High Duct Fired Gas Turbine Combined Heat & Power (DF-GT-CHP): a better steam raising system

Suresh Jambunathan,
Director of Business Development, NA Sales
Larsen & Toubro Technology Services

Cell: 630-335-4544
E-mail: Suresh.Jambunathan@lnttechservices.com

April 9th, 2015
Location: Hilton Houston North Convention Center
Houston, TX
Learning Outcomes

Efficiency & flexibility automatically hedge against price & load volatility - being green is good for your wallet and your conscience.

Plan carefully for utilities when contemplating process plant new build or expansion.

High Duct Fired Gas Turbine Combined Heat & Power (DF GT-CHP) is a financially attractive, technically feasible and sustainable alternative to package boilers to an industrial site’s power & steam needs.
Who is Larsen & Toubro Technology Services (L&TTS)?

L&T: India’s largest Engineering company – our parent group

- A publicly owned $14.3 billion / 50,000+ employee global technology, engineering, manufacturing and construction conglomerate
- Manufacturing facilities in Asia, Middle East and Australia
- Products & services delivered in 40+ countries
- Global supply chain
- 75+ years & growing

L&T Technology Services - a wholly owned subsidiary of L&T

- 175+ global customers
- 47+ Fortune 500 customers
- 157+ patents co-authored
- 9,500+ employees dedicated to engineering services
- 6 ISO 9001:2008 & CMMI Level 5 certified delivery centers
Imagine it …… and we’ll help design-build-commission it

Non-traditional services, solutions & offerings

- Energy Audit & Management (Plant Utility Management & Optimization Services (PUMOS))
- Asset Information Management (AIM)
- Computational Fluid Dynamics (CFD) & Finite Element Analysis (FEA)
- Internet of Things (IoT) & Machine to Machine (M2M) solutions
- Data Analytics
- Machine Design
- Packaging Design
- Industrial & Product Design
- Application Development
- LEED Certification Support
- Procurement Management
- Construction Management
- Product Lifecycle Management (PLM)
- Plastics Engineering

Engineering Disciplines

- Project Controls & Cost Estimation
- Process Engineering
- Mechanical Engineering (Equipment, Piping, Utility)
- Civil & Structural Engineering
- Architectural Engineering
- Electrical Engineering
- Instrumentation & Controls Engineering
- Procurement & Construction Support
- Asset Information Management

Traditional Plant Engineering: Concept to completion

- Core Template
- FEED
- Design, Project Management
- Procurement Support
- Build

Plant Engineering services, solutions & offerings

- Food, Beverages & Dairy
- Specialty Chemicals
- Home & Personal Care
- Oil & Gas
- Pharmaceuticals
- Infrastructure/Discrete Manufacturing
- Energy

Customer Technology

Vendor Packages
Recent headlines reveal a rebirth of US manufacturing

Why U.S. Manufacturing Is Poised for a Comeback (Maybe)
Some Say a Renaissance Is Already Under Way. Here’s the Case They Make—and the Skeptics’ Response
“Trendy” processes hog headlines, but “dowdy” utilities are essential

**UTILITIES**

- Power
- Thermal Energy delivered as steam, hot water, thermal oil, refrigerant
- Compressed air
- Lighting
- Insulation
- Water – surface & sub-surface
- Wastewater treatment: anaerobic & aerobic

**ACME Chemical Co:**

Boss: *We’re investing $$$$$$$ to build process XYZ*

Assistant: *What about utilities?*

Boss: *Just get it done*

Assistant to Plant Manager: *Get it done*

**Plant Manager:**

Orders a new package boiler from “Bigger & Better Boiler” company
Pays ungodly $$ to utility company to upgrade electrical substation

**Rule of Thumb:**

*$$Utilities are 10% to 40% of $$Process*
Energy efficiency vs. waste... the energy recycling advantage

Combined Heat & Power (CHP) at University of Massachusetts, Amherst, MA.
Efficiency >80%

Traditional central power generation.
Efficiency ~35%.... burning money up the stack

Uscommunityenergyguidehi.pdf community energy: planning, development and delivery, IDFA pub.
Michael king 2012
Key utilities (power & steam): Two choices... one is arguably better

**Package boiler system**: safe & unimaginative

- Steam: boiler
- Power: grid supplied

**High duct fired Gas Turbine Combined Heat & Power (DF GT-CHP)**: safe, sustainable & profitable

- Steam: from HRSG
- Power: onsite generation; remote grid provides back-up

---

**STG**: Steam Turbine Generator; **HRSG**: Heat Recovery Steam Generator; **FSF**: Fuel to Steam Factor
Key utilities (power & steam): A closer look favors efficient & high DF GT-CHP

Generate inexpensive power for <= 10% extra fuel

<table>
<thead>
<tr>
<th>Design point results (100 Kpph / 100 psig)</th>
<th>Package boiler system</th>
<th>Duct fired GT-CHP system</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel required MMBtu/Hr, LHV</td>
<td>136</td>
<td>148</td>
<td>12</td>
</tr>
<tr>
<td>Net onsite power, MW</td>
<td>n/a</td>
<td>7.7</td>
<td>7.7</td>
</tr>
<tr>
<td>Fuel-to-Steam Factor (FSF), MMBtu/Klb</td>
<td>1.36</td>
<td>1.46</td>
<td>0.10</td>
</tr>
<tr>
<td>CHP Heat Rate, LHV MMBtu/MWh</td>
<td>n/a</td>
<td>4.5</td>
<td>4.5</td>
</tr>
<tr>
<td>*Net operational cost of steam, $/Klb</td>
<td>$7.3</td>
<td>$4.9</td>
<td>($2.4)</td>
</tr>
<tr>
<td>Fuel cost of power, $/MWh</td>
<td>n/a</td>
<td>$22.3</td>
<td>$22.3</td>
</tr>
</tbody>
</table>

* Net OpEx cost of steam reflects fuel cost, credit from onsite power and O&M costs of both systems
Package boiler efficiency varies with load; sizing & optimal design point?

40% load
Efficiency: 73%

100% load
Efficiency: 83%
DF GT CHP is a better alternative: Duct fire to efficiently & rapidly follow load load.
η_{DF} GT CHP > η_{boiler} across the load curve. CHP Steam-to-Power Factor tracks load.
Higher marginal efficiency of duct firing converges fuel burned per lb steam
What about economics? simplified assumptions

<table>
<thead>
<tr>
<th>Process operations:</th>
<th>8,322 hrs/year</th>
<th>Operations &amp; Maintenance costs:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process steam load:</td>
<td>40 to 100 Kpph @ 100 psig</td>
<td>GT: $10/MWh</td>
</tr>
<tr>
<td>Delivered natural gas:</td>
<td>$5/MMBtu, HHV</td>
<td>Package boiler: 35 to 40 ¢/Klb</td>
</tr>
<tr>
<td>Delivered grid power:</td>
<td>6.5 ¢/KWh ($65/MWh)</td>
<td>HRSG: 35 to 40 ¢/Klb</td>
</tr>
<tr>
<td>Full load package boiler efficiency :</td>
<td>83% LHV</td>
<td></td>
</tr>
<tr>
<td>Gas Turbine heat rate (4.2 MW Centaur 50):</td>
<td>12,200 Btu/KWh, LHV</td>
<td></td>
</tr>
<tr>
<td>Feedwater to DeAerator</td>
<td>100F</td>
<td></td>
</tr>
</tbody>
</table>
Significant and consistent savings with DF GT CHP

With DF-CHP, reduced cost of process steam

Boiler: Net Cost of steam
GT-CHP: net cost of steam
SAVINGS: GT-CHP vs. Boiler

Reflects differences in efficiency, value of displaced grid power, delivered gas cost plus O&M of both systems
Operational NET ZERO: What is your grid power and gas price?

Operational NET ZERO for low (40 Kpph) & high (100 Kpph) steam load

DF-GT CHP operationally profitable above the line

Package boiler operationally profitable below the line
Short payback on incremental investment over package boiler systems

Incremental Investment & Payback: "steaming savings"

Incremental payback, years

Incremental investment, $MM

Likely 2-to-4 yr payback
Additional DF GT-CHP benefits compared to standard package boiler systems.

**Benefit to Grid**
Local grid stability including power factor support and reduced I2R line loss

Balance variable power from wind and solar, thus speed renewable energy deployment

Defer or avoid investment in
- Remote central generation plants
- Transmission & Distribution infrastructure

**Benefit to the thermal host**
Reduced cost of steam and increased steam supply reliability

More reliable power supply

**Benefit to society**
Reduced pollution and lower greenhouse gas emissions

Efficiency equals “free fuel”

http://www.greentechmedia.com/articles/read/3-ways-superstorm-sandy-could-change-utilities-forever

The CHP advantage: Lower Manhattan after super-storm Sandy
Inertia and unfamiliarity
Standard compliance solutions seen as “tried and true”

Energy Policy Act, 2005
Hurts ability of regulated utilities to secure certain cost recovery for long-term Power Purchase Agreements (PPA) with CHP plants. Makes CHP plant financing difficult

Air permit
MACT pollution control regulations allow retaining current air permit. CHP reduces pollution, yet requires a new permit

Standby & exit charges
Imposed by some utilities before allowing CHP systems to interconnect with the grid.

Upfront investment
Greater upfront CapEx required.

Too many people expend too much effort to avoid the effort of thinking.
Why mess with “tried & true”?
Project development: common sense and diligence

L&TTS can help improve your Plant Engineering investment decisions by aiding several elements of project development from concept (FEL1) to completion (FEL5).

1. Set objectives & gather data

2. Conceptualize alternate configurations: Technical & economic appraisal

3. Project development
   - Technical: Configuration, engineering, procurement, construction
   - Legal: Structure of contracting entities (LLC, S or C Corp etc...)
   - Commercial: Contracts for fuel, power, O&M, grants & incentives
   - Environmental: Permits
   - Financial: Financial models, equity & debt
   - Risks & Mitigants: Project Execution Plan (PEP)
Suresh Jambunathan,
Director of Business Development, NA Sales
Larsen & Toubro Technology Services

Cell: 630-335-4544
E-mail: Suresh.Jambunathan@lnttechservices.com

April 9th, 2015
Location: Hilton Houston North Convention Center
Houston, TX
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Engineering</strong></td>
<td>Poor technical design</td>
<td>Technical Sub-Group</td>
<td>Project fails to achieve objectives; project fails to achieve financial viability</td>
<td>High</td>
<td>Possible</td>
<td>Manage</td>
<td>Check track record of engineer; check references; peer review; cheat</td>
<td>Low</td>
<td>Low possibility</td>
</tr>
<tr>
<td><strong>Planning and Permitting</strong></td>
<td>Permit issues</td>
<td>Planning Sub-Group</td>
<td>Project cannot proceed</td>
<td>Extreme</td>
<td>Possible</td>
<td>Actively manage</td>
<td>Early understanding of requirements; early engagement with officials; ongoing engagement; alignment, and reviews</td>
<td>Low</td>
<td>Possible</td>
</tr>
<tr>
<td><strong>Construction</strong></td>
<td>Poor construction</td>
<td>Technical Sub-Group</td>
<td>Work requires correction and remediation; changes impact on project schedule and budget</td>
<td>High</td>
<td>Probable</td>
<td>Actively manage</td>
<td>Monitor and ensure set standards in contractor agreements; obtain insurance cover</td>
<td>Difficult</td>
<td>Difficult</td>
</tr>
<tr>
<td><strong>Performance</strong></td>
<td>Poor performance</td>
<td>Technical Sub-Group</td>
<td>Project fails to achieve objective; impact on financial viability</td>
<td>Medium</td>
<td>Possible</td>
<td>Actively manage</td>
<td>Include performance specification in supplier/contractor agreements; obtain insurance</td>
<td>Off-set</td>
<td>Off-set</td>
</tr>
<tr>
<td><strong>Demand</strong></td>
<td>Does not meet expectations; reduces due to customer actions and/or behavior</td>
<td>Commercial Sub-Group</td>
<td>Impact on technical performance; impact on financial viability</td>
<td>Medium</td>
<td>Possible</td>
<td>Actively manage</td>
<td>Early and engaging engagement with customers; accurate consumption data monitoring; cooperation agreements on customer equipment; volume or price guarantees in contracts</td>
<td>Low</td>
<td>Low possibility</td>
</tr>
<tr>
<td><strong>Input Fuel pricing</strong></td>
<td>Prices increase more than anticipated</td>
<td>Commercial Sub-Group</td>
<td>Impact on financial viability</td>
<td>Medium</td>
<td>Possible</td>
<td>Manage</td>
<td>Use market forecasting service; issue long-term or flexible supply contracts; adjust technical design to allow use of alternative fuels</td>
<td>Low</td>
<td>Possible</td>
</tr>
<tr>
<td><strong>Output Pricing</strong></td>
<td>Revenues fall to cover costs</td>
<td>Commercial Sub-Group</td>
<td>Impact on financial viability</td>
<td>High</td>
<td>Possible</td>
<td>Manage</td>
<td>Active monitoring of costs; table with Technical Sub-Group on performance; indexation in customer contracts</td>
<td>Low</td>
<td>Possible</td>
</tr>
</tbody>
</table>

Figure 20: Example of a risk assessment.