Addressing Combustion Control for Improved Energy Efficiency

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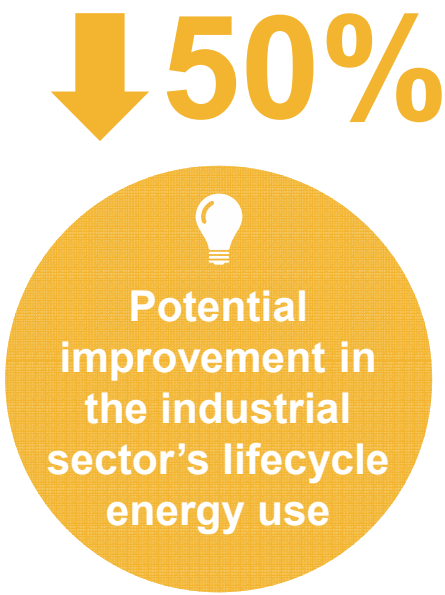
Emerson Process Management Asia Pacific

Energy Efficiency is a Key Industry Challenge

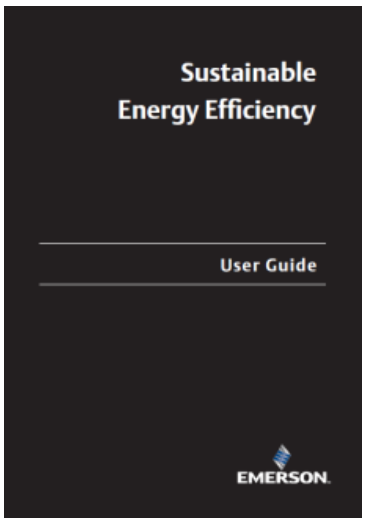
- **50% growth in energy demand** in Asia Pacific – Led by China and India.
- Demand will continue to **push energy costs higher.**
- Industry sector is the **second largest consumer of energy** and producer of emissions
- IEA study on Petro/Chemicals Industry estimates **5-15% energy saving** potential in the short to medium term

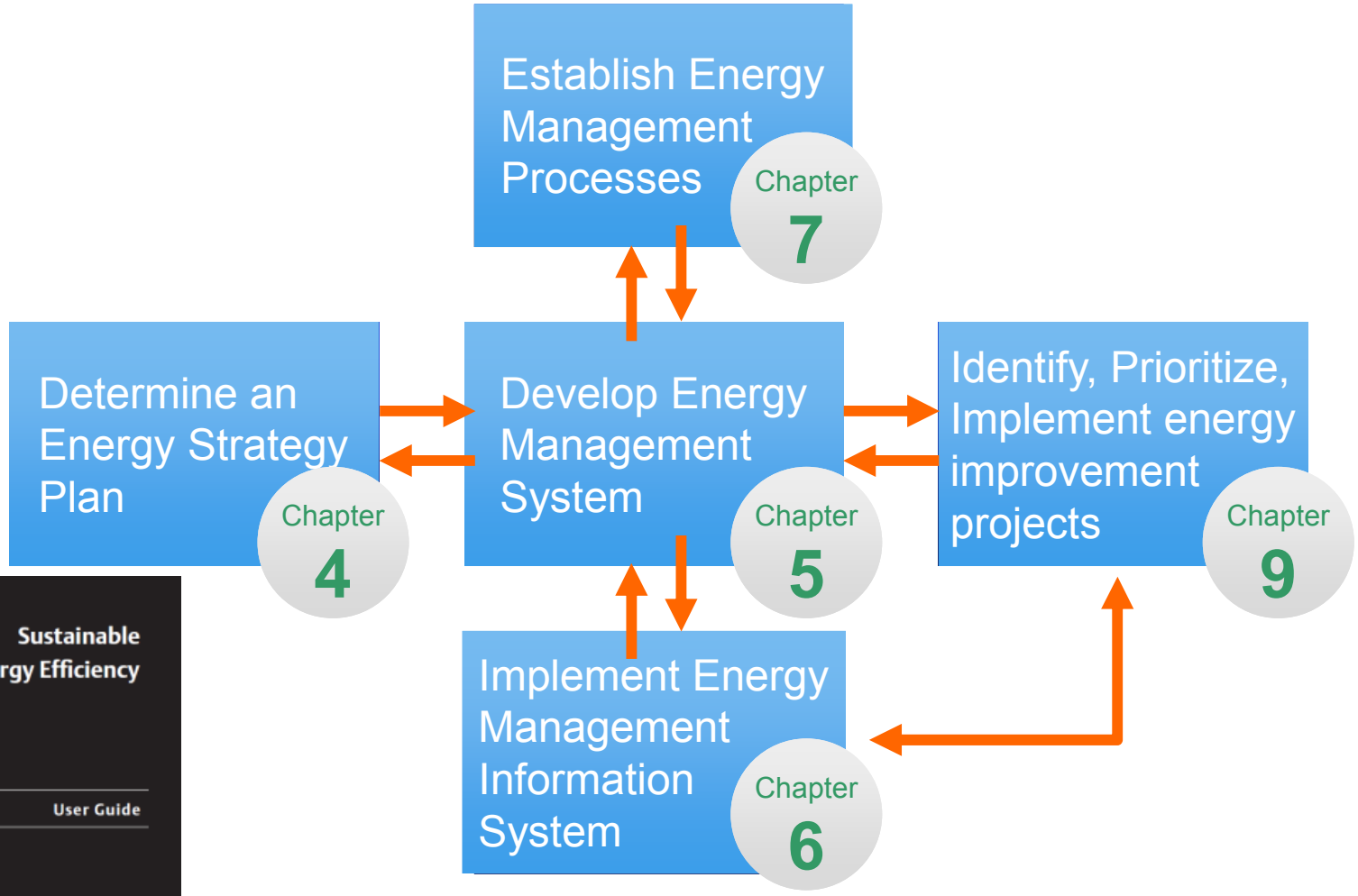


Energy Efficiency Key to Profitability & Sustainable Growth

Source: DOE/EIA-0383 (2012) - Annual Energy Outlook 2012 ; EIA: US Energy Information Administration.; IEA Study 2009, Chemical and Petrochemical Sector, Potential for best practice technology and other measures for improving energy efficiency.

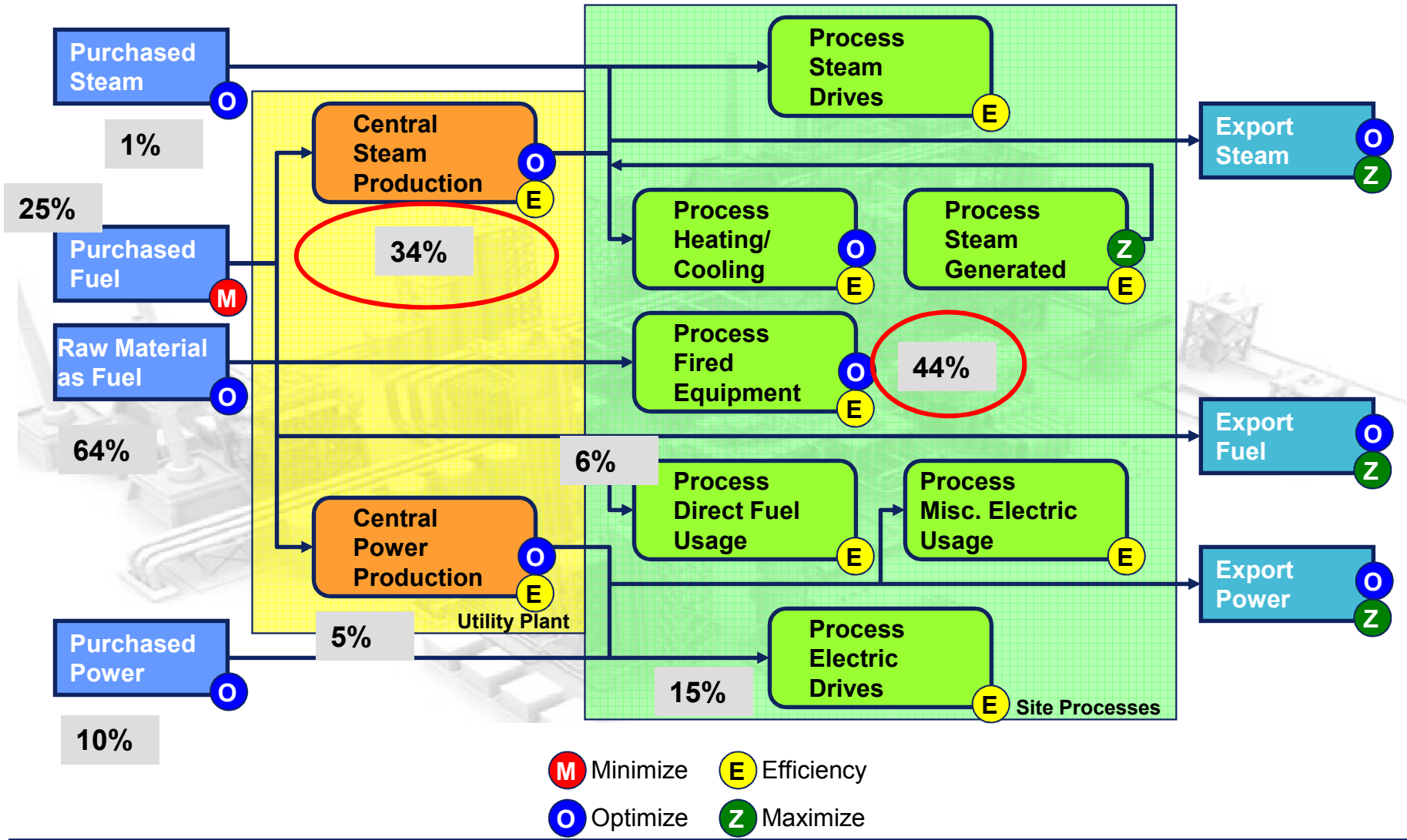
Energy Management (is a) Process Not a Project





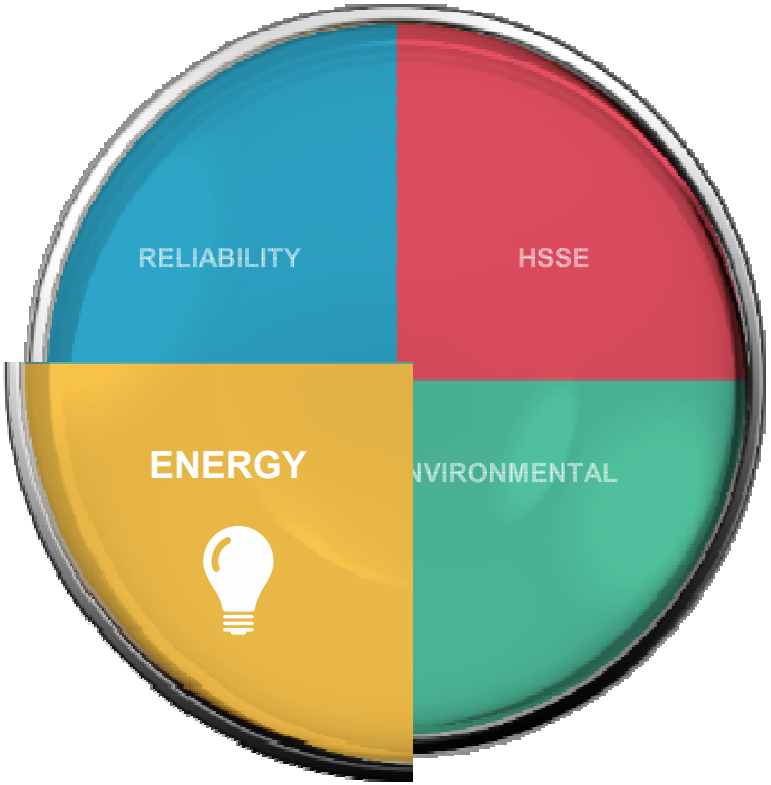
Guide developed in collaboration with an Industry Energy Management Expert

Typical Process Site Energy Flow



Combustion processes typically consume 75% of the energy used

Energy Management Solutions



Energy

- Plant Wide Utilities Monitoring - Metering
- Energy Management Information System - Reporting
- Steam Trap Monitoring
- Heat Exchangers Monitoring
- Cooling Towers Monitoring
- Combustion Control – Boilers and Fired Heaters

Combustion Control Challenges

- The process is not steady state
- Use of alternative fuels with varying heating value
- Optimum operating set points a “moving target”
- Complex dynamics and highly interactive decision variables
- Large number of constraints and conflicting constraints
- Balancing reliability against cost savings

Combustion Control Objectives

- Improve
  - Safety
  - Stability
  - Reliability
- Improve plant agility
  - Better response to process upsets and demand variations
  - Improved operating range (higher capacity, reduced minimum loads)
- Minimize overall utility costs
  - Fuel
  - Power
  - Water
- Reduce emissions and carbon footprint

Industrial Energy Solutions Group

- Emerson has an Industrial Energy Applications Consulting Group, part of the Industrial Solutions Group

- Staffed with **Power and Energy Process Engineers** with Control Expertise
  - E.g Boiler/Utility Process Engineers
  - E.g. Process Engineers

- Provide Operations Consulting, Automation Improvements , and Optimization

- Combine Technical Skill in Process Control with **Detailed Process Knowledge**

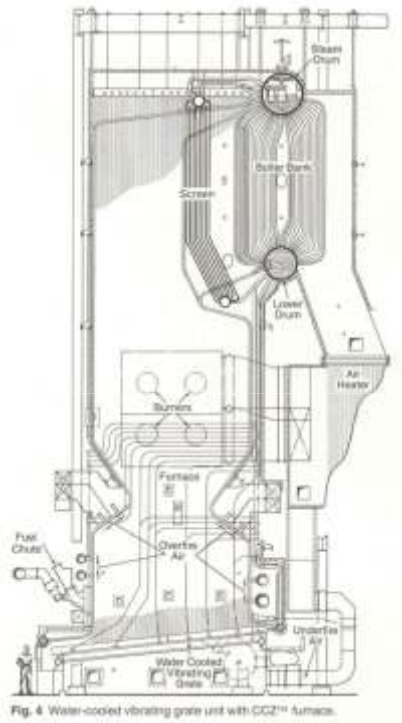
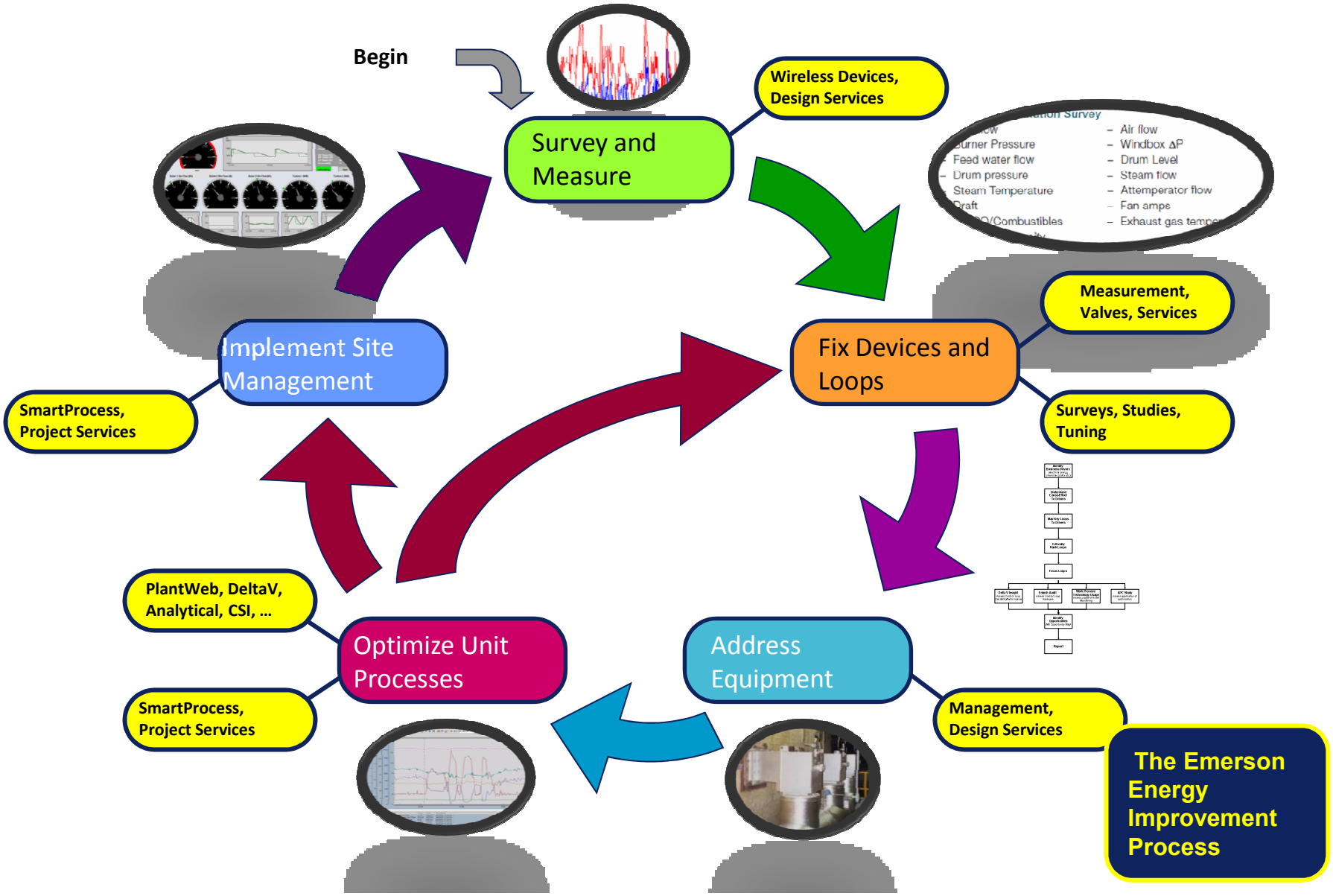


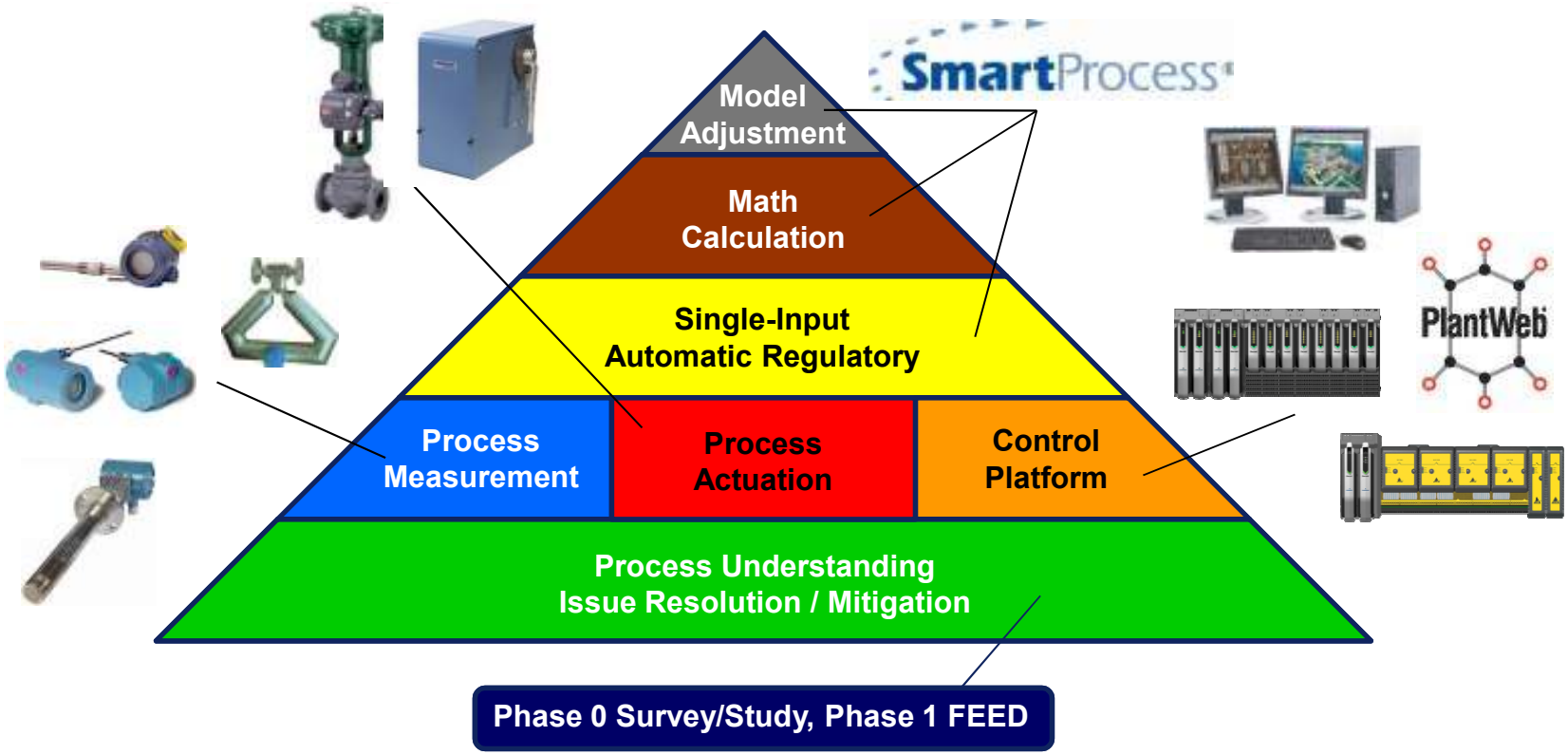
Fig. 4 Water-cooled vibrating grate unit with CCZ™ furnace.

Holistic Process Centric Approach



We Build Solution from Bottom

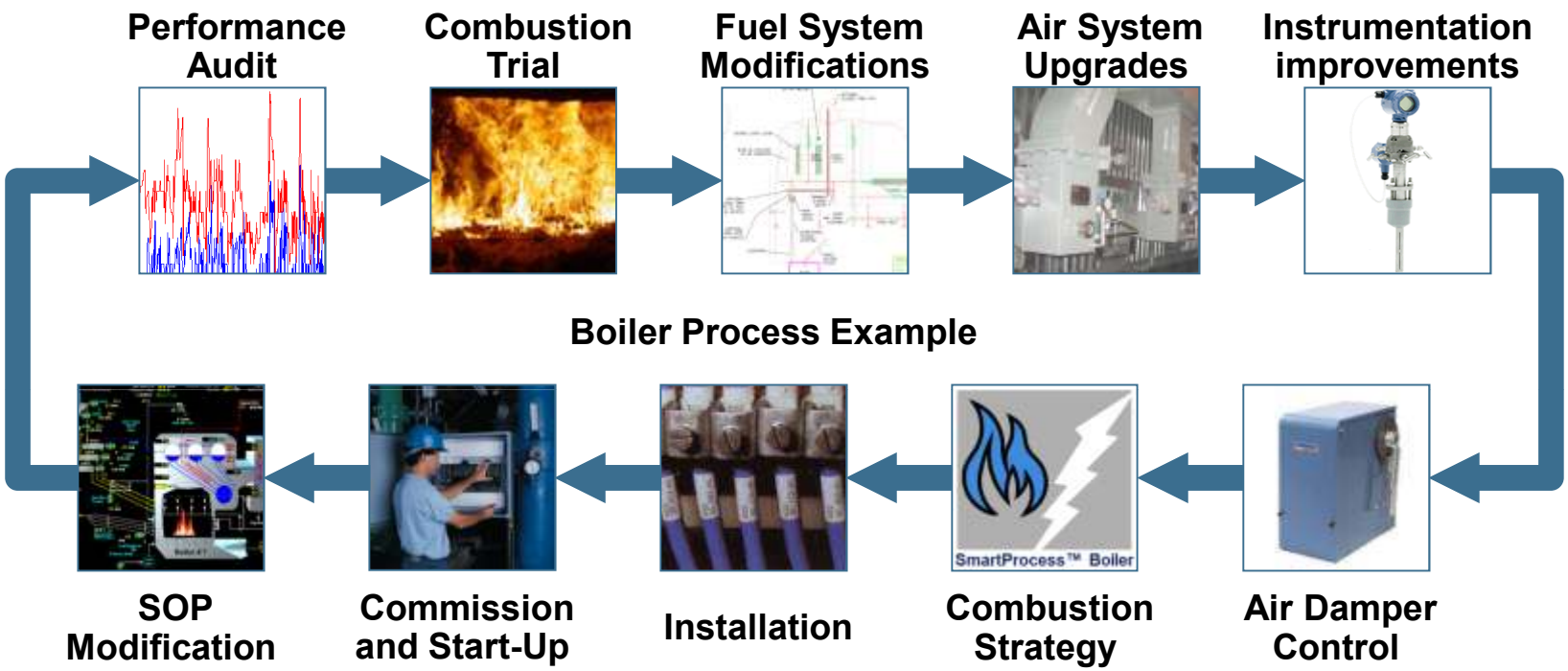
Sustainable Business Results Are at Risk if a Holistic Approach is Not Utilized



Address Process, Measurement, and Actuation, then Build Control

Boiler Improvement Process

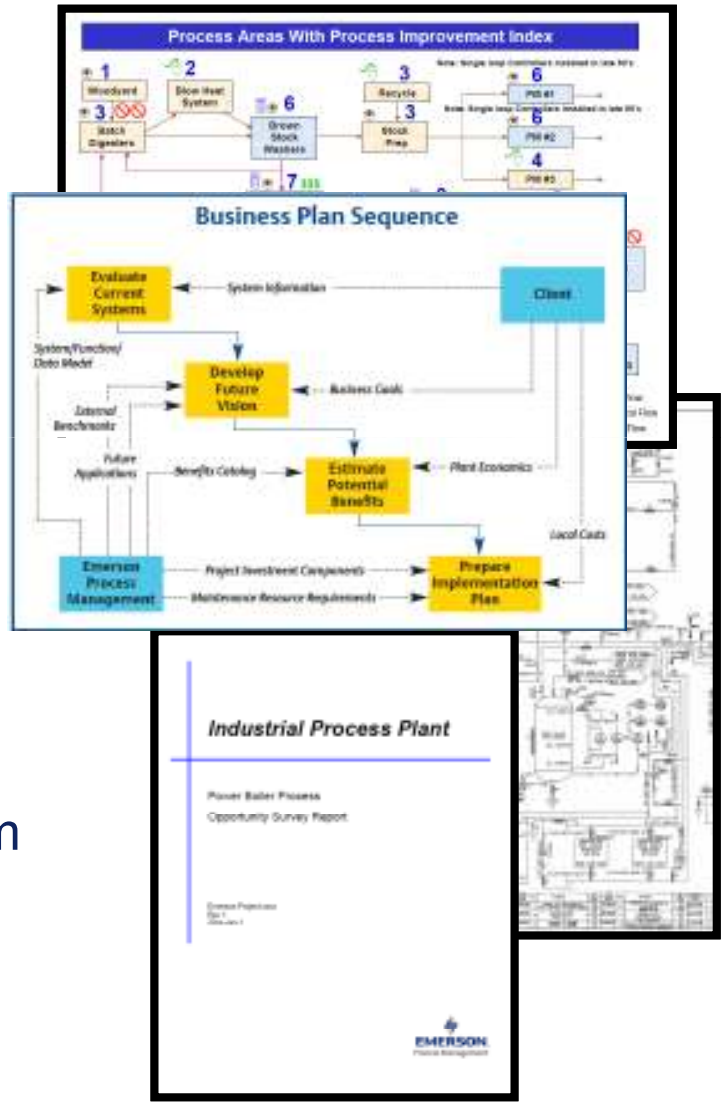
How is the unit behaving? Are there issues or limitations? Audit



Emerson Addresses Mechanical, Field Devices, Control, and Operating Procedures

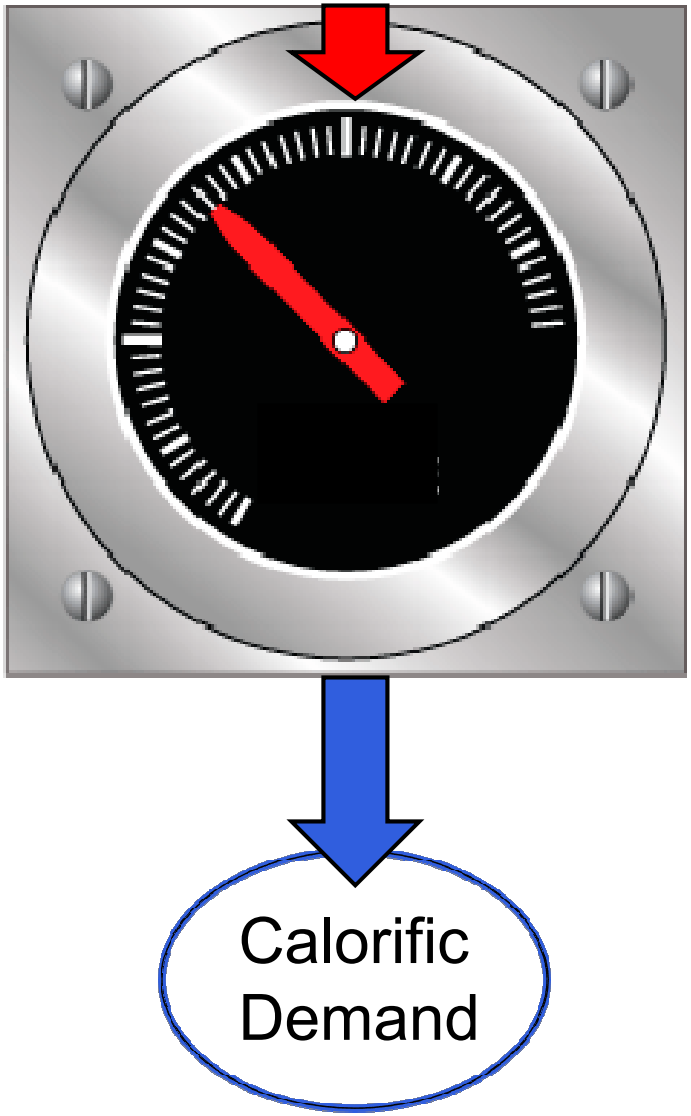
Process Opportunity Survey/Study

- Process documentation review
- Process field surveys
- Personnel interviews
- Operating data analysis
- Current performance benchmarking
- Recommendations development
  - Process mechanical
  - Instrumentation and end devices
  - Standard operating procedures
  - Unit optimization
- Energy Management Information System definition
- **Cost / benefit analysis**

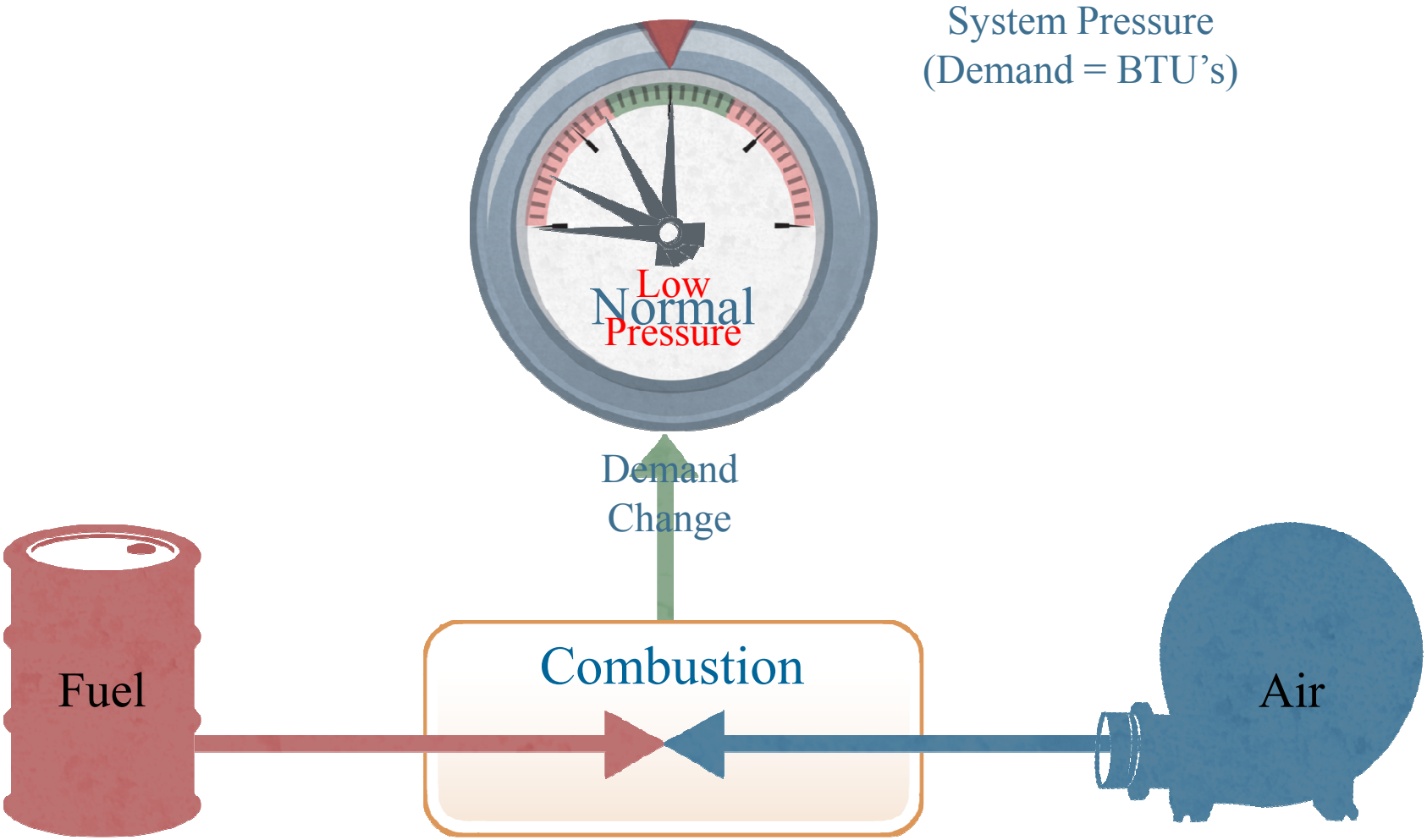


Fundamental Concept (often Overlooked)

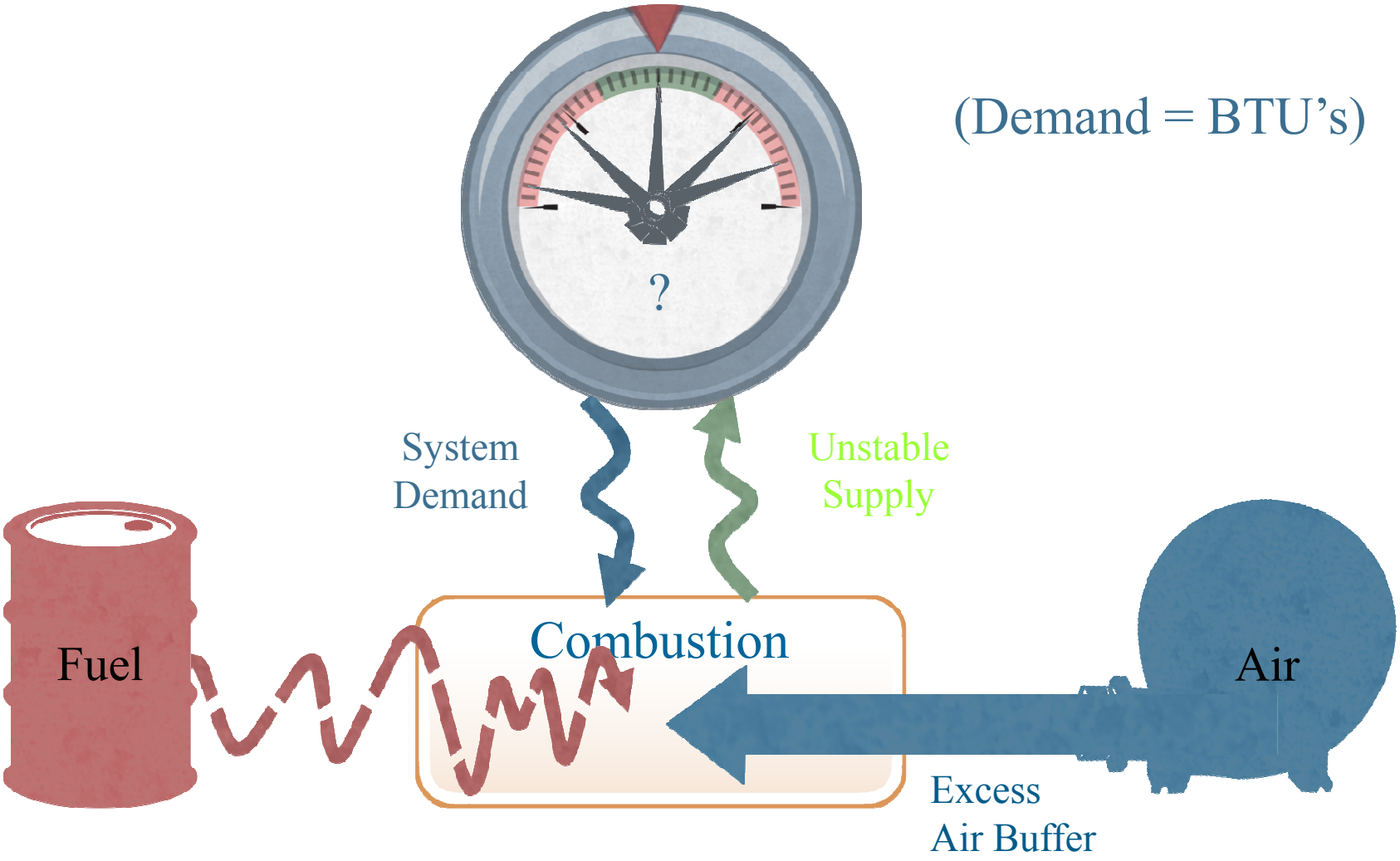
Header Pressure or Product Temperature is a direct indication of thermodynamic system demand!



Combustion 101

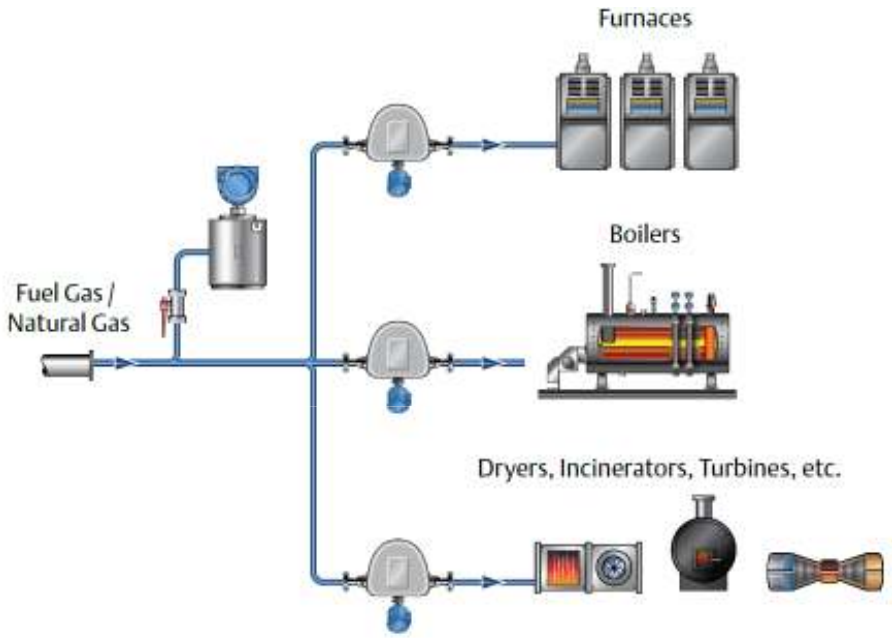


With Variable BTUs, System Supply Is Undependable, Costly & Dangerous



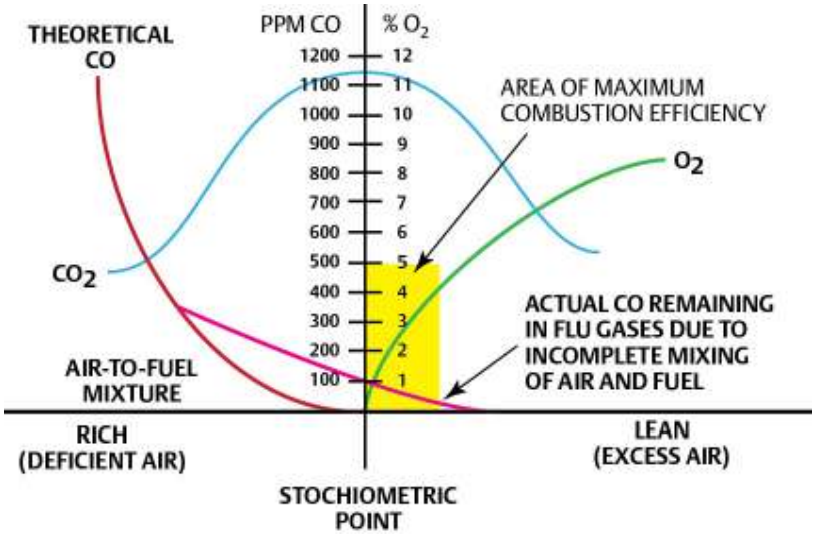
Combustion control objective: Steady heat output, minimum emissions

- Common challenges
  - Poor combustion control
  - Higher emissions
  - Process upsets
- Typical practice
  - Differential Pressure
  - GC or Wobbe meter



Reduce control variability by upto 20 times with mass-based heating value

Heaters and boilers can waste energy from gas composition and excess O2 variability



Variability factors preventing max efficiency

- Air and fuel flow rate (excess 02)
- Fuel composition (heating value)

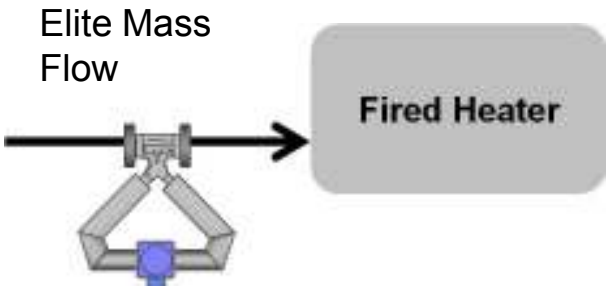
Heat Variability is significantly lowered by mass measurement

Gas Composition changes

Natural Gas Component	Ideal Heating Value BTU/lbm	Ideal Heating Value BTU/SCF	Amarillo	Ekofisk
N2	0	0.0	3.1284	1.0068
CO2	0	0.0	0.4676	1.4954
Methane	23891	1012.3	90.6724	85.9063
Ethane	22333	1773.7	4.5279	8.4919
Propane	21653	2521.9	0.8280	2.3015
I-Butane	21232	3259.4	0.1037	0.3486
N-Butane	21300	3269.8	0.1563	0.3506
I-Pentane	21043	4010.2	0.0321	0.0509
N-Pentane	21085	4018.2	0.0443	0.0480
N-Hexane	20943	4766.9	0.0393	0.0000
N-Heptane	20839	5515.2	0.0000	0.0000
N-Octane	20759	6263.4	0.0000	0.0000
N-Nonane	20701	7012.7	0.0000	0.0000
Variation Hydrocarbons from Average BTU	7.15%	74.77%		
Heating Value BTU/lb			22,217.68	22,293.66
Heating Value BTU/scf			1034.912857	1108.389233
Average on BTU/lb Basis			22,255.67	
Variation % from Average BTU/lb			0.17%	
Average on BTU/scf Basis			1071.65	
Variation % from Average BTU/scf			3.43%	

Mass flow control for Fuel

Reduced variability due to mass based heating value and flow rate



Case 1
22,218 BTU/lb

Case 2
22,294 BTU/lb

22,256 Avg.
± 0.17% error

- Use mass flow when
  - Natural gas with varying hydrocarbon content
  - Constant or low inerts variability
  - Need reduced calibration costs (in situ meter verification
  - Need reduced maintenance costs

Addressing Significant Gas Composition Changes

- Hydrocarbon mixture HV directly proportional to $Density_{base}$ & Specific Gravity
- Constant correction applied for avg. N_2 / CO_2 concentration
- < ±2% variation in inerts concentration

HV=(1560.1(S.G.) + 143.77)

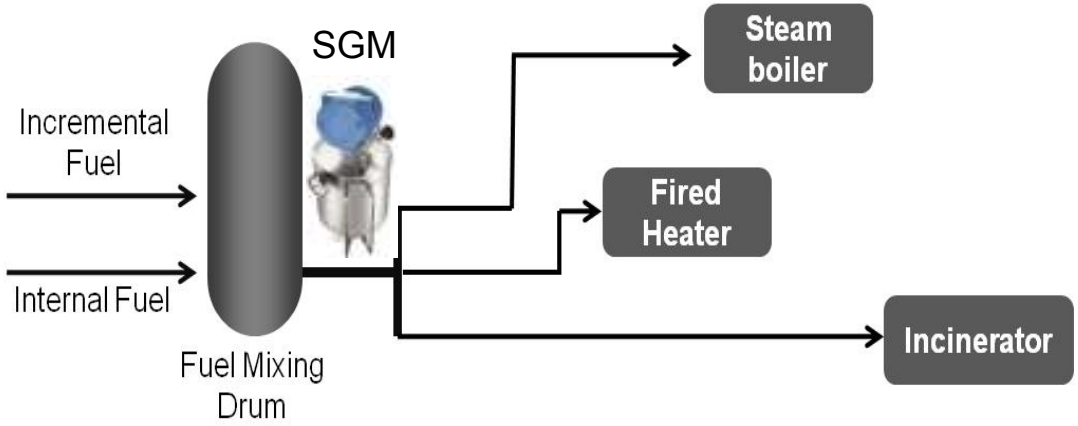
Component	Case 1	Case 2
C1	45.8	68.6
C2	2.0	3.0
C3	0.8	1.1
H2	50	25
CO2	0.3	0.4
N2	1.3	1.9
BTU / lb	25,464	23,520
BTU / scf	654	844

•Significant variation in C1 and H2 composition

•AGA 5 outlines a correlation that can be used to infer heating value of fuel gas with changing hydrocarbon contents

Online Specific Gravity Measurement– Fuel Gas

Reduced variability due to inferred energy



- Handles **wide variations in H2** content
- No compensation for downstream P, T and compressibility
- Reduces analyzer maintenance costs & lag times
- **Early indication of heating value changes**
- Use inferred heating value when:
  - **H2 swings can cause the fuel gas to be too light for the burners (flame instability leading to trips- big safety risk during re-lighting)**
  - Constant or low inerts variability

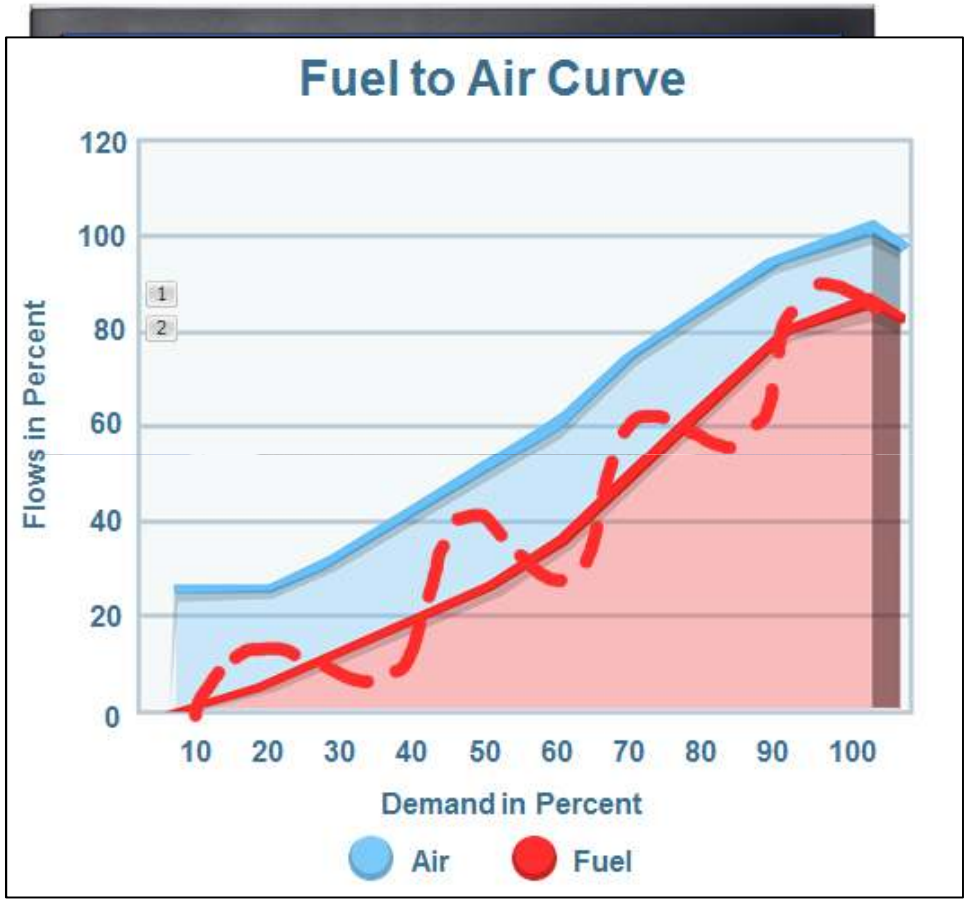
Steam Measurement Confidence

- Best Practices
  - Reduce Installed Cost
  - Eliminate Impulse Lines
  - Extend Rangeability
  - Reduce Straight Pipe Run
  - Decrease Permanent Pressure Loss

Address steam measurement confidence for efficiency calculations and energy balance

Making Best Use of Low-Cost Fuels is Difficult with Old Control Concepts

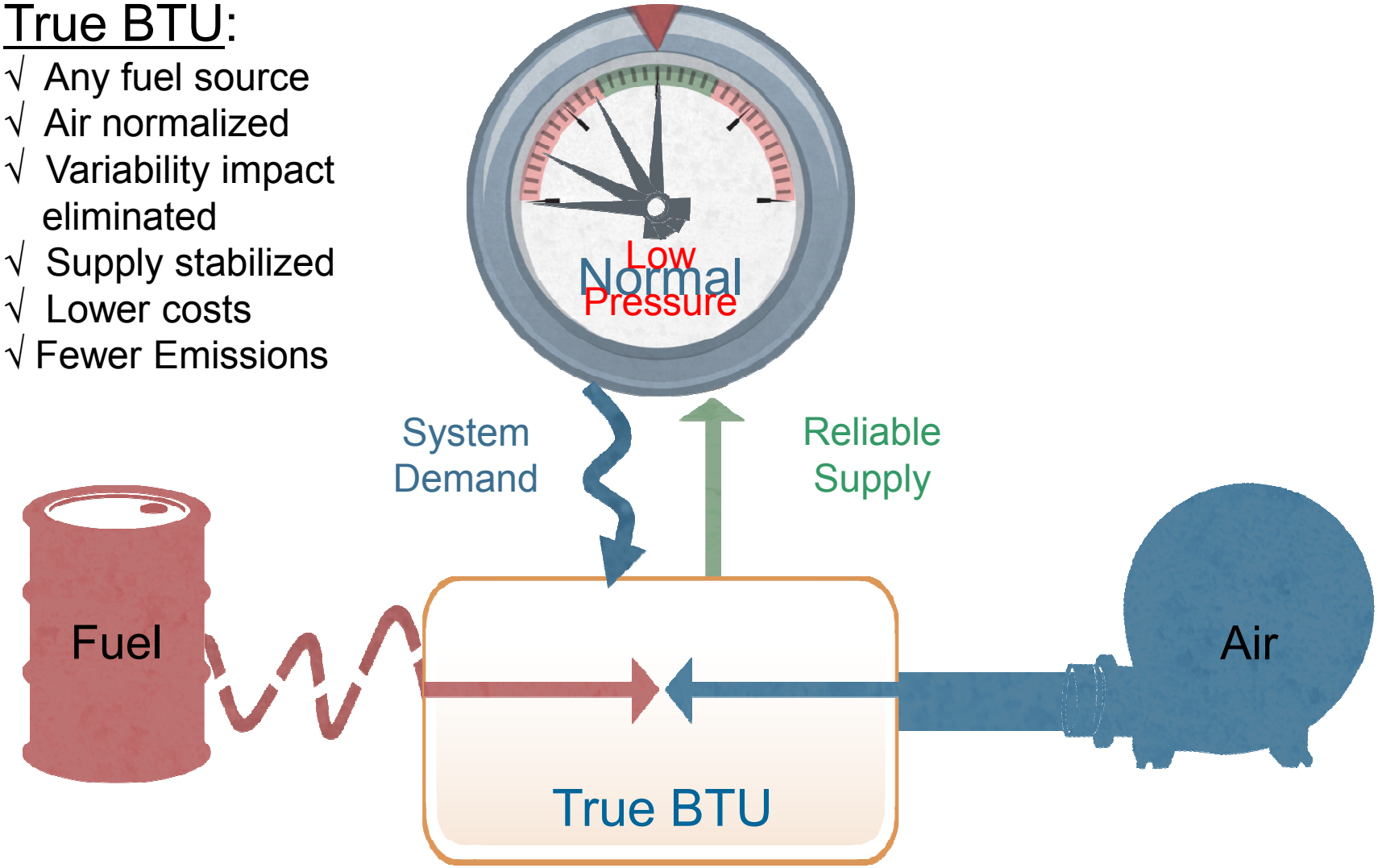
- Fuel to air curves limit combustion performance
- Estimating Btu/calories per volume of fuel is never accurate, even in "consistent" fossil fuels
- "Safety margin" or "buffers" must be included to accommodate fuel variations and changing ambient conditions
- Best efficiency and low-cost fuel use are rarely achieved



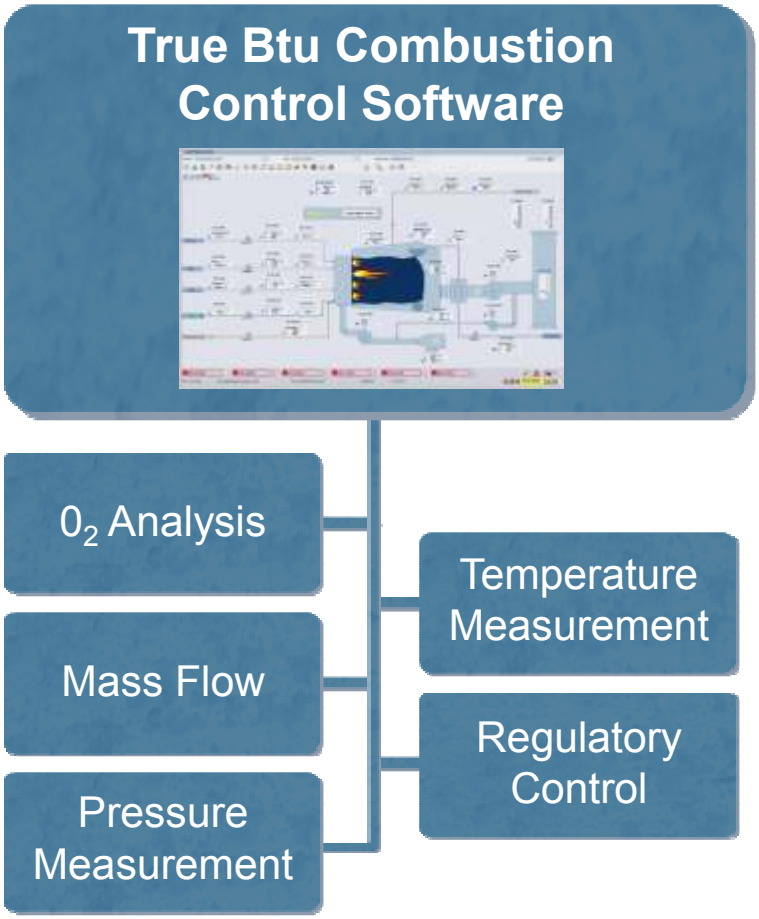
With Emerson's True BTU Technology, Exact BTUs Are Known…Production is Stable

True BTU:

- √ Any fuel source
- √ Air normalized
- √ Variability impact eliminated
- √ Supply stabilized
- √ Lower costs
- √ Fewer Emissions



Optimal Efficiency and Highest Low-Cost Fuel Use are Achieved with True Btu

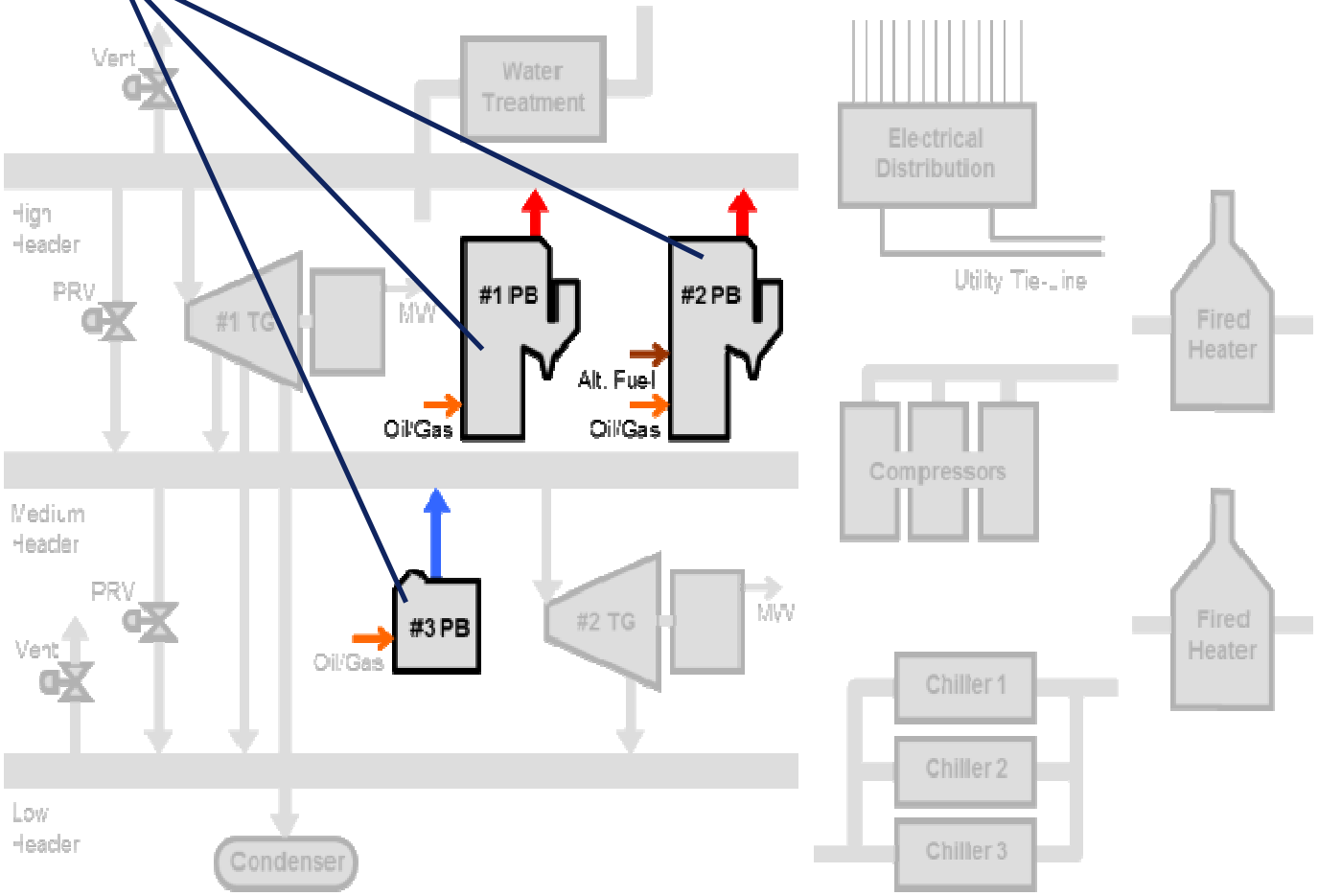


- Complete reinvention of combustion controls
- Eliminates curves
- Incorporates best control and user interface technologies
- Efficiently burn any fuel or combination of fuels with lower emissions
- Patent pending technology
- Calculation based BTU based Control Design

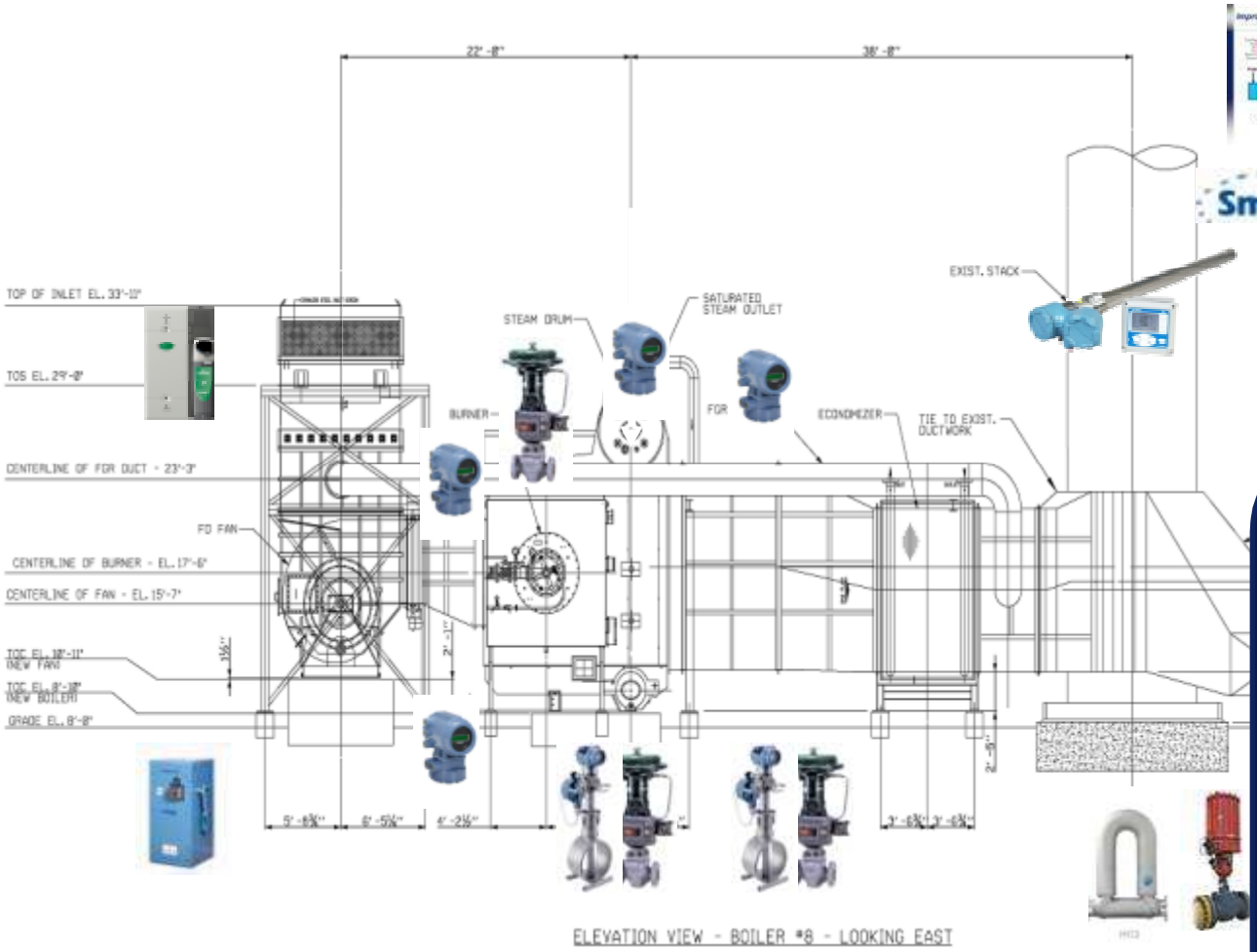
1 - 3 % improvement in thermal efficiency;
10-15% increase in steam from alternate fuel

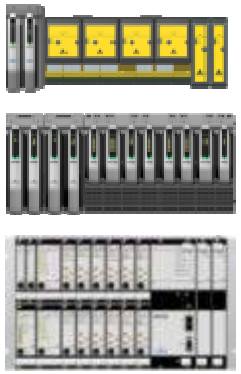
Standard Boiler Solution

SmartProcess™ Boiler — **Put units on full automatic, improve efficiency, reduce emissions, and make more steam from cheap alternate fuel**



Packaged Solution for Boilers

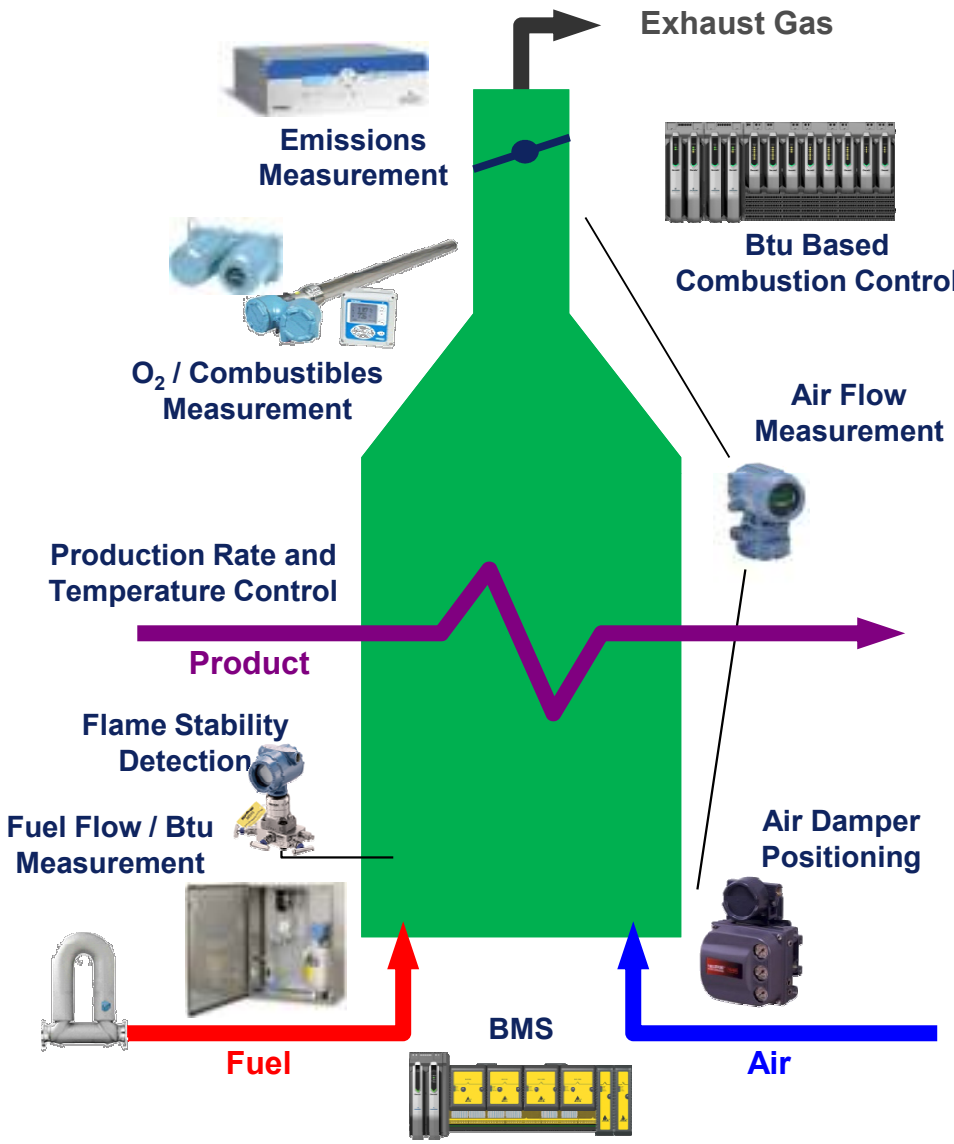




- Fuel Flow ; Specific Gravity Meter
- Analyzers – Combustible, pH, & Conductivity
- Air Flow
- Drum Level
- Feed Water Flow
- Feed Water Control Valve
- Steam Flow
- Temperature & Pressure
- Dampers & Actuators
- Variable Speed Drives

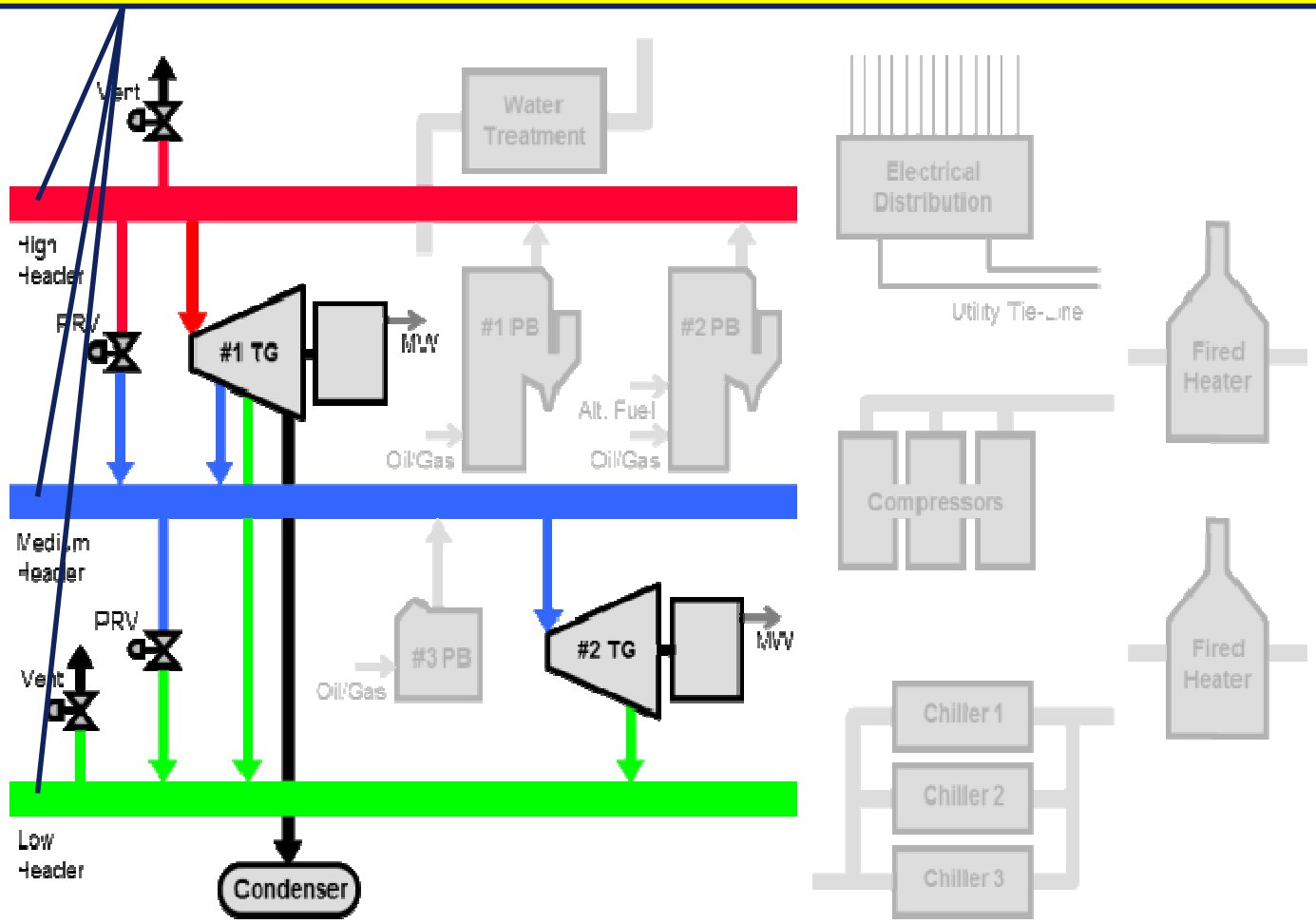
Packaged Process Heater Solution

- Burner Management System (BMS) using Safety Instrumented System (SIS)
- Air damper actuation and position measurement
- Excess Oxygen measurement
- Emission parameter measurement
- Optimized combustion control with fuel Btu compensation
- Production rate control with “Single Knob” ramp function
- Flame stability detection
- Automatic start-up and shut-down routines
- Product charge and temperature optimization
- Asset monitoring functionality with predictive maintenance alerts



Steam Header Management

SmartProcess™ Header — **Coordinate headers and respond to upsets automatically, reduce venting, raise electrical generation**



Steam Header Management

- Coordinate Header Management Objectives
  - Automatic Coordinated Response to Upsets **without Operator Intervention**
  - Minimal Deviation from Pressure Setpoints
  - **Header Prioritization**
  - Energy Conservation Techniques
    - Minimize Venting and PRV Use
    - **Maximize Generation**
    - Prevent Safeties Lifting

Prevent cascade trips, Minimize Steam Venting, and Improve Electricity Generation by 10%

Overall Powerhouse Optimization Strategy

- Continually Calculate Cost of Producing Steam and Electricity by Unit.
- Monitor Purchased Electric Cost.
- Monitor and Feed Forward Steam and Electric Use.
- Calculate Penalties for PRVing, Venting and Condensing.
- Adjust Process Set Points Toward Least Cost.
- Maintain All Constraint Points

Safety and Financial Challenge – Addressing Multiple Goals

Safety Goals

- Personnel Protection
- Environmental Protection
- Asset Protection
- Compliance with standards/practices

SIS Protective System

- Safety rated hardware
- Emergency shutdown procedures
- Effective risk mitigation
- SIL rated Safety Instrumented Functions
- Compliance with standards

Operational Goals

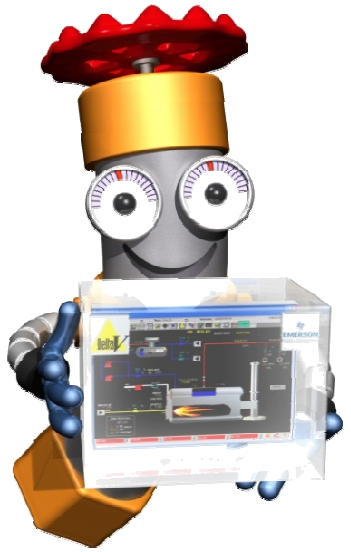
- Less downtime
- Increased throughput
- Improved reliability
- Improved availability
- Improved operator efficiency

Burner Management System Implemented as SIS

- Automated sequences for lightoff and shutdown
- Smart instruments for diagnostics
- Easy to understand
- Easy to test and maintain
- Operator assistance
- Status information
- Reduce human error

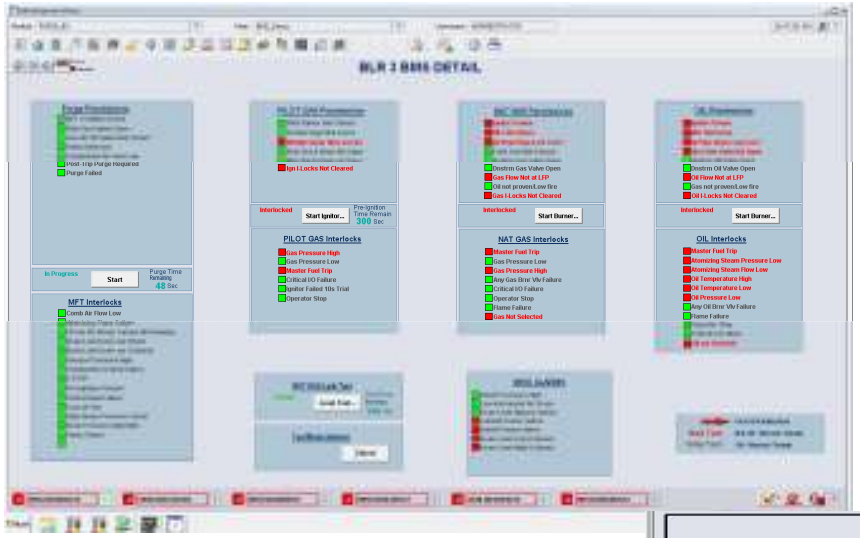
Burner Management Solution Overview

- **Burner Management System (BMS), Flame Safety System (FSS)**
  - Ensures Safe Firing of Boiler
  - Traditionally Been PLC or Black Box Solution
- **BMS Functionality in Standard Solution**
  - Per NFPA 85, IEC61508, and Other Codes
  - Separate Controller
- **Same Control Platform as Combustion System**
  - Single User Interface
  - Tightly Integrated with Combustion Out of the Box
- **Extensive Diagnostics**
  - First Out Cause of Trip
  - Missing Interlocks and Permissive
  - System Hardware Fault Identification
  - Field Device Failure

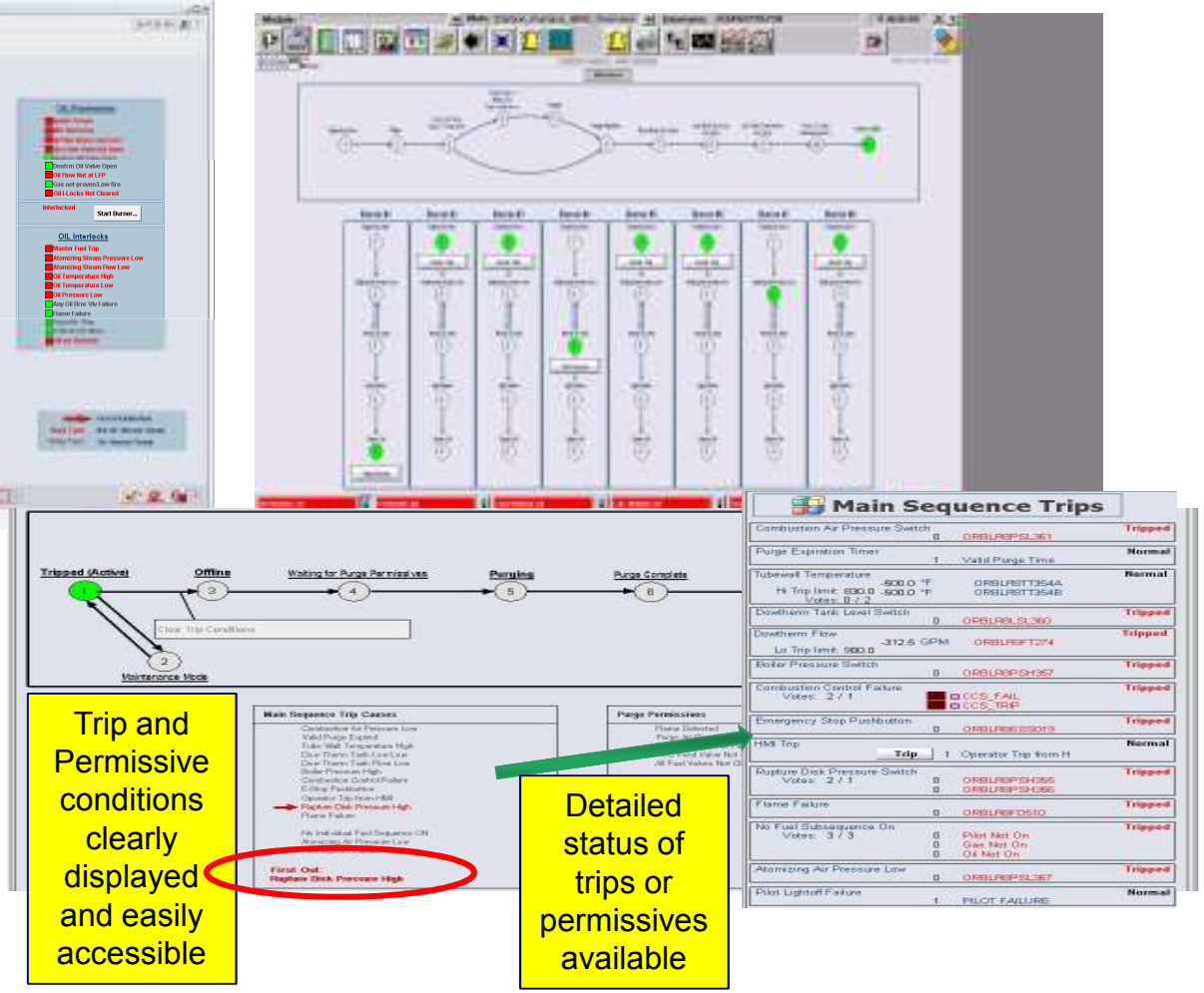


Burner Management Solution
Easier to implement & Use

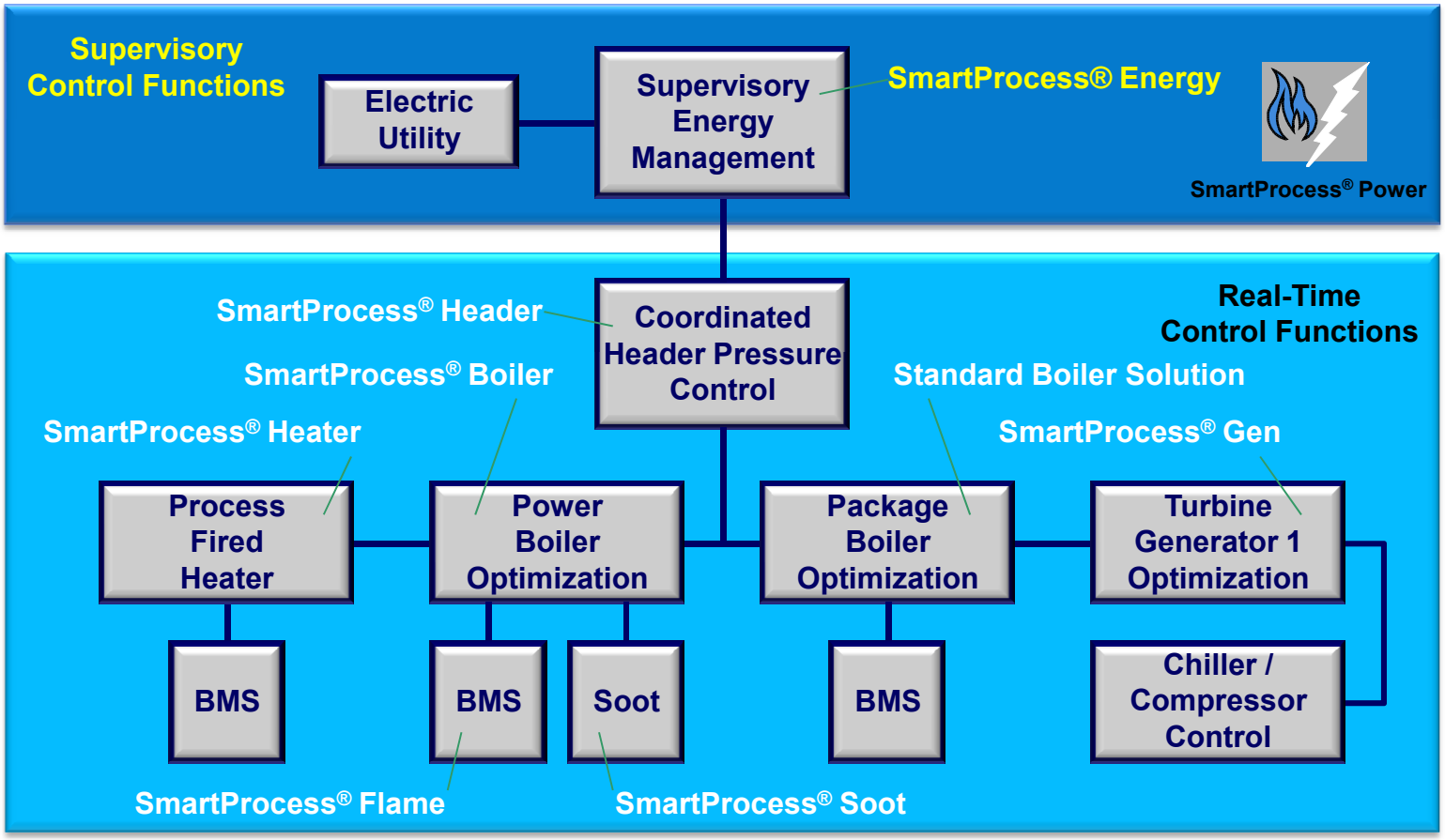
Traditional Graphic



Package BMS Solution



Energy Solutions - Combustion Control and Safe Firing



Note: SmartProcess intellectual property has patents pending

SmartProcess®

Emerson Solutions Deliver Results

- **Multi-Fuel Boiler / Fired Heater Control and Optimization**
  - 10-15% increased steam from waste/biomass fuel
  - 1-3% thermal efficiency improvement
- **Steam Header Control and Coordination**
  - Prevent cascade trips leading to total outages
  - Increase on-site electrical generation by 10-20%
- **Overall Powerhouse Energy Management Solution**
  - Manage overall utilities to decrease total cost 1-3%
  - Streamline operating manpower requirements and eliminate constant manual intervention
  - Precisely track energy usage and immediately identify unusual waste
- **Burner Management System**
  - Eliminate nuisance trips and simplify boiler start-up
  - Provide implementation per applicable codes
- **Soot blowing Control and Optimization**
  - Reduce quantity of steam used for cleaning
  - Improve cleaning results

Summary

- Energy is the largest controllable cost in process operations; Savings go directly to the bottom line.
- Efficient energy production and use are keys to profitability.
- Combustion processes typically consume 75% of a site's energy
- Implementation of a program to save energy requires a disciplined approach to evaluation and analysis.
- Automation is an effective way to achieve energy efficiency quickly and cost effectively.
- Emerson's holistic approach and combustion control solutions can deliver sustainable energy efficiency improvements.

Thank You

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