System optimization approach: capturing and sustaining energy savings and cost reduction in industry

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Outline of Presentation

- The importance of energy efficiency
- What is systems optimization?
- Component vs system approach to energy efficiency
- Why in industry a system approach matters
- Why systems optimization opportunities exist
- Examples of system optimization measures
- Conclusions

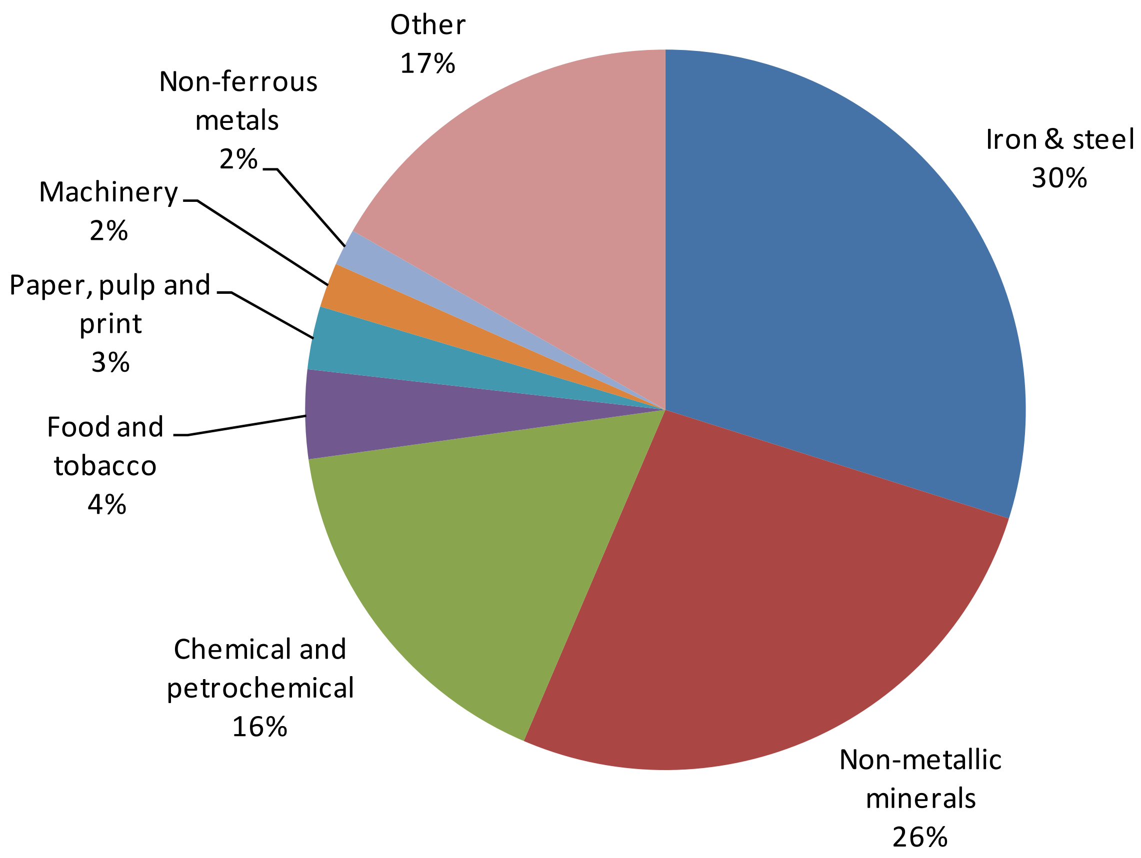
Importance of Industrial Energy Efficiency

- Represents more than *one-third* of global primary energy[1]
- Direct industrial energy and process CO2 emissions represent about *25% of total worldwide emissions* - 6.7 Gigatonnes[2]
- Application of best available technologies worldwide would result in a *19-32% reduction* in current industrial CO2 emissions[2]
  - Includes improvements to steam and motor systems, which offer efficiency improvements of 15-30%
  - Additional potential could be realized from renewable & alternative energy sources including combined heat and power (CHP)

1 Price, et al 2006

2 IEA 2008 Energy Technology Perspectives: Scenarios and Strategies to 2050 (excludes petroleum refining)

Global CO_2 Emissions by Industrial Sector



Source: IEA 2008

Industrial Energy Use in Emerging Economies

- Characteristics of Developing and Emerging Economies:
  - Industrial energy use can be up to *50%* of the total and can produce supply problems
  - Lead global growth in both industrial energy use and carbon-related emissions
  - Emerging industrial infrastructure requires many new facilities, rapidly built and expanded
  - Includes substantial growth in energy intensive sectors
- Better *build in energy efficiency* the first time rather than retrofit it later
- New and expanding plants represent a very significant opportunity.

Why optimize energy systems

- Identify and implement improvement opportunities
- Economic savings
- Energy savings
- Environmental savings
- Productivity, reliability and quality improvements
- Security of supply
- Reduce exposure to rising energy prices
- Baseline / Benchmark system operation

What is system optimization?

- Involves looking at the full system rather than individual components
- System examples:
  - Steam
  - Compressed air
  - Lighting
  - Pumping
  - Refrigeration, etc
  - Motors - very possibly not a system but a component!
- Example: fix air leaks before purchasing a more efficient compressor

Component v system approach

- Component approach involves segregating components and analyzing in isolation
  - Can result from education by particular technology sales engineer, e.g. variable speed drive, steam trap, etc
- System approach involves looking at how the whole group functions together and how changing one can help or impact another
  - Requires more knowledge of the system and its interactions
- The energy savings opportunities from systems are far greater than from individual components
  - 2-5 % efficiency gains for individual components

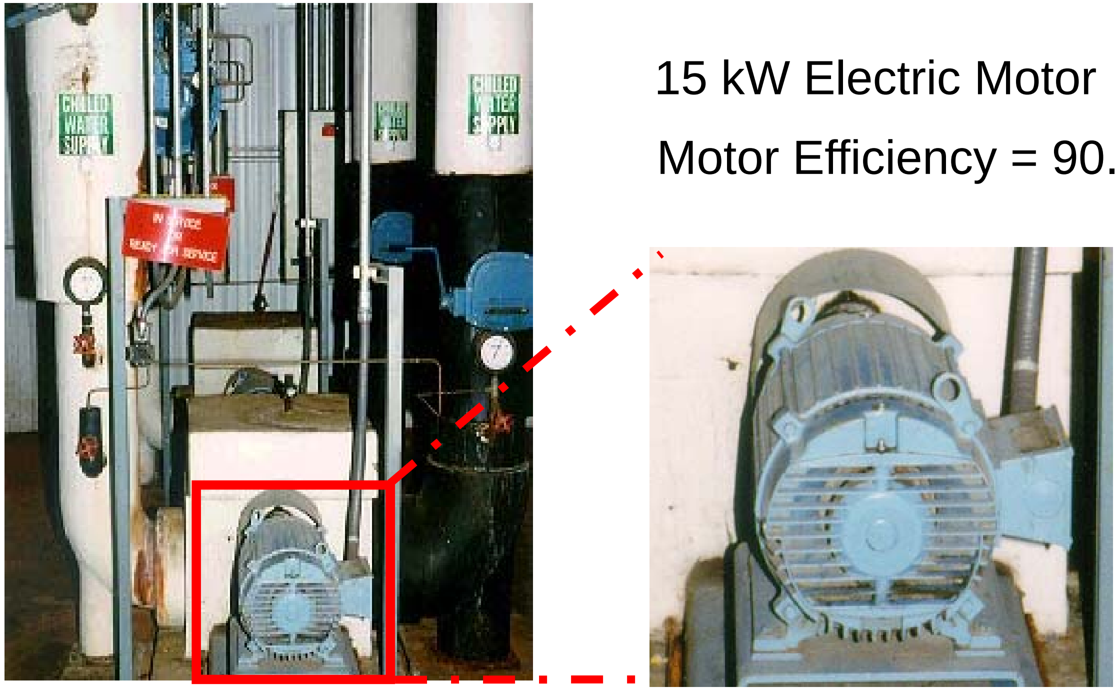
Why a system approach matters

- If approached randomly a boiler can often be optimized or tuned at, say, 70% of its output and then use is reduced and boiler is no longer efficient.
- Industrial operations are more variable than commercial or residential
  - Production schedules change
  - Utilities need to follow production but remain optimized.
  - Exception of heating/cooling systems in commercial operations
- Steam and motor-driven systems account for more than 50% of final manufacturing energy use worldwide
  - Motors drive systems include compressors, pumps, fans

Pump system example

Motor – Pump –Throttled Valve System

Motor



15 kW Electric Motor

Motor Efficiency = 90.6%

Motor rated hp	20
Shaft power, hp	19.6
Motor efficiency, %	90.6
Motor power factor, %	81.9
Motor current, amps	23.7
Electric power, kWe	16.2
Annual energy, MWhr	141.7
Annual cost, $1,000	7.7

Courtesy of Don Casada, Diagnostic Solutions, LLC

Pump system example

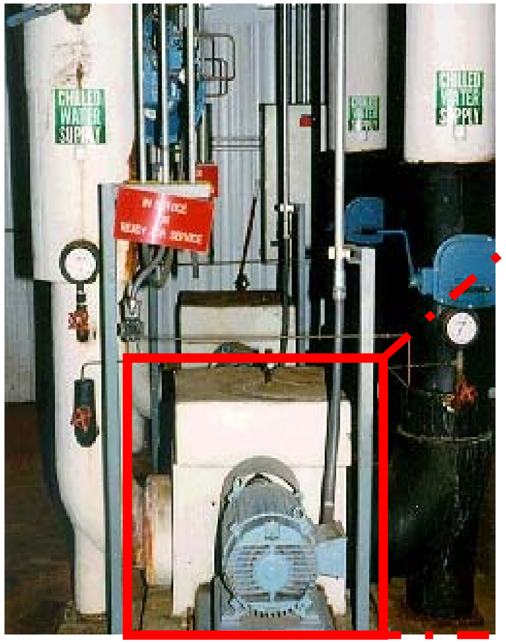
Motor – Pump –Throttled Valve System

Motor and Pump

Pump head: 36 m

Flow rate: 97.6 m^3/h

Hydraulic power delivered = 9.6 kW



Pump + Motor Efficiency

59%

Courtesy of Don Casada, Diagnostic Solutions, LLC

Pump system example

Motor – Pump –Throttled Valve System

Motor and Pump and System

Courtesy of Don Casada, Diagnostic Solutions, LLC

28 m pressure drop across the throttled valve

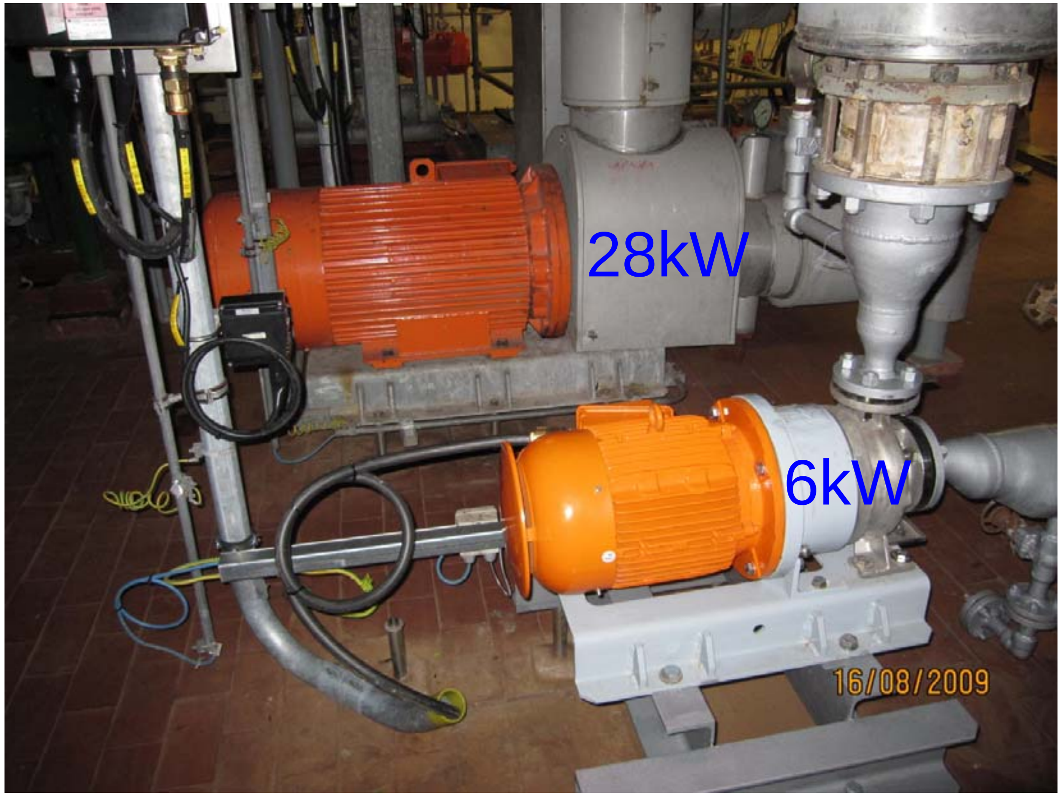
Useful hydraulic power = 2.1 kW

Actual System Efficiency = 13%

Replacing the existing motor with a more efficient one would accomplish very little

Other pump system example

1. Minimise user requirements
2. Shut bypasses
3. Determine actual usage
4. Reselect pump and motor
5. Replace 150m3/h with 25m3/h
6. Save 75% or 176 MWh p.a.



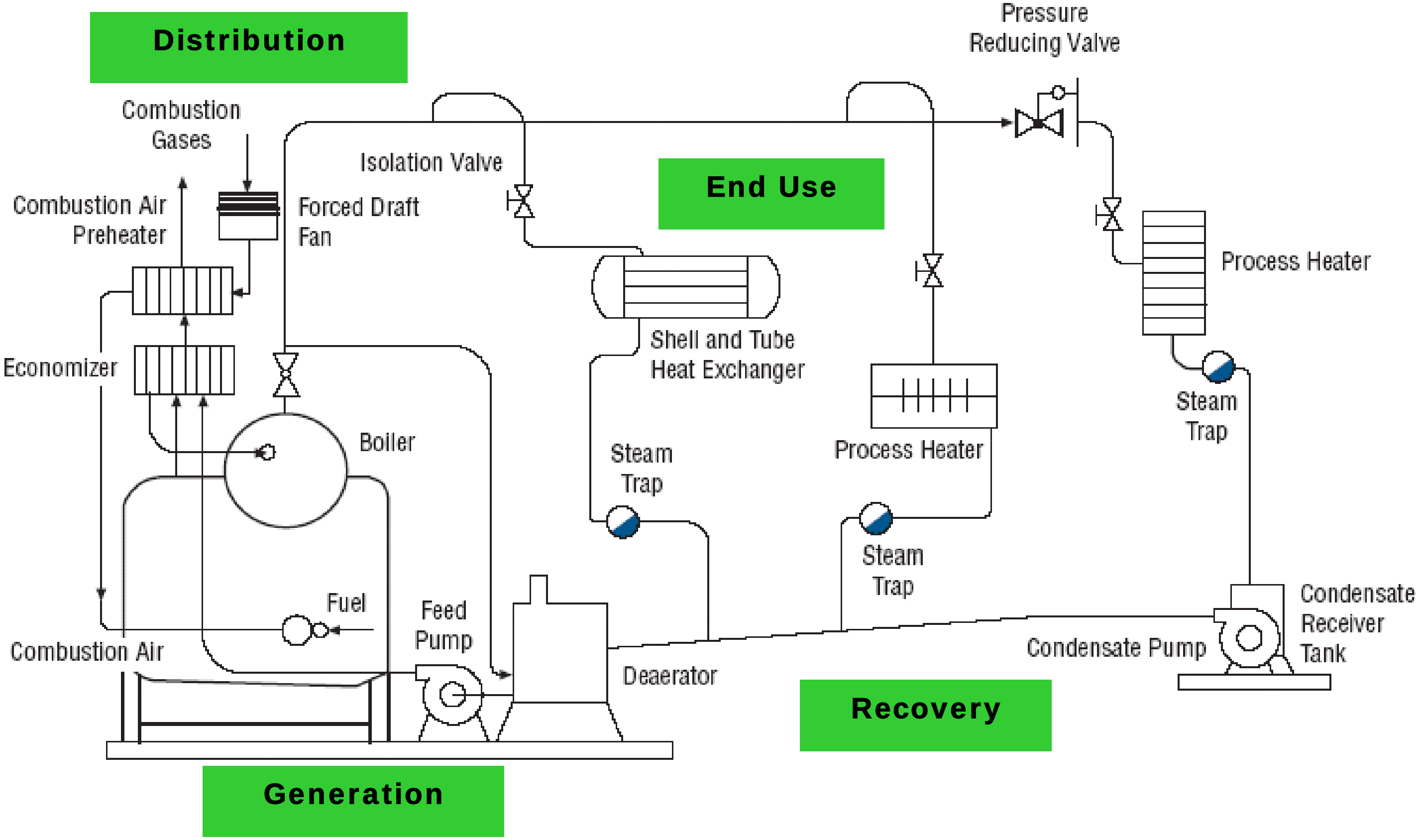
Why do system optimization opportunities exist?

- Most energy systems (steam, motor-driven, etc.) are initially designed with:
  - The assumption that “more” is better, where supply is concerned
  - Little or no thought given to system efficiency
  - No plan for increases or decreases in system demand
  - A “lowest first cost” goal
- Changes to existing systems face the same issues
- Improper operation
- Poor maintenance
- System requirements change over time

Typical System Optimization Process

1. What does the user need?
   - Consider variations, e.g. seasonal, occupancy, production schedules, etc.
2. Optimize use of the service
3. Optimise distribution of the service
4. Finally optimise generation of the service
   - Include how it is operated and maintained at each step

Steam system example

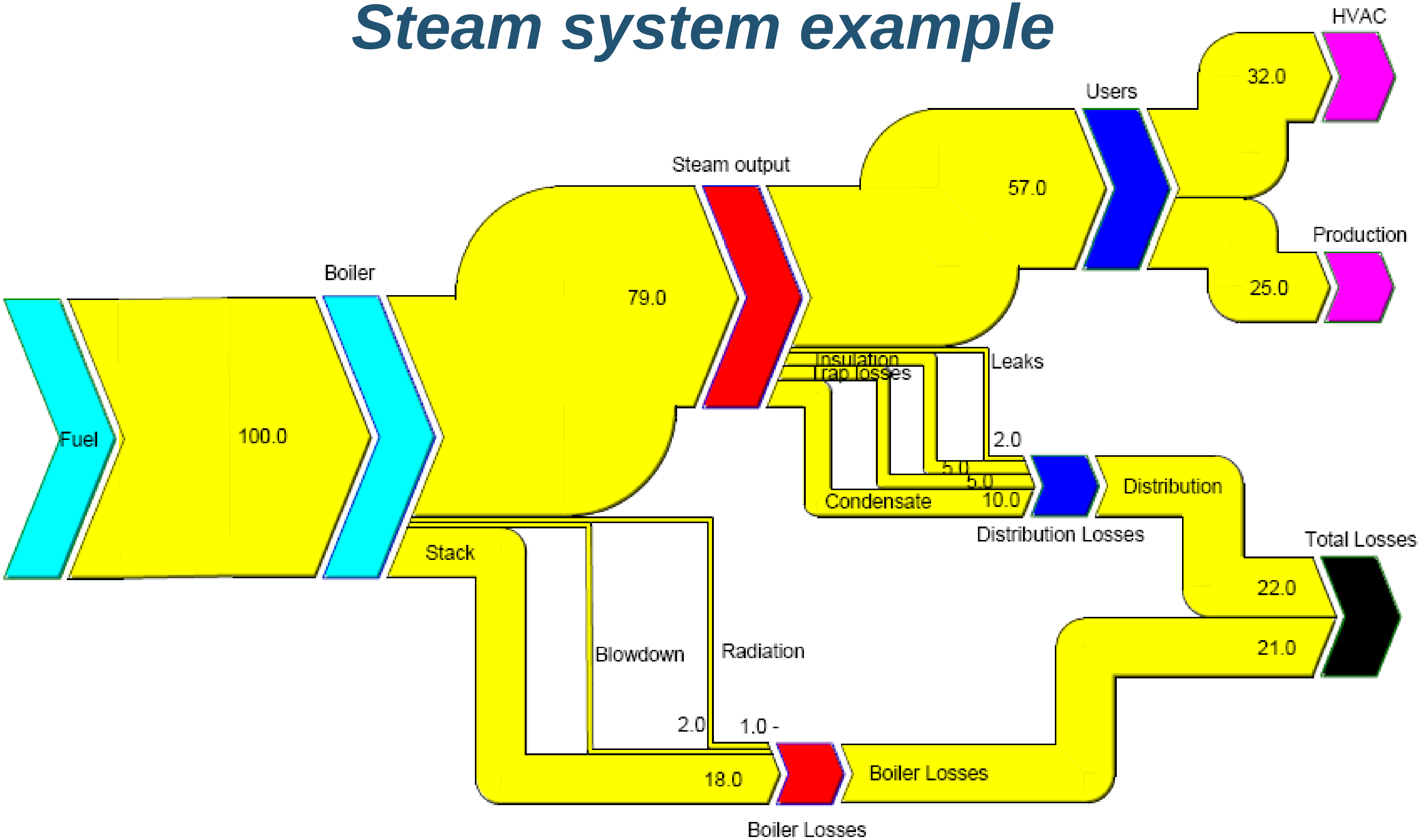


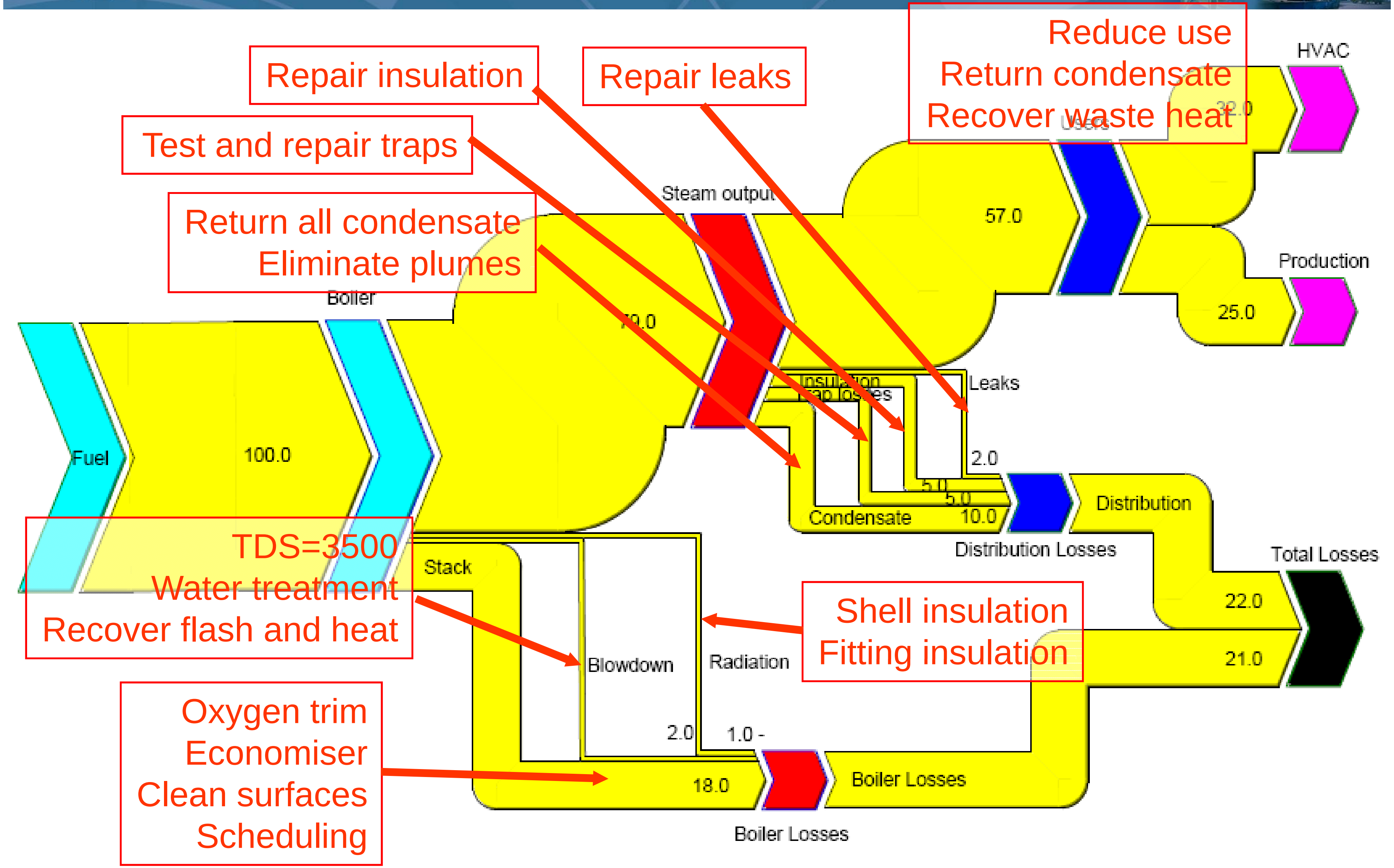
A boiler may have an operating efficiency of 85%, but if steam is being vented due to system balance issues then the overall system efficiency will be much lower

Steam system example

1. Is steam required at all?
   - Temperature, pressure, flowrate
   - Why use steam to heat air to 20°C?
   - Is waste heat available?
2. Reduce usage
   - Leaks, set points, switch off, isolate, heat recovery, PINCH analysis, etc.
3. Optimise distribution
   - Leaks, insulation, condensate recovery, flash steam, isolate unused sections, etc.
4. Optimise Generation
   - Boiler sequencing, control, blowdown, insulation, economizer, oxygen trim, etc.

Steam system example




Repair insulation
Repair leaks
Reduce use
Return condensate
Recover waste heat
Test and repair traps
Return all condensate
Eliminate plumes
HVAC
32.0
Users
57.0
Steam output
Production
25.0
Boiler
70.0
Fuel
100.0
Leaks
2.0
5.0
5.0
10.0
Condensate
Distribution
Distribution Losses
Total Losses
22.0
21.0
TDS=3500
Water treatment
Recover flash and heat
Stack
Blowdown
Radiation
Shell insulation
Fitting insulation
2.0
1.0 -
Oxygen trim
Economiser
Clean surfaces
Scheduling
18.0
Boiler Losses
Boiler Losses

Energy Efficient Design (EED)

- Confirm **real** user requirements first
  - Pressure, temperature, flow, humidity, air changes, etc.
  - Integrate with other systems, e.g. use waste heat for space heating
- Design in user optimization features
- Design distribution system to minimise losses
- Design and size generation equipment last
  - It is often purchased first due to longer lead times
  - Include best available technology (BAT) and control
- EED will often reduce capital cost
- Allow for future expansion only if realistically expected

Refrigeration system – R22 replacement

- Opportunity to review system
- Current load is ~ 1MW cooling (COP 2.1 @ -25°C)
- Review users
  - Temperature (-25°C to -15°C)
  - Flow reduced by 50%
  - Thermal leakage
- Generation
  - Smaller VSD compressor
  - Sub-cooling
  - Desuperheater
  - Oil cooler heat recovery
  - Improved control
  - Existing condenser and evaporator are now oversized - reduced temperature lift
- New COP = 2.4 >=> Savings ~ 15%

Engine Maintenance facility

- Brief was to specify new air compressor (75kW)
- System reviewed initially
- Detected and repaired leaks (25% reduction)
- Moved some users away from compressed air (20%)
- Split system into high and low pressures
- Eliminated pressure drop at filters
- Replaced dryers with heated type (17% air use)

Dairy industry

- PINCH analysis of heat/cool system
  - Thermocompression
  - Heat/cool recovery
- Boiler sequencing
  - Methane from waste treatment
  - CHP
  - Natural gas
- Cooling tower sequencing

Pharmaceutical plant - refrigeration

- 3 to 4 compressors of 4 running (250kW each)
- Needed to add capacity as no back up available
- System Review
  - Analysed use -very good data available
  - Rebalanced user building
  - Reset VSD controls on distribution pumps
  - Reset compressor sequencing
- Result: one compressor only on part load
- Savings: greater than 65% (>4 GWh p.a.)

Results – UNIDO in China

System / facility	Total Cost [$US]	Energy savings [kWh/year]	Payback Period
Compressed air/forge plant	18,600	150,000	1.5 years
Compressed Air/machinery	32,400	310,800	1.3 years
Compressed air/tobacco	23,900	150,000	2.0 years
Pump system/ hospital	18,600	77,000	2.0 years
Pump system/ pharmaceuticals	150,000	1.05M	1.8 years
Motor systems/ petrochemicals	393,000	14.1M	0.5 years

Notes

- Evaluate work requirements and patterns
- Match system supply to these requirements
- Identify, correct and upgrade maintenance problems
- Eliminate or reconfigure inefficient energy uses and practices (throttling, open blowing, etc)
- Replace or supplement existing equipment (boilers, motors, pumps, compressors) to better match work requirements and increase operating efficiency
- Apply relevant control strategies and technologies such as variable speed drives that allow greater flexibility to match supply with demand if it is variable
- Verify savings through measurement and estimation

Conclusions

- Use a Systems Approach to optimize industrial energy assets
- Measurement is a key factor for optimizing energy systems
  - You are not managing what you do not measure
  - If you do not manage you cannot save!
  - This is often achieved with standard instrumentation
- Complete a detailed energy assessment and identify near, mid and long-term opportunities
  - Develop an action plan
- Understand both the Utilities and Process side constraints
- System level integration between Utilities & Process leads to the state-of-the-art Best Practices operation

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Thank you

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