SuperBoiler and Energy Intensive Processes Update

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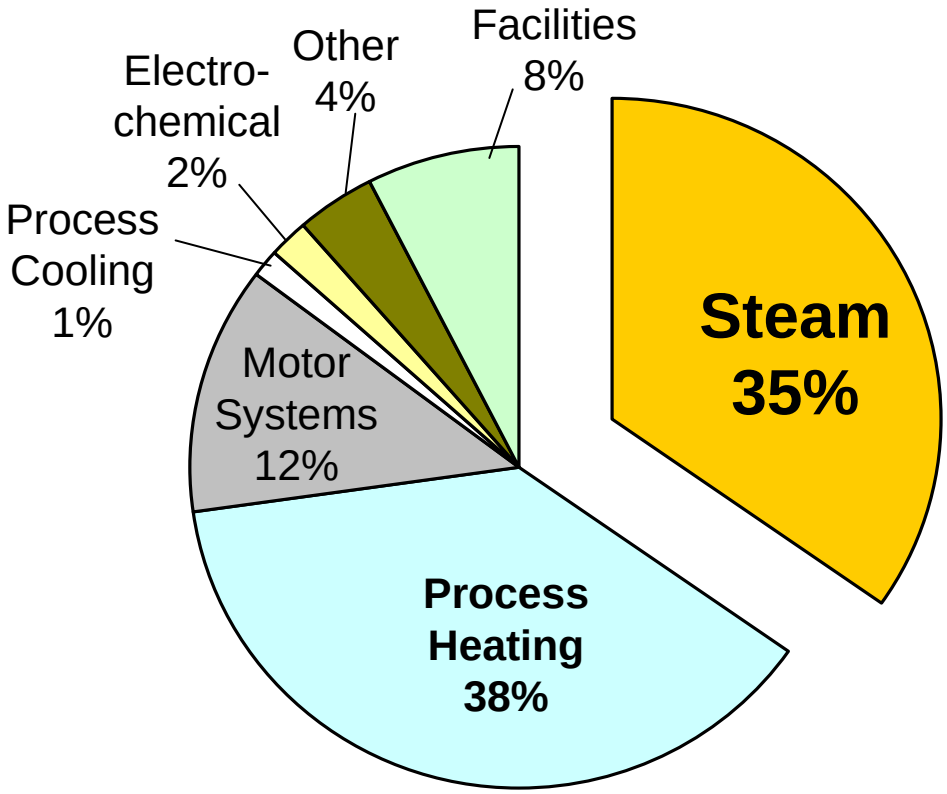
Industrial Boilers

and

Steam Use

Manufacturing and Mining Energy End Use



- **Steam Use: ~6,200 trillion Btu/yr**
- **Steam Onsite Losses: 2,800 Tbtu/yr**
  - **Generation ~ 1,200 Tbtu/yr**
  - **Distribution ~ 1,000 Tbtu/yr**
  - **Conversion ~ 600 Tbtu/yr**

Note: Does not include offsite losses

Age of Boilers

- Total sales of new boilers over the last 40 years are smaller than the current boiler inventory. This suggests that many boilers used today are more than 40 years old
- Approximately 7% of boiler capacity is less than 10 years old

***2005 DOE Report*: "Characterization of the U.S. Industrial Commercial Boiler Population"**

Target Opportunity: Steam Generation

Big numbers

- Boiler population
- Energy consumption
- Emissions

Aging Boiler Fleet Creates Opportunities for New Technology!

SuperBoiler Vision

Target – Steam Generation

Potential Impacts:

- ✓ **Increase industrial package boiler efficiency from 75% to 95%**
- ✓ **Reduce emissions of SOx, NOx, and carbon oxides**

Energy Savings of 1,049 TBtu in 2030

Controls
- "Smart" system controls
- Modeling

Heat Transfer
- Innovative heat transfer concepts
- Modeling and materials

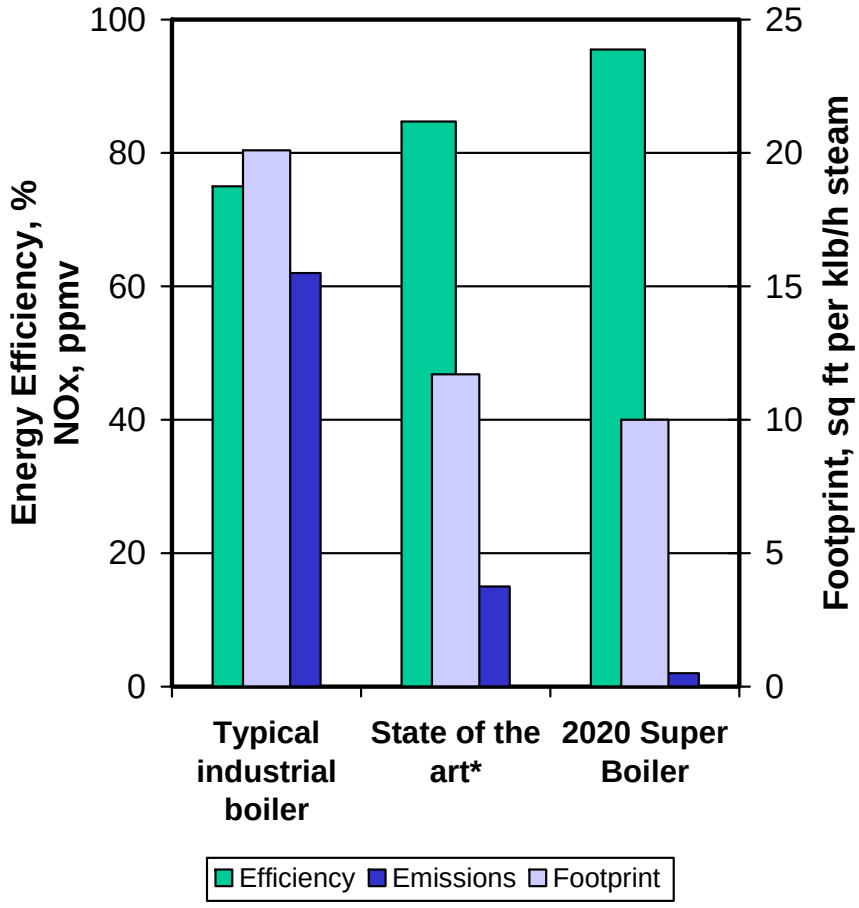
System Engineering
- System integration approach
- Modeling to expedite overall design

Heat Production
- Fundamental R&D
- CFD Modeling
- "Smart" burners

Heat Recovery
- Improved materials
- Innovative concepts for heat recovery

SuperBoiler?

- Not a bigger boiler but a ***better*** boiler**!**
  - Higher energy efficiency - more than 95% HHV
  - Super-low emissions - down to 2 ppm NOx *and* 5 ppm CO
  - Smaller and lighter - reduce size and weight by 50 percent
  - Competitive performance
  - Cost-effective



*** Not all in the same boiler**

First Generation

SuperBoiler

1st Generation SuperBoiler Concept

- Evaluate four fundamental components in modern boilers
  - Combustion
  - Heat Transfer
  - Heat Recovery
  - Control
- R&D focus
  - Advancements in all 4 boiler components
  - System integration
  - Evaluate a near-term product design that “meet” the RFP goals

Potential Benefits of 1st Generation SuperBoiler

- 499,900,000 MMBtu/year energy savings
- $2 billion/year fuel cost savings
- 18,386,000 ton/year CO2
- 580,700 ton/year CO
- 205,600 ton/year NOx
- ***Compelling economic benefits to accelerate replacement of aging boilers***

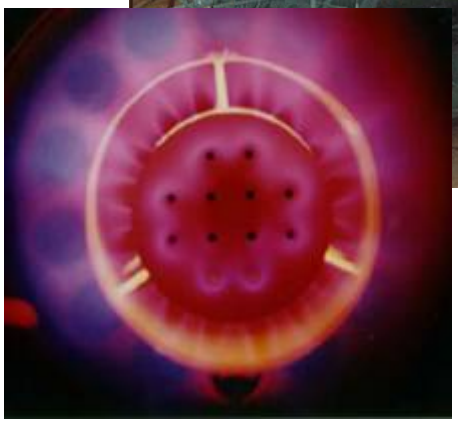
First Generation SuperBoiler Project

Project Description:

- Gas-fired firetube boiler using innovative concepts in burner, heat transfer, heat recovery & control
- Develop and test a prototype at industrial host site
- Meet aggressive performance targets
- Partnered with Cleaver-Brooks

Technical Objectives

- 94% efficiency (from 70-83%)
- <5 ppm NOx (from 30-100 ppm)



Funding

- $2,600,000 -- DOE
- $3,500,000 – industry cost share

Where are We?

- Lab testing Complete
  - Optimized combustion performance
  - Validated computer models for scale-up
  - Optimized heat recovery system performance
  - Optimized control strategy
- Field demonstration
  - First field demonstration at a site in Alabama complete
    - Single stage combustion design with transport membrane condenser to recover latent heat
    - Over 6,000 hours of operation with no significant problems
  - Currently installing dual stage combustion design at a fruit processing plant in Ontario, California
  - Planning underway to demonstrate retrofit of transport membrane condenser
- Commercialization (Role of Private Sector)
  - Introduce into commercial and light industrial market

SuperBoiler

Next Steps

SuperBoiler Vision – Next Steps

- August 2004 Workshop on Ultra-High Efficiency Industrial Steam Generation R&D Opportunities
- FY 2005 Solicitation Objectives:
  - Thermal efficiency greater than 94% (HHV)
  - NOx emissions below 2 vppm
  - CO emissions below 2 vppm
  - VOC emissions below 1 vppm
  - Capable of operating on multiple fuels
  - ***Capable of producing high temperature/high pressure steam (greater than 1500°F/1500 psig)***
  - System weight and footprint 50% of currently available boilers with comparable performance

SuperBoiler Vision – Next Steps

- Solicitation for Second Generation Watertube SuperBoiler closed April 14, 2005
- Three proposals selected for funding
  - Babcock and Wilcox
  - Gas Technology Institute
  - Research Engineering Incorporated
- Research delayed due to elimination of Combustion budget in 2006
- Two of three projects restarted in 2007
  - Gas Technology Institute
  - Research Engineering Incorporated
- Two phases:
  - Phase I
    - Up to two years
    - Preliminary design and development
  - Phase II (Following down select)
    - Prototype development and field trial

Energy Intensive Processes

Crosscutting: Energy Intensive Processes

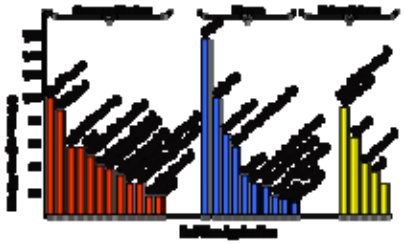
Four Technology Platforms:

Maximize energy and carbon reduction throughout industry

- **Industrial Reactions & Separations**
- **High-Temperature Processing**
- **Waste Heat Minimization & Recovery**
- **Sustainable Manufacturing**

Platform selection criteria included alignment with:

- Industry's top energy-saving opportunities
- ITP mission and goals
- Industry priorities
- Existing R&D projects



Energy Intensive Processing (EIP): Strategy

Energy-intensive process R&D will focus on the following four platform areas:

- Waste Heat Minimization and Recovery
- Industrial Reactions and Separations
- High-Temperature Processes
- Sustainable Manufacturing

- Technology platform approach to address broad industry needs
  - Consistent, long-term R&D agenda
  - Maximum synergy among technologies
  - Greater flexibility in launching new initiatives
- Leveraging national labs to include
  - Review of existing IP and results of prior investments
  - Building cross-lab teams with appropriate industry partners
- Continue to solicit industry proposals to address R&D focus areas and restock our "pipeline" of advanced technologies
- Focus on concept definition studies and limited prototype development and field testing (FY08)

Energy Intensive Processes – 4 Technology Platforms

Industrial Reactions & Separations

- Advanced Water Removal
- Advanced Gas Separations
- Hybrid Distillation
- Energy-Intensive Conversion Processes

High-Temperature Processing

- Low-Energy, High-Temperature Materials Processing
- New Materials Development
- Materials Processing for Enabling Emerging Industries

Waste Heat Minimization & Recovery

- Super Boiler
- Ultra-High Efficiency Furnace
- Waste Heat Recovery Systems

Sustainable Manufacturing

- Net and Near-Net Design & Manufacturing
- Engineered Functional Materials and Coatings
- Advanced Casting, Forming, Joining, and Assembly
- Integrated, Predictive Manufacturing & Energy-Efficient Material Handling and Plant Operations

EIP Waste Heat Minimization/Recovery Portfolio

Key Market Facts

- Waste heat minimization/recovery consists of equipment and technologies used to convert, transport, manage, and recover or reuse energy needed for industrial processes
  - Process heating
  - Steam

Key Energy Facts

- Combustion systems account for nearly two thirds (15 quads) of the energy used in manufacturing
- Waste heat recovery potential of 1.8 quads has been identified in select industrial processes

Key Stakeholders

- Chemicals, petroleum, and bio-based products
- Metals
- Pulp and paper
- Food processing
- Other industries that use steam and process heat
- CIBO
- ABMA
- IHEA

EIP Reactions and Separations Portfolio

Key Market Facts

- Reaction and separation processes transform raw materials (e.g., oil, natural gas, biomass) into energy, paper, chemicals and other products for use by utilities, manufacturing, and consumers
  - Crude oil into the gasoline and essential chemical feedstocks
  - Feedstocks and natural gas into basic inorganic and organic chemicals
  - Wood into paper products

Key Energy Facts

- Chemical and petrochemical reaction/separation processes account for over half of total U.S. manufacturing energy use
  - Distillation alone accounts for 15% of the total

Key Stakeholders

- Chemicals and petrochemicals producers
- Pulp and paper manufacturers
- Food and agricultural processors
- Biomass processors
- Biotechnology and pharmaceuticals
- Biorefineries

EIP High-Temperature Processing Portfolio

Key Market Facts

- High-temperature processing covers the processing of raw materials and intermediate products at elevated temperatures
  - Produce intermediate or finished products and alter the thermo-physical and chemical properties of the materials being heated

Key Energy Facts

- High-temperature processes in the steel industry consume >1 Quad/yr
- Heat treating presently accounts for energy use of more than 500 TBtu/yr at a cost of nearly $20 billion

Key Stakeholders

- Metals and metal casting companies
- Metal fabricators
- Automotive companies
- Glass and ceramic manufacturers
- Photovoltaic and battery industries

EIP Sustainable Manufacturing Portfolio

Key Market Facts

- Sustainable manufacturing supports the entire spectrum of manufacturing industries
- Yield losses during the manufacture of finished components from raw materials can be as high as 30%

Key Energy Facts

- The additive energy costs that result from each step in the manufacturing supply chain are a large fraction of the ultimate product cost
- Improved yields per unit energy used will significantly impact overall product costs

Key Stakeholders

- Energy-intensive process industries
- Transportation and aerospace
- Equipment and component suppliers
- Manufacturers of advanced energy conversion devices

Current Status

- Laboratory call issued in February, 2008
  - All four platforms addressed
  - Solicitation closed April 1, 2008
  - 35 proposals received, covering all four platforms
  - Review concluded May 16, 2008
  - Winners to be announced in June/July

- Industry call issued March 6, 2008
  - All four platforms addressed
  - Solicitation closed May 7, 2008
  - 63 proposals received, covering all four platforms
  - Review in late June
  - Winners to be announced in late summer