Modular On-Demand Steam Systems

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Presentation Overview:

- U.S. energy & environmental overview
- Overview of U.S. boiler inventory & opportunities for performance improvements
- Review of current & future boiler efficiency metrics
- Introduction to modular On-Demand boiler technology
- Boiler water treatment considerations / support systems
- First Steps: Boiler performance benchmarking
- Case Studies of successful projects
Energy / Eco Opportunity Drivers:

- Age of U.S. Boiler Inventory
- Stagnation in Boiler Technology Innovation
- Confusion in Boiler Efficiency Metrics vs Utility Costs
- Production Focus in Boiler Operations (Unequal Attention to Energy Efficiency)
- Boiler Performance – Tolerance Inversion
- Thermal Energy Management Constrained by Aged / Obsolete Technology
- Persisting Use of “Dirty” Fuel Sources
- Boilers = “Front-line” in Carbon Footprint Reduction
- Large Potential for Neutral / Negative-Cost Carbon Abatement via Energy Efficiency
Global Impact:

- Global Sales ~ 143,000 Units (~ 12,000,000 BHP)
  - Asia ~ 140,500
  - North America ~ 2,500

- ~ 500 Trillion Btu Annual Energy Savings Worldwide
- ~ 180 Million Metric Tons of Annual CO₂ Reductions Worldwide
Sustainable Business Principles:

“Triple Bottom Line”:

- **Social Responsibility**
  - Extended Product Stewardship
  - Online Maintenance System
  - Safe & Easy Operation

- **Environmental Stewardship**
  - Reduced Fossil Fuels Consumption
  - Reduced GHG Emissions
  - Reduced Water Consumption

- **Economic Prosperity**
  - Reduced Fuel Costs
  - Reduced Operation Costs
  - Increased Operational Efficiency
Sustainability Consortium:

- U.S. companies leading the way by “greening” their operations & supply chain…
U.S. Energy Inventory:

- **U.S. Energy Flow – (Quadrillion Btu’s)*:**

- **Industrial Sector – 32.3 Quads of energy OR ~ 33% of all energy consumed in the U.S.**

- **Fossil Fuels – 86.25 Quads or 85% of all energy consumption (C/I boilers account for as much as 40% of energy consumption)**

*1 Quad Btu = 40 - 1,000 MW Power Plants*
U.S. Energy Costs – Historical Trends / Future Projections:

- U.S. energy prices have historically been very low when compared to average global energy prices.
- Future projections forecast a steady increase in energy prices as demand increases.
- U.S. natural gas prices are projected to increase 60% from 2010 to 2030.

$100,000 annual fuel savings ~ $2.7 million in lifecycle fuel savings.
U. S. Boiler Inventory: 
Energy Consumption

- U.S. Industrial Boilers – Energy Consumption (2005): ~ 6.5 Qbtu / yr or up to 40% of all energy at industrial facilities
- CO₂ Emissions - Industrial Boilers: ~ 500+ MtCO₂ / yr
Unlocking U.S. Energy Efficiency

Bang for Buck – Industrial Sector

- 2009 McKinsey EE Report for DOE / EPA:

~ 13 Quadrillion Btu’s at an avg. capital investment of ~ $7 / MMBtu
North American Inventory / Opportunity:

60,000,000 BHP

Energy / $ / Environmental Impact:

~ 6 Quadrillion Btu
~ $ 5 Billion
~ 300 MtCO$_2$

*1 Quad Btu = 40 - 1,000 MW Power Plants
Unlocking Energy Efficiency

U.S. Industry

- U.S. DOE Industrial Technologies Program:
- Providing resources focused on key industrial energy intensive processes:
  - Steam
  - Process Heat
  - Pumps
  - Compressors
  - Motors
- Targeting energy intensity reduction of 25% in the next 10 years
Steam System BEST PRACTICES:

http://www1.eere.energy.gov/industry/bestpractices/steam.html

- Benchmark the fuel costs of steam generation
- Minimize Radiant Losses from Boilers
- Minimize Boiler Blow-down
- Utilize Automatic Blow-down Control Systems
- Utilize Energy-Efficient Burners / Combustion Systems
- Minimize Boiler Idling & Short-Cycling Losses
- Utilize Feedwater Economizer for Waste Heat Recovery
- Maintain Clean Boiler Water-Side Heat Transfer Surfaces
- Inspect & Repair / Replace Steam Traps
- Maintain Insulation on Steam / Condensate Lines
- Consider Replacing PRV’s with Back-Pressure Turbines for On-Site Power Generation
- Map of ozone non-attainment areas in the U.S.:
- Ground level ozone pollution is the primary driver of NOx emissions regulation in the U.S.

Nonattainment areas are indicated by color. When only a portion of a county is shown in color, it indicates that only that part of the county is within a nonattainment area boundary.
U.S. GHG Emissions:

- **U. S. GHG Emissions Flow – 2005 (total mtCO2e):**
  - Commercial + Industrial Sectors ~ 1.4 Billion mtCO$_2$e, as much as **20%** of all U.S. GHG emissions

7.2 Billion mtCO$_2$e
Total U.S. GHG Emissions
U.S. GHG Emissions:

- U.S. CO₂ Emissions (Gigatons CO₂e) – 1990 - 2030:
- ~20% of GHG’s Traced to Site Emissions in Industry

Overall GHG emissions – 1990-2030
Gigatons CO₂e

<table>
<thead>
<tr>
<th>Year</th>
<th>Emissions</th>
<th>Sinks</th>
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</thead>
<tbody>
<tr>
<td>1990</td>
<td>5.4</td>
<td>-0.8</td>
</tr>
<tr>
<td>2005</td>
<td>6.1</td>
<td>-1.1</td>
</tr>
<tr>
<td>2030</td>
<td>8.7</td>
<td>-1.0</td>
</tr>
</tbody>
</table>

**Fossil Fuels – Carbon Content:**

- **Comparison of carbon content of major fuels:**
  - Coal ~ twice the carbon content of natural gas

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Carbon Content (lbs/MMBtu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>117 lbs</td>
</tr>
<tr>
<td>Propane</td>
<td>139 lbs</td>
</tr>
<tr>
<td>Distillate Fuels</td>
<td>162 lbs</td>
</tr>
<tr>
<td>Residual Fuels</td>
<td>174 lbs</td>
</tr>
<tr>
<td>Coal (BC)</td>
<td>205 lbs</td>
</tr>
<tr>
<td>Coal (AC)</td>
<td>227 lbs</td>
</tr>
</tbody>
</table>

**CO₂ Equivalents (lbs/MMBtu)**

- Natural Gas – 117 lbs
- Propane – 139 lbs
- Distillate Fuels – 162 lbs
- Residual Fuels – 174 lbs
- Coal (BC) – 205 lbs
- Coal (AC) – 227 lbs

U. S. Boiler Inventory: Age Distribution

- U.S. Boilers – Age Distribution of Boilers > 10 MMBtu/hr (2005):
- C/I Boiler Inventory – 163,000 units w/ capacity of 2.7 Trillion Btu/hr

47% of existing inventory – 40+ yrs. old
76% of existing inventory – 30+ yrs. Old
Assessing Conventional Boiler Performance:

- Design Limitations of Conventional Boilers:
  - Physical Size / Footprint
  - Excessive Warm-up Cycle
  - Excessive Radiant Losses
  - Poor Response to Changing Loads
  - Poor System Turn-Down Capability
  - Sub-par Overall Operational Efficiency / Load Management Capabilities
  - Innate Safety Issues via Explosive Energy
  - Lack of Integrated NOx Emissions Control
  - Lack of Integrated Heat Recovery
  - Lack of Integrated Controls / Automation
  - Lack of Integrated 24/7 Online Monitoring
Managing Energy Load Variability: **Conventional Systems**

- Conventional boiler systems expend large amounts of energy to meet variable load conditions.
- Design limitations of conventional boilers prevent them from efficiently responding to every-changing load demands.
- Result: Significant wasted energy & emissions at load swings.

Diagram showing energy load variability with a single 1000 BHP boiler.
Managing Energy Load Variability: 
**Modular On-Demand Systems**

- Modular on-demand boiler systems reduce energy consumption required to meet variable loads by dividing the output capacity among multiple small units (like gears in a transmission).
- Modular systems are designed specifically to meet varying load demands.
- Result: Significantly reduced energy & emissions at load swings.
Optimized Energy Management via Modularity

- Modular design concept:

- 200HP TDR=1:3 Step(H,L)
- 200HP TDR=1:3 Step(H,L)
- 200HP TDR=1:3 Step(H,L)
- 200HP TDR=1:3 Step(H,L)
- 200HP TDR=1:3 Step(H,L)
Optimized Energy Management via Modularity

- Modular design concept:
- Each boiler unit acts like a single piston in the overall boiler system

1000HP boiler system
TDR=1:15
(15 steps of modulation)
Modular Capacity Range: **Flexibility + Efficiency**

- Boiler Types & General Capacity Ranges
- Modular – Point-of-Use to District Energy Capacities

<table>
<thead>
<tr>
<th>Boiler Type</th>
<th>Max. Individual Capacity (+/- 10 MMBtu/hr or 10,350 lbs/hr)</th>
<th>Max. Multi-Unit Capacity with Single Controller (+/- 150 MMBtu/hr or 150,000 lbs/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Watertube Boilers</td>
<td>100 MMBtu/hr</td>
<td>1,000 MMBtu/hr</td>
</tr>
<tr>
<td>Large Watertube Boilers</td>
<td>100,000 MMBtu/hr</td>
<td>10,000 MMBtu/hr</td>
</tr>
<tr>
<td>MIURA Boilers</td>
<td>1,000 MMBtu/hr</td>
<td>10,000 MMBtu/hr</td>
</tr>
<tr>
<td>Firetube Boilers</td>
<td>10 MMBtu/hr</td>
<td>100 MMBtu/hr</td>
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<tr>
<td>Stoker Boilers</td>
<td>100 MMBtu/hr</td>
<td>1,000 MMBtu/hr</td>
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<tr>
<td>Fluidized Bed Boilers</td>
<td>100 MMBtu/hr</td>
<td>1,000 MMBtu/hr</td>
</tr>
<tr>
<td>Pulverized Coal Boilers</td>
<td>100 MMBtu/hr</td>
<td>1,000 MMBtu/hr</td>
</tr>
</tbody>
</table>

- **Multiple Boiler Installation to Meet Specific Demand** (Multiple Boilers & Controllers)
  - Max. Multi-Unit Boiler Capacity with Single Controller (+/- 150 MMBtu/hr or 150,000 lbs/hr)
  - Max. Individual Boiler Capacity (+/- 10 MMBtu/hr or 10,350 lbs/hr)
Space Savings – Addition by Subtraction:

- Small boiler footprint (good for point-of-use applications)
- No tube-pull space required
- Double the boiler output of a typical boiler room (existing facilities)
- Reduce required boiler room area by over 50% (new construction)
Space Savings – Addition by Subtraction:

- The 21st century boiler plant…

- Take advantage of freed-up space to:
  - Increase capacity
  - Incorporate other functions (in lieu of costly new construction)

- Miura has received UL certification for zero side-clearance modular configuration
Modularity = Flexibility: Meet N+1 with Less Overall Capacity

- **Conventional Approach:** Primary + Back-up
  - Total Capacity = 1,200 BHP

- **Modular Approach:** Integrated Back-up
  - Total Capacity = 800 BHP

- Reduce purchased capacity by ~ 30% while also complying with N+1 requirements
Understanding Boiler Efficiency:

In-Service Efficiency

Boiler Efficiency = \( \frac{\text{Output Energy}}{\text{Input Energy}} \)

Steam / Hot Water
Understanding Boiler Efficiency:

“Combustion Efficiency” \( (E_c) \)
- The effectiveness of the burner to ignite the fuel
- Per ANSI Z21.13 test protocol

“Thermal Efficiency” \( (E_t) \)
- The effectiveness of heat transfer from the flame to the water
- Per the Hydronics Institute BTS-2000 test protocol
- Recognized by ASHRAE 90.1 standard

“Boiler Efficiency”
- Often substituted for combustion or thermal efficiency

“Fuel-to-Steam Efficiency” (A.K.A. Catalog Efficiency)
- The effectiveness of a boiler operating at maximum capacity and a steady state, with flue losses and radiation losses taken into account.
Understanding Boiler Efficiency: Accounting for Load Variability

- Current boiler efficiency metrics are limited to best-case operation (steady-state)
- Current boiler efficiency metrics are limited to snapshot-in-time vs. annualized measurement

At any given moment, various boilers may be:

- Off and isolated (via modular, on-demand system)
- Off, but with through-flow from active boilers
- Operating at steady-state high fire
- Modulating
- Operating at steady-state low fire
- Cycling
- Idling
Understanding Boiler Efficiency:

- Fuel-to-Steam vs. In-Service Efficiency
- Understanding operating efficiency = tracking energy losses

FUEL IN

Radiation Loss
Exhaust Loss
Start-up Losses
Pre- & Post-purge Losses
Blow-down Losses
Loss @ High Turndown
Changing Loads
Radiation Loss @ Idle / Stand-by

Fuel-to-Steam Efficiency

IN-SERVICE EFFICIENCY
Increasing Efficiency = Reducing Losses: \textit{Radiant Losses}

- With energy efficiency, size matters...
- Increase efficiency via reduced boiler thermal footprint

\begin{itemize}
  \item \textbf{200 BHP Firetube Boiler}
  \item \textbf{200 BHP Modular Boiler}
\end{itemize}

\begin{itemize}
  \item \textbf{1,000+ Gallons VS 65+ Gallons}
\end{itemize}

Smaller Boiler Surface Area = Significant Reduction in Radiant Losses
Increasing Efficiency = Reducing Losses: Radiant Losses

- **Radiant Losses:** 12 MMBtu/hr input at 100% output
- **Option A – Conventional System:**
  - Single 12 MMBtu/hr unit input
  - Rated at 2% radiant loss
  - 240,000 Btu/hr energy loss
- **Option B – Modular System:**
  - 3 x 4 MMBtu/hr unit input
  - Rated at 0.5% radiant loss
  - 3 x 20,000 Btu/hr losses = 60,000 Btu/hr energy loss
Increasing Efficiency = Reducing Losses: 

**Radiant Losses**

- **Radiant Losses**: 12 MMBtu/hr input at 33% output
- **Option A – Conventional System:**
  - Single 12 MMBtu/hr unit at 33% = 4 MMBtu/hr input
  - 240,000 Btu/hr energy loss
  - Results in 6% total radiant loss
- **Option B – Modular System:**
  - 3 x 4 MMBtu/hr units (only 1 operating)
  - 1 x 20,000 Btu/hr losses = 20,000 Btu/hr energy loss
  - Only 0.5% total radiant loss
Increasing Efficiency = Reducing Losses: **Exhaust Losses**

- Utilize feed-water economizer for built-in waste heat recovery
- Feed-water economizers increase efficiency by capturing waste exhaust gases to preheat feed-water entering the boiler
- Boiler efficiency can be increased by 1% for every 40°F decrease in stack gas temperature

<table>
<thead>
<tr>
<th>Recoverable Heat from Boiler Flue Gases</th>
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<tbody>
<tr>
<td><strong>Initial Stack Gas Temperature, °F</strong></td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td>400</td>
</tr>
<tr>
<td>500</td>
</tr>
<tr>
<td>600</td>
</tr>
</tbody>
</table>

Based on natural gas fuel, 15% excess air, and a final stack temperature of 250°F.
Increasing Efficiency = Reducing Losses: Start-up Losses

- Thermal shock/stress is the #1 cause of fire-tube boiler damage & repair

- Conventional boiler performance is limited by thermal stress resulting in inefficiency by requiring slow boiler start-up & perpetual idling

- Firetube boilers ~ 90 min. warm-up cycle / must remain idling when in stand-by mode (resulting in wasted energy & emissions)
Increasing Efficiency = Reducing Losses: Start-up Losses

- Innovative “Floating Header” pressure vessel design eliminates thermal shock
- All welded tube to tube-sheet construction
- X-ray & dye-penetrant quality control with heat treatment for stress relief of steel
- Single-pass design for even temperature distribution
- No more “re-rolling tubes” or “tube popping”...
- Allows for steam production in 5 minutes from cold start
Increasing Efficiency = Reducing Losses: Blow-down Losses

- U.S. DOE steam systems BEST PRACTICES recommendation:
  
  "Improve boiler efficiency and reduce water consumption by utilizing automatic surface blow-down in lieu of continuous and/or manual blow-down."

- Miura’s BL Controller boiler control system includes automatic blow-down for optimization of blow-down for highest efficiency operation.

- Automatic blow-down is managed by the BL Controller via a proportional flow system & back-up conductivity probe that monitor TDS to maximize boiler performance and efficiency.
Increasing Efficiency = Reducing Losses: *Pre- & Post-Purge Losses*

- Utilize a control system that includes an intelligent purge system to optimize boiler performance
- “Purge Cancel” function interrupts post purge when fast restart is required, eliminating energy loss & improving response time
- Optimized response time (w/in 10 seconds) = increased efficiency + reduced emissions

**Typical controller**

- Boiler stop
- Restart signal
- Post-purge
- Pre-purge

**“Smart” controller**

- Post-purge = Pre-purge
- Boiler start sequences
Increasing Efficiency = Reducing Losses: Losses at High Turn-down

- Modular boiler system:
- Sequential boiler staging via “master” & “slave” controllers for precise load matching capability

![Diagram of modular boiler system with four boilers and controllers]
Boiler Scale Detection & Prevention: 
*Heat Transfer Losses - Scale*

- An eggshell thickness of scale can reduce boiler efficiency as much as **10%*** (25% for 1/8” thickness, 40% for 1/4” thickness)

*Just 1/32” of scale thickness multiplied times each industrial boiler in the U.S. inventory ~

- Over $7 billion in wasted energy / yr (@ $1.00/therm)
- Over 50 million metric tons of CO₂ emissions / yr
Boiler Scale Detection & Prevention: *Water Hardness Monitoring*

- Installed between water softener & feed water tank
- Colormetry “sips” feed water every 30 minutes
- Detects water hardness below 1 ppm
- Automatically increases surface blow-down when water hardness is detected
- Interfaces with BL Controller & M.O.M. System
- Easily replaceable cartridges
Boiler Scale Detection & Prevention: **Integrated Water Softener System**

- “Smart” water softener system
- Enhanced performance via *split-flow regeneration*
- Automatically alternates between primary / regeneration tanks for optimized performance
- Monitors brine tank level & alarms thru BL Controller
- Interfaces with Colormetry, BL Controller & Online Monitoring Systems
Boiler Scale Detection & Prevention: 
**Integrated Water Softener System**

- **Online Interface:**
  - Raw Water Hardness / Pressure
  - Treated Water Hardness / Flow
  - Primary / Regen Tank Operating Status
  - Automatic Primary / Regen Tank Switching
  - Brine Flow / Concentration
  - Brine Concentration Alarm
Boiler Tube Protection: BOILERMATE Water Treatment System

- Eco-friendly Silicate-based water treatment
- Eliminates need for high temperature feed-water (i.e., DA tank) to activate chemical treatment
- Provides increased boiler efficiency by +1-2% via reduced blow-down & low temperature feed-water
- Reduces boiler chemical treatment costs due to more effective tube protection & computer controlled chemical feed system
- Reduces maintenance issues related to constant monitoring & adjustment of boiler water chemistry
- Reduces boiler performance issues such as feed-water pump cavitation, increasing pump efficiency by +10-20%

![Graph showing Boiler Efficiency vs. Stack Temperature](image)
Boiler Tube Protection:
**BOILERMATE Water Treatment System**

- Silicate filmer water treatment feed is modulated via an interface with the MI Controller.
- Chemical feed is based on steam demand measured by the steam pressure sensor.
- Scale dispersant also available to address scale formation without down-time.

![Diagram of the BOILERMATE Water Treatment System with labels for MI Chemical Controller, Water Treatment Tank, Control Signal, Chemical Pump, and Feed Water Tank.](image-url)
Online Monitoring / Management: Online “Energy Dashboard” Systems

- Stand-alone online monitoring system that interfaces with boiler control system as thermal energy management “dashboard”
- Provides 24/7 online M&T/ M&V online maintenance system
- Real-time 24/7 operation, fuel/water consumption, efficiency & emissions tracking capabilities
- Communicates with operations staff via workstation interface, PDA, email alerts
- Provides monthly reports
Online Monitoring / Management:  
**ER System “Energy Dashboard”**

- **24/7 Real-time Operational Parameters:** LX Series Interface

  - Firing Rate
  - Steam Pressure
  - Scale Monitor
  - High Limit
  - Flue Gas Temp
  - Feedwater Temp
  - Flame Voltage
  - Next Blow-down
  - Surface B/down
  - Conductivity
  - Date / Time
Boiler Systems - Introduction:

- Available Models:
  - LX Series
  - EX Series
Boiler Model Summary: **LX Series**

- Gas Only – Natural Gas / Propane
- 50, 100, 150, 200, 300 BHP Models
- Steam in 5 min. from Cold Start
- Low NOx Design (as low as 9ppm)
- Horizontal Flame Path
- 70-150 PSI Standard Operating Pressure (low and high pressure options available)
- Also Available in Hot Water Version
Boiler Model Summary: 
**EX Series**

- Duel Fuel – Natural Gas/Propane & Oil
- 100, 150, 200, 250, 300 BHP Models
- Steam in 5mins From Cold Start
- Vertical Flame Path (top down)
- 70-150 PSI Standard Operating Pressure 
  (high pressure option available)
- Also Available in Hot Water version
Unlocking Energy Efficiency

DOE Resources

- DOE Regional Industrial Assessment Centers:
  [http://www1.eere.energy.gov/industry/bestpractices/iacs.html](http://www1.eere.energy.gov/industry/bestpractices/iacs.html)
Benchmarking to Save Energy: In-Service Efficiency (ISE) Study

You are not managing what you do not measure...

- Meter existing equipment & collect data on current consumption, including:
  - Gas & water consumption rates
  - Gas pressure at the meter
  - Gas temperature at the meter
  - Feedwater temperature
  - Steam pressure
  - Blow-down rate

- Review utilities statements for historical data

- Size loads and determine load “profile” (i.e., high-low load swings) over test period

- Determine In-Service Efficiency to “benchmark” existing energy performance

Courtesy of ENERGY STAR Program Guide
In-Service Efficiency Analysis: Benchmarking Tools

- Miura’s Data Logger records metered usage to benchmark existing efficiency:

  - Tank
  - Radiant Losses
  - Gas Meter
  - Water Meter
  - Gas
  - Water
  - Existing Boiler
  - Blow-down
  - Steam Demand
  - Steam
  - Miura Data Logger
  - Miura’s Data Logger records metered usage to benchmark existing efficiency.
Boiler In-Service Efficiency: Tracking Results

- Benchmarked energy efficiency of 25 boilers via ISE data:
- Average In-Service Efficiency = 66% at 33% average load factor

<table>
<thead>
<tr>
<th>Company</th>
<th>Industry</th>
<th>Manufacture</th>
<th>HP</th>
<th>Year</th>
<th>Ave. Load</th>
<th>ISE</th>
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<tbody>
<tr>
<td>1</td>
<td>Chemical</td>
<td></td>
<td>1600</td>
<td>1978</td>
<td>17%</td>
<td>70.8%</td>
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<tr>
<td>2</td>
<td>Foods</td>
<td>CB</td>
<td>150</td>
<td>1976</td>
<td>21%</td>
<td>68.9%</td>
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<tr>
<td>3</td>
<td>Hospitals</td>
<td>GE</td>
<td>250</td>
<td>1975</td>
<td>21%</td>
<td>68.9%</td>
</tr>
<tr>
<td>4</td>
<td>Foods</td>
<td>Hurst</td>
<td>50</td>
<td>1975</td>
<td>23%</td>
<td>64.3%</td>
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<tr>
<td>5</td>
<td>Chemical</td>
<td>CB</td>
<td>350</td>
<td>1976</td>
<td>60%</td>
<td>75.9%</td>
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</table>

**Average:**

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<tbody>
<tr>
<td>PSI</td>
<td>HP</td>
<td></td>
</tr>
<tr>
<td>365</td>
<td>33%</td>
<td>66.0%</td>
</tr>
</tbody>
</table>
Steam Cost Calculator: TCO (Total Cost of Operation) Analysis

- Fuel Cost
- Water Cost
- Sewer Cost
- Electricity Costs
- Chemical Costs
- Service Contract
- O&M Costs
- Future CO₂ Costs
- Projected Lifecycle Costs

![Diagram of Steam Cost Calculator]

<table>
<thead>
<tr>
<th>Customer's name</th>
<th>Example 1</th>
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<table>
<thead>
<tr>
<th>Usage</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler HP</td>
<td>400 HP</td>
</tr>
<tr>
<td>Number of boilers</td>
<td>2 boilers</td>
</tr>
<tr>
<td>Average load</td>
<td>25 %</td>
</tr>
<tr>
<td>Operation time</td>
<td>24 hours/day</td>
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<table>
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<tr>
<th>Price for customer</th>
<th>Reference</th>
</tr>
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<tbody>
<tr>
<td>Water (supply + sewer)</td>
<td>5.8 $/kcal</td>
</tr>
<tr>
<td>Fuel gas (oil)</td>
<td>0.6 $/therm</td>
</tr>
<tr>
<td>Electricity</td>
<td>7 C/KWH</td>
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<tr>
<td>Chemical</td>
<td>0.8 $/100HP</td>
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<tr>
<td>Labor charge</td>
<td>2,500 $/month</td>
</tr>
<tr>
<td>Maintenance contract</td>
<td>10,000 $/boiler</td>
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<tr>
<td>Carbon tax</td>
<td>0 $/ton-CO₂</td>
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</tbody>
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<table>
<thead>
<tr>
<th>System information</th>
<th>Reference</th>
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<tbody>
<tr>
<td>Steam pressure</td>
<td>130 PSI</td>
</tr>
<tr>
<td>Steam enthalpy</td>
<td>1193.5 btu/lb</td>
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<tr>
<td>Blow down ratio</td>
<td>5 %</td>
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<tr>
<td>Feed water temp</td>
<td>190 °F</td>
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<tr>
<td>In service Efficiency</td>
<td>73 %</td>
</tr>
<tr>
<td>Condensation return</td>
<td>30 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Steam Price per 100 HP</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Fuel Gas (oil)</td>
<td>36.7</td>
</tr>
<tr>
<td>2) Water</td>
<td>1.8</td>
</tr>
<tr>
<td>3) Electricity</td>
<td>1.1</td>
</tr>
<tr>
<td>4) Chemical</td>
<td>0.8</td>
</tr>
<tr>
<td>5) Labor charge</td>
<td>0.2</td>
</tr>
<tr>
<td>6) Maintenance Contract</td>
<td>2.0</td>
</tr>
<tr>
<td>7) Carbon tax cost</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td>47.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total price for a year</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Fuel Gas (oil)</td>
<td>264,171</td>
</tr>
<tr>
<td>2) Water</td>
<td>13,032</td>
</tr>
<tr>
<td>3) Electricity</td>
<td>7,560</td>
</tr>
<tr>
<td>4) Chemical</td>
<td>5,760</td>
</tr>
<tr>
<td>5) Labor charge</td>
<td>30,000</td>
</tr>
<tr>
<td>6) Maintenance Contract</td>
<td>20,000</td>
</tr>
<tr>
<td>7) Carbon tax cost</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>340,523</td>
</tr>
</tbody>
</table>
In-Service Efficiency by Boiler Type:

Miura’s modular systems provide increased energy efficiency at around 85% consistently from low to high load factors.
Reducing Boiler “Footprint”

**Physical Footprint:**
- Reduced space requirements
- Reduced energy plant construction costs
- Reduced boiler “hardware”

**Energy Footprint:**
- Reduced energy consumption / wasted energy
- Reduced explosive energy
- Reduced embodied energy

**Environmental Footprint**
- Reduced consumption of natural resources
- Reduced harmful emissions
- Reduced carbon footprint
Case Studies: Suntory Breweries (Kyoto, Japan)

- Total Boiler Units in Operation: (22) LX-160
- Total Boiler Capacity: 3,520 BHP
- Total System Turn-Down: 1:72
- Placed into Service: 2005
- Process applications: pasteurization, heating water, C.I.P.
Case Studies: Gekkeikan (California)

- **Boiler System:** (2) 200 BHP, (1) 100 BHP
  LX Series units
- **Placed into service:** 1996, 1997, 2010
- **Process applications:** pasteurization, heating water, C.I.P.
  - **LOW LOAD:** LX-100 (Low Fire)
  - **MED LOAD 1:** LX-100 (Low/High Fire) + LX-200 (High Fire)
  - **MED LOAD 2:** LX-100 (High Fire) + LX-200 (Low/High Fire) with LX-200 (Standby – Backup)
  - **HIGH LOAD:** LX-100 (High Fire) + LX-200 (High Fire) + LX-200 (Low/High Fire as needed)
Case Studies: Beverage Industry

**Pepsico Bottling** *(Pennsylvania)*

- **Boiler Upgrade** – (3) LXL-100 BHP units
- **Placed into service:** 2010
- **Estimated avg. operating cost savings:** $130,000 / yr. (173,300 therms / yr.)
- **Estimated avg. reduced CO2 emissions:** 870 metric tons of CO2 / yr.

- “The new, low-pressure steam boilers are 80 to 85 percent energy efficient, produce lower plant emissions, and they’re cost-efficient. In fact, during the 2009-2010 calendar year, PBC Philadelphia saved 27 percent on fuel costs, which amounted to a company savings of over $130,000.” – *Peter Eilskov, Maintenance Manager*

- “We needed a more efficient steam-generating solution that would improve on the 60 percent efficiency we were getting from our two 30-yr-old fire-tube boilers. As gas prices increased, costs to maintain our 100 and 200 horsepower boilers increased. As part of PepsiCo’s Performance with Purpose mission – a commitment to deliver sustainable growth by investing in a healthier future for people and the planet - PBC explored energy- and cost-efficient solutions with lower emissions.” – *Eilskov*
Questions:

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