOF.ceer.utexas.edu under “Documents and Presentations”.

Throughout the day, attendees were asked to record ideas for next steps. These were collected and prioritized by attendees at the end of the day. Table 2 lists the highest priority actions, based on the attendees’ input via voting. Appendix 2 contains a complete list of the results from the idea generation and prioritization process.

Results
An electronic survey of attendees after the Technology Forum determined that end-users were interested in following up on all technologies presented. (Due to a last minute scheduling conflict, speakers on the Kalina Cycle were not able to attend, although their presentation is posted on the website.)

Eighteen of the 40 attendees responded to the electronic survey. Of the 18, almost three-quarters (13 of 18) were from chemical or refining companies. Table 3 shown on the next page reports the responses to the technology follow-up question. The number of responses to this question totals greater than 13 as respondents were not limited to only one response.

Seven respondents expressed an interest in following up on the organic rankine cycle and the fuel cell technologies, respectively. Four respondents were interested in further information on absorption chilling and two had interest in chilled water. Only two of the 13 respondents reported that they were not going to follow up on any technologies presented at the Forum.

<table>
<thead>
<tr>
<th>Table 2: High Priority Interest Areas (Based on Attendee Voting)</th>
</tr>
</thead>
</table>

**Identifying Opportunities**
- Increase site awareness of energy opportunities

**Tools and Analysis**
- A better guide to know which technology to apply in each waste heat recovery application

**Improving the Economics**
- Capital costs need to be reduced to make recovery economical especially for retrofits.

**Research**
- Further develop hydrogen purification and delivery process
- Support application development for CHHP for petro-chem. industry
- Integrate hybrid system. ORC + fuel cell for higher benefits
- Identify best solution for large mass flow < 200 °F

**Policy**
- Environmental requirements can be an impediment to project execution.
Table 3: Response on Technology Follow-up Question
By End-Users

<table>
<thead>
<tr>
<th>Answer Options</th>
<th>Response Percent</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic rankine cycle</td>
<td>53.8%</td>
<td>7</td>
</tr>
<tr>
<td>Absorption chilling</td>
<td>30.8%</td>
<td>4</td>
</tr>
<tr>
<td>Chilled water</td>
<td>15.4%</td>
<td>2</td>
</tr>
<tr>
<td>Kalina cycle</td>
<td>0.0%</td>
<td>0</td>
</tr>
<tr>
<td>Fuel cell</td>
<td>53.8%</td>
<td>7</td>
</tr>
<tr>
<td>Other waste heat recovery not listed above</td>
<td>0.0%</td>
<td>0</td>
</tr>
<tr>
<td>Not following up on any</td>
<td>15.4%</td>
<td>2</td>
</tr>
</tbody>
</table>

answered question 13

Acknowledgements
Texas IOF would like to recognize Jim Quinn with the Institute for Industrial Productivity for support of this project and Riyaz Papar with Hudson Technologies for his technical guidance.
Appendix 1: Notes on Waste Energy Streams
<table>
<thead>
<tr>
<th>Industry</th>
<th>Process or Flue Gas or Utilities</th>
<th>Liquid, Gas or Either</th>
<th>Temp. (in F)</th>
<th>Opportunities</th>
<th>Other Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical</td>
<td>Stack Gas</td>
<td>G</td>
<td>300</td>
<td>Opportunity in Fired Heaters with stack around 300F</td>
<td>Opportunities in Steam Leaks - Numerous leaks which are continuous</td>
</tr>
<tr>
<td>Chemical</td>
<td>Stack Gas</td>
<td>G</td>
<td>350</td>
<td>Opportunities in Stack Gas from thermal oxidizers with a temperature of 350F</td>
<td>Steam condensate opportunities</td>
</tr>
<tr>
<td>Refineries &amp; Chemicals</td>
<td>Process</td>
<td>L</td>
<td>350-450</td>
<td>Firing rate - 50MMBtus to 200 MMBtus, relatively clean stack gases - 300 F to 400F stack gases</td>
<td></td>
</tr>
<tr>
<td>Refineries</td>
<td>Process</td>
<td>L</td>
<td>180-220</td>
<td>Opportunities in process streams around 180 - 220F</td>
<td>Small for liquid and most of it actual product streams</td>
</tr>
<tr>
<td>Chemicals</td>
<td>Stack Gas</td>
<td>G</td>
<td>350-450</td>
<td>Reduced energy cost $20Million/yr, more energy in stack gas wasted</td>
<td>Duplicate boiler operations, interested in quick startup units</td>
</tr>
<tr>
<td>Chemicals</td>
<td>Stack Gas</td>
<td>G</td>
<td>300-350</td>
<td>Fired heaters and cracker units; have identified projects already and step by step implementation is being performed</td>
<td></td>
</tr>
<tr>
<td>Chemicals</td>
<td>Process</td>
<td>L</td>
<td>300-350</td>
<td>Run-down and product streams; have identified projects already and step by step implementation is being performed</td>
<td></td>
</tr>
<tr>
<td>Chemicals</td>
<td>Stack gas</td>
<td>G</td>
<td>300-350</td>
<td>Opportunities in several stack gases, 1) Several NG Fired Furnaces at 350 - 400 F Stack, 2) Corrosive gases in the 400F range that are pressurized at 50 psig range, used to generate 15 psig steam</td>
<td>Burn coal, distillation column overheads, identified opportunities but no economic justification</td>
</tr>
<tr>
<td>Industry</td>
<td>Process or Flue Gas or Utilities</td>
<td>Liquid, Gas or Either</td>
<td>Temp. (in F)</td>
<td>Opportunities</td>
<td>Other Comments</td>
</tr>
<tr>
<td>---------------</td>
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<td>-----------------------</td>
<td>-------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Refineries</td>
<td>Process</td>
<td>either</td>
<td>235</td>
<td>40MMBtus Hexane goes to finfans - 235 F streams - 15 psig stream</td>
<td>Roughly saved $40Million all over, distillation columns</td>
</tr>
<tr>
<td>Refineries</td>
<td>Utilities</td>
<td>Either</td>
<td>300</td>
<td>Steam Leaks - Low pressure steam, excess low pressure steam @ 30-40psig range</td>
<td></td>
</tr>
<tr>
<td>Chemicals</td>
<td>Utilities</td>
<td>L</td>
<td></td>
<td>Opportunities in steam condensate - Current condition not recovered.</td>
<td></td>
</tr>
<tr>
<td>Chemicals</td>
<td>Stack gas</td>
<td>G</td>
<td></td>
<td>Opportunities in Steam crackers which are very high energy intensive process, Current condition - capture energy only in higher levels still possibility for low level heat capture.</td>
<td>Reaction processes - exothermic - produce LP steam for the finfan</td>
</tr>
<tr>
<td>Chemicals</td>
<td>Stack Gas</td>
<td>G</td>
<td></td>
<td>Opportunities in steam crackers totally 8 of them, furnace stack, boilers, Gas turbine, cooling towers, Current Condition - They do small projects like preheat air, preheat water but not entered the big players</td>
<td>Hard to justify the return for ORC - Economics not justified</td>
</tr>
<tr>
<td>Refineries</td>
<td>Stack gas and P</td>
<td>G &amp; L</td>
<td>250</td>
<td>Opportunities to capture energy in steam letdown, cutoff point for recovery - 250F rundown temperatures, Capturing stack gas heat maybe an opportunity</td>
<td>Recovering heat back into the process as opposed to WHR, capture of stack gas heat</td>
</tr>
<tr>
<td>Refineries &amp; Chemicals</td>
<td></td>
<td></td>
<td></td>
<td>Really Interested to know the Coefficient of performance of both Absorption and ORC technologies</td>
<td></td>
</tr>
<tr>
<td>Chemicals</td>
<td>Stack gases</td>
<td></td>
<td>400-450</td>
<td>Smaller Heaters, Economy of scale</td>
<td>Liquid streams always better, heat transfer coefficient better, regulatory environment is an issue</td>
</tr>
</tbody>
</table>

Mass Transfer & Liquid Separation
Appendix 2: Results from Idea Generation and Prioritization Process
Technology Forum:
Low Temperature Waste Energy Recovery
in Chemical Plants and Refineries
May 16, 2012

Compilation of Results from
Project Identification and Prioritization Session

Tools and Analysis
- Software tool for fast overview economic analysis of project – 4 dots
- Cataloging of industrial waste heat sources (m, T, metallurgy, distances, etc.) – 1 dot
- Create a database of technologies by criteria – 0 dots
- I need a better guide to know which technology to apply in each W.H. application – 9 dots
  - Develop list of criteria for technology. – 1 dot
  - User screening tool to map heat source to applicable technology – 2 dots

Improving the Economics
- Capital costs need to be reduced to make recovery economical, especially for retrofits – 11 dots
- Reduce investment ($/KW installed capacity) – 4 dots
- If electricity costs are key factor, what is solution? Higher conversion efficiency or make a higher value product? 0 dots
- How to account for ancillary economic benefits from waste heat recovery--0 dots

Policy
Incentives and Rebates
- State incentives – 0 dots
- Rebates? Incentives? – 1 dot

Regulatory Barriers
- Work with regulatory body to allow proj.- 3 dots
- Environmental laws can get in way – 8 dots
• Remove regulatory hurdles – 1 dot

Policy
• Government encourage energy recovery reorganizing waste heat as renewable – 5 dots
• Create further policy changes supporting H2 – 0 dots

Example industrial projects – 1 dot

Research
• Further develop H2 purification and delivery process – 8 dots
• Support application development for CHHP for petro-chem. industry – 10 dots
• Integrated hybrid system. ORC + fuel cell for higher benefits – 5 dots
• Better heat exchangers – 0 dot
• Conduct demo projects – 2 dots
• Integration of research into operations – 4 dots
• Identify best solution for large mass flow but < 200 °F – 9 dots
• Multi-purpose demo. – convert low-level heat to FC power and higher value co-products – 1 dot
• All gas comp have either intercoolers or and/or after coolers. This energy is generally wasted thru cooling water. Can this not be used for process stream heating in cold weather? - 0 dots

Identifying Opportunities
• Keep interaction going to ID opportunities – 1 dot
• Opportunity assessments? – 0 dots
• Increase site awareness of energy opportunity – 8 dots

Miscellaneous
• Mechanisms for partnering (honest broker eval. of technology and potential savings) – 0 dots
• Can we run waste water anaerobically to feed fuel cell – 0 dots
• Cold weather area—heating building/work places or other energy recovery? – 0 dots
• Can we use ammonia to cool unipol cycle gas, then recover from purge – 3 dots