Introduction to Energy Management

CET CENTER FOR ECOTECHNOLOGY

We help people and businesses save energy and reduce waste

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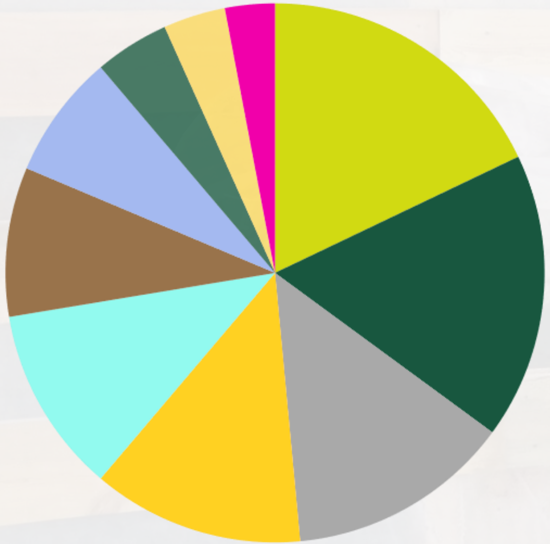
We make green make sense

Comprehensive Projects

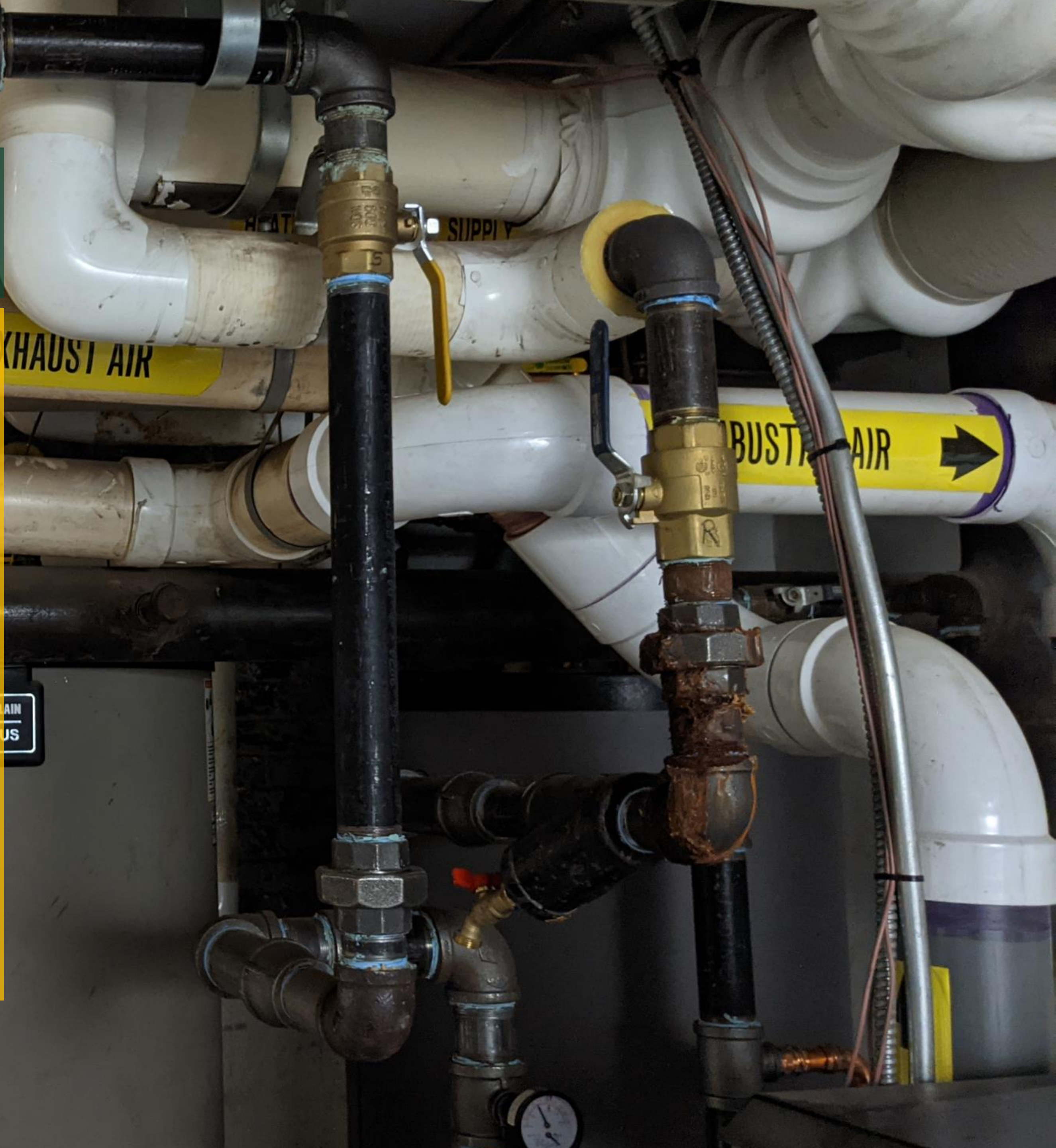


Installation Vendor Partnerships

- ACELA ENERGY GROUP
- ThermaXX jackets
- B-G Mechanical Contractors
- ANCHOR INSULATION
- JK energy solutions
- RES solar renewable energy systems, llc
- Stafford Mechanical Services, Inc. Heating & Cooling Contractors
- WILKINSON GEORGE T. WILKINSON, INC. ENERGY EFFICIENCY ENGINEERS®
- engie
- COLLINS & CO. A TruTeam Company
- Energia Your Local Energy Efficiency Experts EnergiaUS.com
- CET CENTER FOR ECOTECHNOLOGY
- ROGERS INSULATION SPECIALISTS
- Clark HVAC Services, LLC
- SIEMENS Ingenuity for life
- Midco, Inc. Mechanical Insulation Contractors
- Grodsky SINCE 1918
- McCormick - Allum Co. HVAC
- STEAM TRAP SYSTEMS Home Of The Triple Trap
- APM STEAM
- HDAIR® Hurley & David
- earthlight SOLAR AND ENERGY SOLUTIONS
- AEG ADVANCED ENERGY GROUP

What is Energy Management?

"The use of engineering and economic principles to control energy costs while providing needed services in buildings and industries."



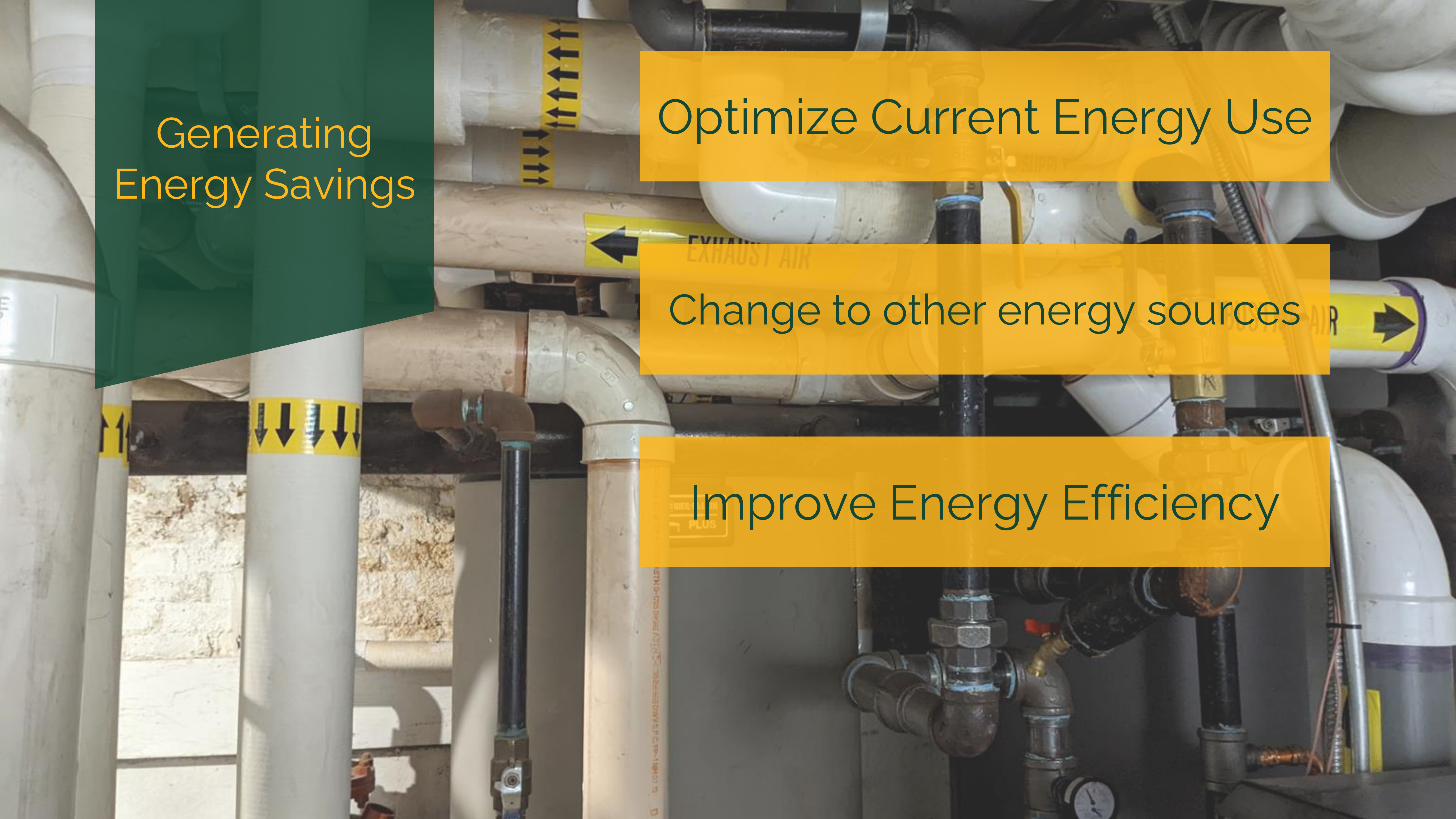
Energy Management

Understand Energy Usage

Conduct Energy Surveys

Create Cost-effective Improvements

Get Additional Help


Generating Energy Savings
Optimize Current Energy Use
Change to other energy sources
Improve Energy Efficiency
EXHAUST AIR

Benefits of Energy Improvement

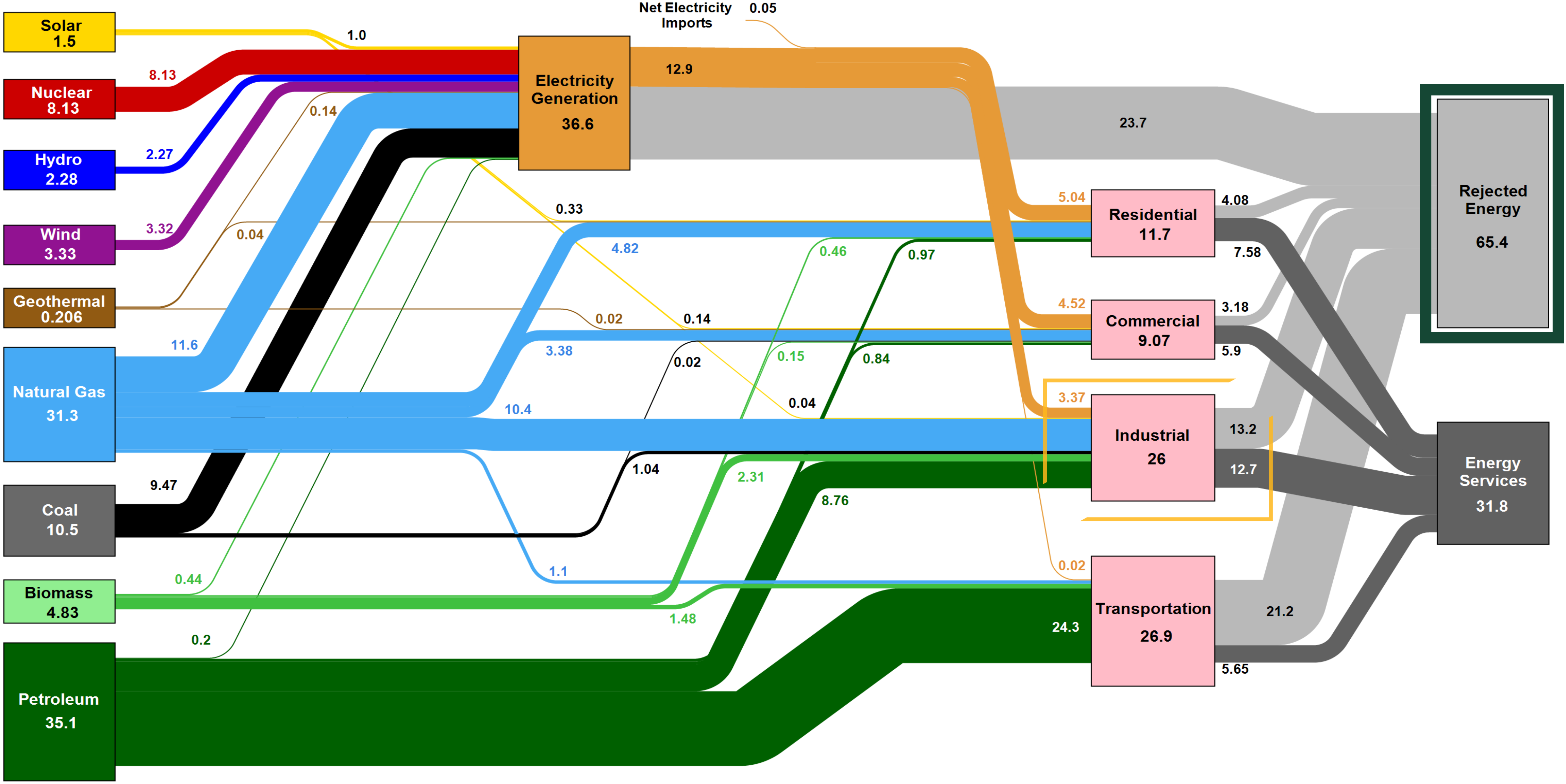
Lower Energy Bills

Lower CO_2 Emissions

Improve Safety & Efficiency


What percentage of energy produced in the U.S. is wasted?

Estimated U.S. Energy Consumption in 2021: 97.3 Quads



Source: LLNL March, 2022. Data is based on DOE/EIA MER (2021). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector and 49% for the industrial sector, which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Topics

What is Energy?

What is an Energy Audit?

Boilers & Steam Systems

Industrial Systems

Energy

Energy is defined as the amount of work (force x distance) that is done.

The standard unit for energy in the US is the British Thermal Unit (Btu).

1 Btu = The amount of energy required to heat one pound of water one degree Fahrenheit

Power

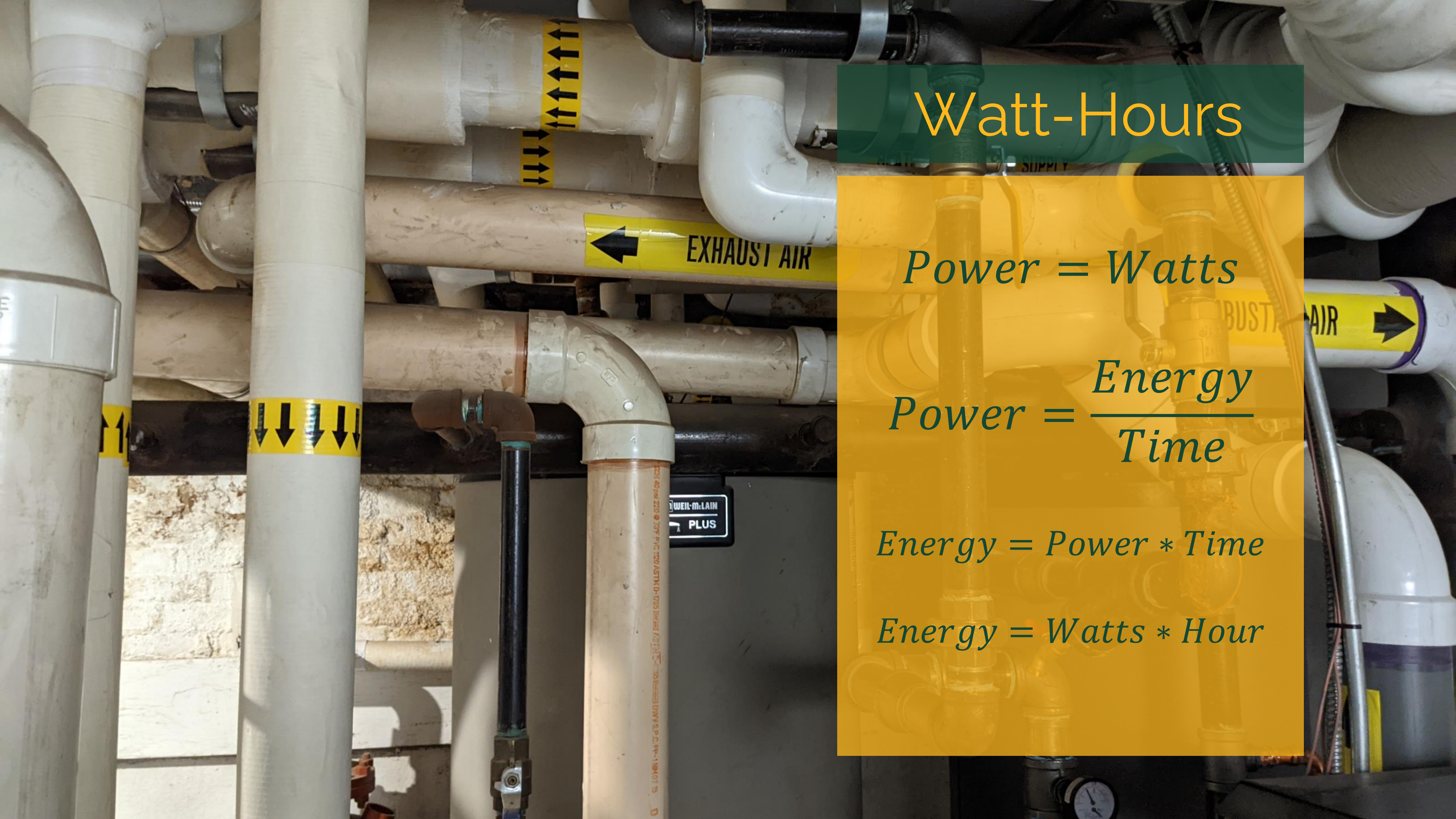
Power is the measure for how fast work is done.

The rate at which energy is used.

$$\text{Power} = \frac{Energy}{Time\ Required} = \frac{Btu}{hour} = MBH$$

Electrical Power is measured in Watts ($\frac{Joules}{second}$)


What is the unit for Electrical Energy?



Watt-Hours

$$Power = Watts$$

$$Power = \frac{Energy}{Time}$$

$$Energy = Power * Time$$

$$Energy = Watts * Hour$$

Energy or Power?

Energy and Power get confused very often.

Energy - The odometer tells us how far we've driven.
Power - The speedometer tells us how fast we're going.

Helpful Energy Conversion Units

1 Watt = 3.412 Btu/hr
1 kW = 1000 Watts
1 Electric HP = 746 Watts
1 cubic foot Natural Gas = 1MBtu = 1000 Btu
1 Ccf Natural Gas = 100 cubic ft natural gas
1 therm Natural Gas = 100,000 Btu
1 Gallon #2 Fuel Oil = 140,000 Btu

Energy Conversion Example

How many MBtu's are in 10 gallons of #2 fuel? (1 gallon = 140,000 Btu)

$$10\ \cancel{gallons} * \frac{140,\cancel{000}\ \cancel{Btu}}{1\ \cancel{gallon}} * \frac{1MBtu}{1,\cancel{000}\cancel{Btu}}$$
$$= 1,400\ MBtu$$

Practical Application

Point of Use (POU) cost depends on how expensive your energy is purchased for as well as how efficiently the equipment makes use of the fuel.

By converting different types of fuel to a common energy unit, we are able to compare fuels to one another.

The MMBtu (1,000,000 Btu) is the Common Unit.

Point of Use Example

A facility has a dual-fuel steam boiler that can operate using natural gas or #2 fuel oil.
Using natural gas purchased at $1.42 per therm, the boiler is 80% efficient
Using oil at $4.70 per gallon, the boiler is 75% efficient.

Which fuel source provides the lowest operating cost?
(1 Therm = 100,000 Btu. 1 Gallon Oil = 140,000 Btu)

Solution

$$Gas = \frac{\$1.42}{therm} * \frac{1\ Therm}{100{,}000 Btu} * \frac{1{,}000{,}000 Btu}{1 MMBtu} * \frac{1}{0.80} = \frac{\$17.75}{MMBtu}$$

$$Oil = \frac{\$4.70}{gallon} * \frac{1\ gallon}{140{,}000\ Btu} * \frac{1{,}000{,}000 Btu}{1 MMBtu} * \frac{1}{0.75} = \frac{\$44.76}{MMBtu}$$

One More Example

Calculate the POU cost per MMBtu for each:

Natural gas at $1.42 per therm. Efficiency of 75%

#2 Fuel oil at $4.71 per gallon. Efficiency of 80%

Electricity at $0.14 per kWh. Efficiency of 99%

(1 Therm = 100,000 Btu. 1 Gallon Oil = 140,000 Btu. 1kWh=3,412 Btu)

Energy Audits

Energy Audits

An Energy Audit is a method of surveying a facility to identify unoptimized systems and identify energy-saving opportunities.

The Hierarchy of Projects is

- Waste Elimination
- Low-Risk Projects (Improved Techniques)
- Major Conservation
- Major Capital Improvement Projects

Energy Audits

- Identify Significant Energy Users (SEU's)
- Identify Key Performance Indicators (KPI's)
- Identify Opportunities
- Quantify Opportunities
- Provide a roadmap for the Client


Which of these project types provide the best
Return on Investment (ROI)?

Typical ROI

Equipment Replacement (>20%)

Demand Side Management (>50%)

Conservation (>100%)

Energy Conservation

Energy Conservation generally includes Waste Minimization and Maintenance

Occupied Heating and Cooling Setpoints always in effect

Overridden Schedules

Missing Pipe Insulation

Bad Steam Traps

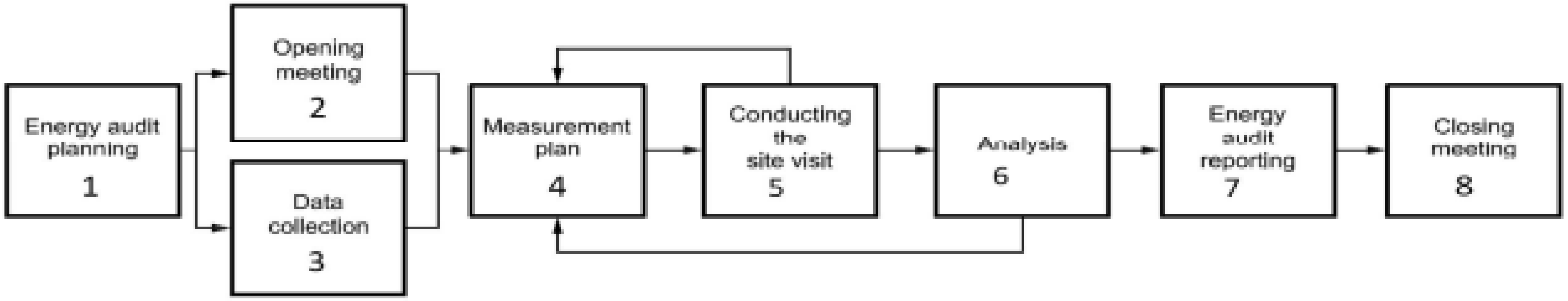
ISO 50001

- Globally applicable energy management standard
- Requires that top management must stablish, implement, and maintain an energy policy and provide funding for projects
- Designed to:
  - help companies better use their energy-consuming assets
  - evaluate and prioritize the implementation of energy-efficiency technology
  - promote efficiency throughout the supply chain

Energy Audit Process

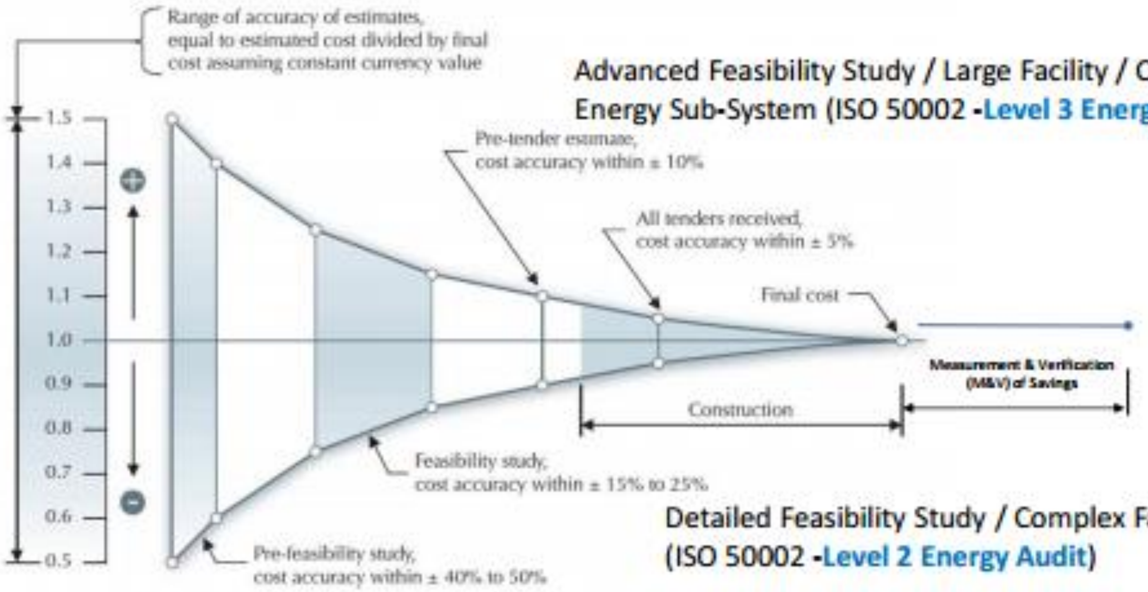
Energy Audit Process

ISO 50002 - Energy audit steps



Energy Conservation

Energy Audit Types



Advanced Feasibility Study / Large Facility / Complex Energy Sub-System (ISO 50002 -**Level 3 Energy Audit**)

Detailed Feasibility Study / Complex Facility (ISO 50002 -**Level 2 Energy Audit**)

Pre-Feasibility Study / Simple Facility (ISO 50002 -**Level 1 Energy Audit**)

Walkthrough

- Also known as an ASHRAE Level 1 Audit
- Site Visit with personnel on-site to gather data
- Identify Operation & Maintenance Issues
- Identify Low-Cost Energy Efficiency Measures (EEMs)
- Include Rough Estimates for Returns on Investment
- Identify Capital Projects

Analysis

- Also known as an ASHRAE Level 2 Audit
- Review O&M procedures qualitatively and in-depth
- Take measurements and collect data
- Provide an engineering study to produce a more detail savings & cost analysis.
- List potential capital-intensive improvements requiring further study

Simulation

- Also known as an ASHRAE Level 3 Audit
- Requires detailed and time-intensive field data gathering
- Provides detailed project cost and savings information
- Computer simulation is provided for hourly analysis of energy usage and impacts
- Present High, low, and most likely case assumptions.

Utility Offerings

Your utility provides no-cost energy assessments for your facilities.

Engineering studies are also incentivized, usually at 50-50.

CET can provide an ASHRAE Level 1 audit at no cost to you.

Boilers and Steam Systems

Benefit of Boilers

Boilers make use of water as a medium for heat exchange.

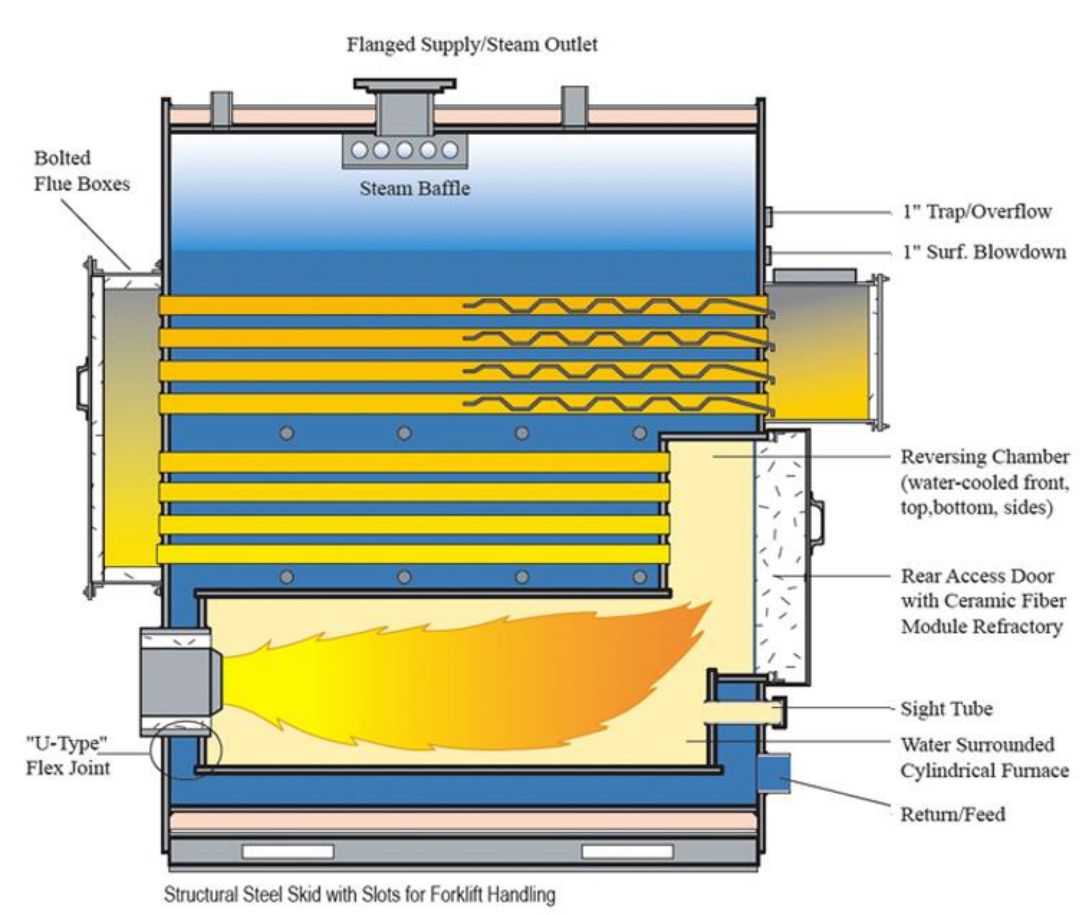
Water and steam have good heat transfer properties

Widely available and low cost

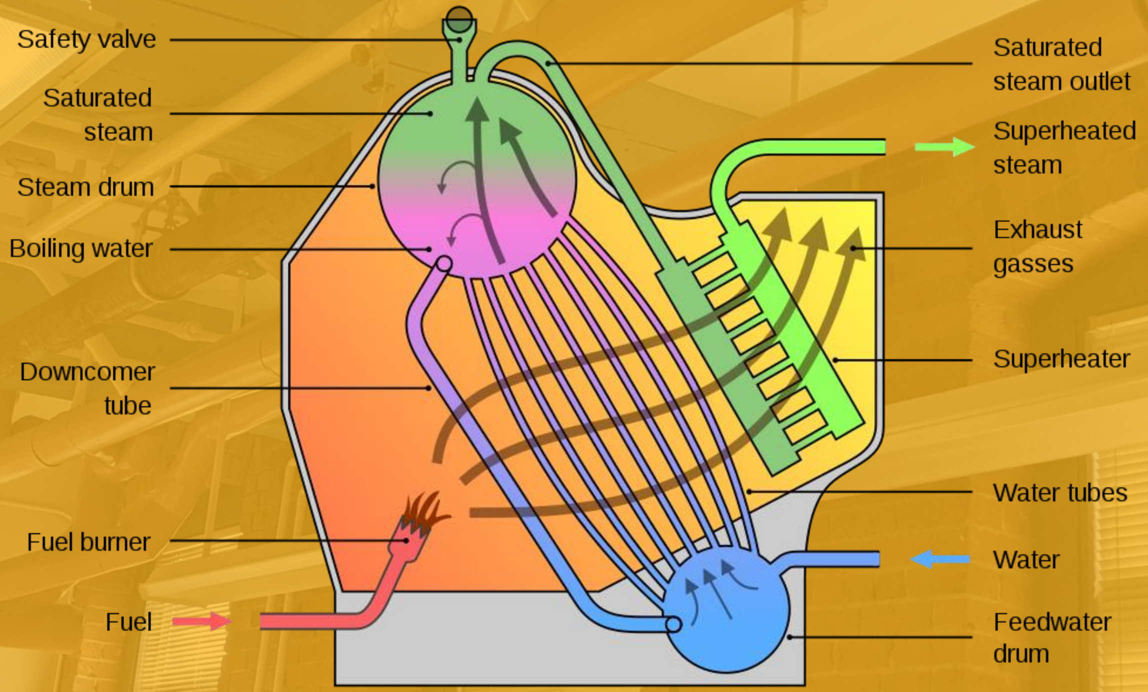
Clean, non-toxic, and generally safe

Good ability to control pressure and temperature

Fire-tube Boilers



Water-tube Boilers



Sizing Boilers

Boilers are sized based on their input and output.

Boiler input rate (**power**) is measured in MMBtu/hr

Boiler output rate is measured in horsepower.

1 Boiler HP = 33,475 Btu/hr

Horsepower

If a boiler is 80% efficient and uses natural gas at a rate of 10MMBtu/hr, what is its horsepower?

$$0.8 * \frac{10{,}000{,}000 BTU}{hr} * \frac{HP}{33{,}475 \frac{Btu}{hr}} = 239\ HP$$

What is the relationship between efficiency, input, and horsepower?

As efficiency increases, the necessary input for an equivalent HP decreases.

Combustion

Combustion is the chemical reaction by which heat is created and released.

Fuels get their energy production potential from hydrocarbons, which are molecules that contain carbon and hydrogen.

In an ideal reaction (stoichiometric) where there is exactly enough air to react with all the fuel:

$$CH_4 + 2O_2 + 8N_2 \rightarrow CO_2 + 2H_2O + 8N_2$$

Reality

Because there is always excess air in the reaction, there is excess O_2 exhausted out of the boiler.

The three T's of optimal combustion are: Time, Temperature, and Turbulence.

$$CH_4 + 2O_2 + 8N_2 \rightarrow CO_2 + 2H_2O + 4N_2 + heat + O_2 + NO_x + SO_x$$

Boiler Efficiency

Exhausted heat and excess air are two metrics by which boiler inefficiency can be measures.

As a rule of thumb, boiler efficiency increases by 1% for each 40° reduction in stack gas temperature or 15% reduction in excess air.

There are Combustion Efficiency Tables for different fuel types available.

% Excess			Stack Temperature Rise, °F																	
Air	O_2	CO_2	170	180	190	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340
0.0	0.0	11.8	86.3	86.1	85.9	85.7	85.5	85.3	85.1	84.9	84.7	84.5	84.2	84.0	83.8	83.6	83.4	83.2	83.0	82.8
2.2	0.5	11.5	86.3	86.1	85.9	85.6	85.4	85.2	85.0	84.8	84.6	84.4	84.1	83.9	83.7	83.5	83.3	83.1	82.8	82.6
4.5	1.0	11.2	86.2	86.0	85.8	85.6	85.3	85.1	84.9	84.7	84.5	84.2	84.0	83.8	83.6	83.4	83.1	82.9	82.7	82.5
6.9	1.5	11.0	86.1	85.9	85.7	85.5	85.2	85.0	84.8	84.6	84.4	84.1	83.9	83.7	83.5	83.2	83.0	82.8	82.6	82.3
9.5	2.0	10.7	86.1	85.8	85.6	85.4	85.2	84.9	84.7	84.5	84.2	84.0	83.8	83.6	83.3	83.1	82.9	82.6	82.4	82.2
12.1	2.5	10.4	86.0	85.7	85.5	85.3	85.1	84.8	84.6	84.4	84.1	83.9	83.7	83.4	83.2	83.0	82.7	82.5	82.3	82.0
15.0	3.0	10.1	85.9	85.7	85.4	85.2	85.0	84.7	84.5	84.2	84.0	83.8	83.5	83.3	83.0	82.8	82.6	82.3	82.1	81.8
18.0	3.5	9.8	85.8	85.6	85.3	85.1	84.8	84.6	84.4	84.1	83.9	83.6	83.4	83.1	82.9	82.6	82.4	82.2	81.9	81.7
21.1	4.0	9.6	85.7	85.5	85.2	85.0	84.7	84.5	84.2	84.0	83.7	83.5	83.2	83.0	82.7	82.5	82.2	82.0	81.7	81.5
24.5	4.5	9.3	85.6	85.4	85.1	84.8	84.6	84.3	84.1	83.8	83.6	83.3	83.1	82.8	82.6	82.3	82.0	81.8	81.5	81.3
28.2	5.0	9.0	85.5	85.2	85.0	84.7	84.5	84.2	83.9	83.7	83.4	83.2	82.9	82.6	82.4	82.1	81.8	81.6	81.3	81.1
31.9	5.5	8.7	85.4	85.1	84.9	84.6	84.3	84.1	83.8	83.5	83.3	83.0	82.7	82.4	82.2	81.9	81.6	81.4	81.1	80.8
35.9	6.0	8.4	85.3	85.0	84.7	84.4	84.2	83.9	83.6	83.3	83.1	82.8	82.5	82.2	82.0	81.7	81.4	81.1	80.9	80.6
40.3	6.5	8.2	85.1	84.9	84.6	84.3	84.0	83.7	83.4	83.2	82.9	82.6	82.3	82.0	81.7	81.5	81.2	80.9	80.6	80.3
44.9	7.0	7.9	85.0	84.7	84.4	84.1	83.8	83.5	83.3	83.0	82.7	82.4	82.1	81.8	81.5	81.2	80.9	80.6	80.3	80.0
49.9	7.5	7.6	84.8	84.5	84.2	84.0	83.7	83.4	83.1	82.8	82.5	82.2	81.9	81.6	81.3	80.9	80.6	80.3	80.0	79.7
55.3	8.0	7.3	84.7	84.4	84.1	83.8	83.5	83.1	82.8	82.5	82.2	81.9	81.6	81.3	81.0	80.7	80.4	80.0	79.7	79.4
61.1	8.5	7.0	84.5	84.2	83.9	83.6	83.2	82.9	82.6	82.3	82.0	81.6	81.3	81.0	80.7	80.4	80.0	79.7	79.4	79.1
67.3	9.0	6.7	84.3	84.0	83.7	83.3	83.0	82.7	82.3	82.0	81.7	81.4	81.0	80.7	80.4	80.0	79.7	79.3	79.0	78.7
74.2	9.5	6.5	84.1	83.8	83.4	83.1	82.8	82.4	82.1	81.7	81.4	81.0	80.7	80.3	80.0	79.7	79.3	79.0	78.6	78.3
81.6	10.0	6.2	83.9	83.5	83.2	82.8	82.5	82.1	81.8	81.4	81.1	80.7	80.3	80.0	79.6	79.3	78.9	78.5	78.2	77.8
89.8	10.5	5.9	83.6	83.3	82.9	82.5	82.2	81.8	81.4	81.1	80.7	80.3	79.9	79.6	79.2	78.8	78.4	78.1	77.7	77.3
98.7	11.0	5.6	83.4	83.0	82.6	82.2	81.8	81.5	81.1	80.7	80.3	79.9	79.5	79.1	78.7	78.3	78.0	77.6	77.2	76.8
108.7	11.5	5.3	83.1	82.7	82.3	81.9	81.5	81.1	80.7	80.3	79.9	79.4	79.0	78.6	78.2	77.8	77.4	77.0	76.6	76.2
119.7	12.0	5.1	82.7	82.3	81.9	81.5	81.1	80.6	80.2	79.8	79.4	78.9	78.5	78.1	77.7	77.2	76.8	76.4	75.9	75.5
132.0	12.5	4.8	82.4	81.9	81.5	81.0	80.6	80.2	79.7	79.3	78.8	78.4	77.9	77.5	77.0	76.6	76.1	75.7	75.2	74.8
145.8	13.0	4.5	82.0	81.5	81.0	80.6	80.1	79.6	79.1	78.7	78.2	77.7	77.3	76.8	76.3	75.8	75.4	74.9	74.4	73.9
161.5	13.5	4.2	81.5	81.0	80.5	80.0	79.5	79.0	78.5	78.0	77.5	77.0	76.5	76.0	75.5	75.0	74.5	74.0	73.5	73.0
179.5	14.0	3.9	81.0	80.4	79.9	79.4	78.8	78.3	77.8	77.2	76.7	76.2	75.7	75.1	74.6	74.0	73.5	73.0	72.4	71.9
200.2	14.5	3.7	80.3	79.8	79.2	78.6	78.1	77.5	76.9	76.4	75.8	75.2	74.7	74.1	73.5	72.9	72.4	71.8	71.2	70.6
224.3	15.0	3.4	79.6	79.0	78.4	77.8	77.2	76.6	76.0	75.3	74.7	74.1	73.5	72.9	72.3	71.7	71.0	70.4	69.8	69.2

Savings Calcs

Let's use a previous example to see how to calculate savings.

You have a gas-fired boiler with an input of 10MMBtu/hr that currently measures at 310° stack temperature rise and 11% Excess O_2

After maintenance, you measure 200° stack temperature rise and 2% Excess O_2

How much money are you now saving?

% Excess			Stack Temperature Rise, °F																	
Air	O_2	CO_2	170	180	190	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340
0.0	0.0	11.8	86.3	86.1	85.9	85.7	85.5	85.3	85.1	84.9	84.7	84.5	84.2	84.0	83.8	83.6	83.4	83.2	83.0	82.8
2.2	0.5	11.5	86.3	86.1	85.9	85.6	85.4	85.2	85.0	84.8	84.6	84.4	84.1	83.9	83.7	83.5	83.3	83.1	82.8	82.6
4.5	1.0	11.2	86.2	86.0	85.8	85.6	85.3	85.1	84.9	84.7	84.5	84.2	84.0	83.8	83.6	83.4	83.1	82.9	82.7	82.5
6.9	1.5	11.0	86.1	85.9	85.7	85.5	85.2	85.0	84.8	84.6	84.4	84.1	83.9	83.7	83.5	83.2	83.0	82.8	82.6	82.3
9.5	2.0	10.7	86.1	85.8	85.6	85.4	85.2	84.9	84.7	84.5	84.2	84.0	83.8	83.6	83.3	83.1	82.9	82.6	82.4	82.2
12.1	2.5	10.4	86.0	85.7	85.5	85.3	85.1	84.8	84.6	84.4	84.1	83.9	83.7	83.4	83.2	83.0	82.7	82.5	82.3	82.0
15.0	3.0	10.1	85.9	85.7	85.4	85.2	85.0	84.7	84.5	84.2	84.0	83.8	83.5	83.3	83.0	82.8	82.6	82.3	82.1	81.8
18.0	3.5	9.8	85.8	85.6	85.3	85.1	84.8	84.6	84.4	84.1	83.9	83.6	83.4	83.1	82.9	82.6	82.4	82.2	81.9	81.7
21.1	4.0	9.6	85.7	85.5	85.2	85.0	84.7	84.5	84.2	84.0	83.7	83.5	83.2	83.0	82.7	82.5	82.2	82.0	81.7	81.5
24.5	4.5	9.3	85.6	85.4	85.1	84.8	84.6	84.3	84.1	83.8	83.6	83.3	83.1	82.8	82.6	82.3	82.0	81.8	81.5	81.3
28.2	5.0	9.0	85.5	85.2	85.0	84.7	84.5	84.2	83.9	83.7	83.4	83.2	82.9	82.6	82.4	82.1	81.8	81.6	81.3	81.1
31.9	5.5	8.7	85.4	85.1	84.9	84.6	84.3	84.1	83.8	83.5	83.3	83.0	82.7	82.4	82.2	81.9	81.6	81.4	81.1	80.8
35.9	6.0	8.4	85.3	85.0	84.7	84.4	84.2	83.9	83.6	83.3	83.1	82.8	82.5	82.2	82.0	81.7	81.4	81.1	80.9	80.6
40.3	6.5	8.2	85.1	84.9	84.6	84.3	84.0	83.7	83.4	83.2	82.9	82.6	82.3	82.0	81.7	81.5	81.2	80.9	80.6	80.3
44.9	7.0	7.9	85.0	84.7	84.4	84.1	83.8	83.5	83.3	83.0	82.7	82.4	82.1	81.8	81.5	81.2	80.9	80.6	80.3	80.0
49.9	7.5	7.6	84.8	84.5	84.2	84.0	83.7	83.4	83.1	82.8	82.5	82.2	81.9	81.6	81.3	80.9	80.6	80.3	80.0	79.7
55.3	8.0	7.3	84.7	84.4	84.1	83.8	83.5	83.1	82.8	82.5	82.2	81.9	81.6	81.3	81.0	80.7	80.4	80.0	79.7	79.4
61.1	8.5	7.0	84.5	84.2	83.9	83.6	83.2	82.9	82.6	82.3	82.0	81.6	81.3	81.0	80.7	80.4	80.0	79.7	79.4	79.1
67.3	9.0	6.7	84.3	84.0	83.7	83.3	83.0	82.7	82.3	82.0	81.7	81.4	81.0	80.7	80.4	80.0	79.7	79.3	79.0	78.7
74.2	9.5	6.5	84.1	83.8	83.4	83.1	82.8	82.4	82.1	81.7	81.4	81.0	80.7	80.3	80.0	79.7	79.3	79.0	78.6	78.3
81.6	10.0	6.2	83.9	83.5	83.2	82.8	82.5	82.1	81.8	81.4	81.1	80.7	80.3	80.0	79.6	79.3	78.9	78.5	78.2	77.8
89.8	10.5	5.9	83.6	83.3	82.9	82.5	82.2	81.8	81.4	81.1	80.7	80.3	79.9	79.6	79.2	78.8	78.4	78.1	77.7	77.3
98.7	11.0	5.6	83.4	83.0	82.6	82.2	81.8	81.5	81.1	80.7	80.3	79.9	79.5	79.1	78.7	78.3	78.0	77.6	77.2	76.8
108.7	11.5	5.3	83.1	82.7	82.3	81.9	81.5	81.1	80.7	80.3	79.9	79.4	79.0	78.6	78.2	77.8	77.4	77.0	76.6	76.2
119.7	12.0	5.1	82.7	82.3	81.9	81.5	81.1	80.6	80.2	79.8	79.4	78.9	78.5	78.1	77.7	77.2	76.8	76.4	75.9	75.5
132.0	12.5	4.8	82.4	81.9	81.5	81.0	80.6	80.2	79.7	79.3	78.8	78.4	77.9	77.5	77.0	76.6	76.1	75.7	75.2	74.8
145.8	13.0	4.5	82.0	81.5	81.0	80.6	80.1	79.6	79.1	78.7	78.2	77.7	77.3	76.8	76.3	75.8	75.4	74.9	74.4	73.9
161.5	13.5	4.2	81.5	81.0	80.5	80.0	79.5	79.0	78.5	78.0	77.5	77.0	76.5	76.0	75.5	75.0	74.5	74.0	73.5	73.0
179.5	14.0	3.9	81.0	80.4	79.9	79.4	78.8	78.3	77.8	77.2	76.7	76.2	75.7	75.1	74.6	74.0	73.5	73.0	72.4	71.9
200.2	14.5	3.7	80.3	79.8	79.2	78.6	78.1	77.5	76.9	76.4	75.8	75.2	74.7	74.1	73.5	72.9	72.4	71.8	71.2	70.6
224.3	15.0	3.4	79.6	79.0	78.4	77.8	77.2	76.6	76.0	75.3	74.7	74.1	73.5	72.9	72.3	71.7	71.0	70.4	69.8	69.2

Savings Calcs

$$\frac{\$1.42}{therm} * \frac{1\,Therm}{100{,}000Btu} * \frac{1{,}000{,}000Btu}{1MMBtu} * \frac{10MMBtu}{hour} * \frac{1}{0.78} = \frac{\$182.05}{hour}$$

$$\frac{\$1.42}{therm} * \frac{1\,Therm}{100{,}000Btu} * \frac{1{,}000{,}000Btu}{1MMBtu} * \frac{10MMBtu}{hour} * \frac{1}{0.854} = \frac{\$166.28}{hour}$$

Approximately $15.77/hour in savings.

Assuming the boiler runs 16 hours a day, 6 days a week, that's $250/day, $1500/week, $78,750/year.

How to Reduce STR

- Clean the heat transfer surface
- Install sensible heat recovery
- Preheat incoming combustion air
- Ensure condensing boilers are condensing

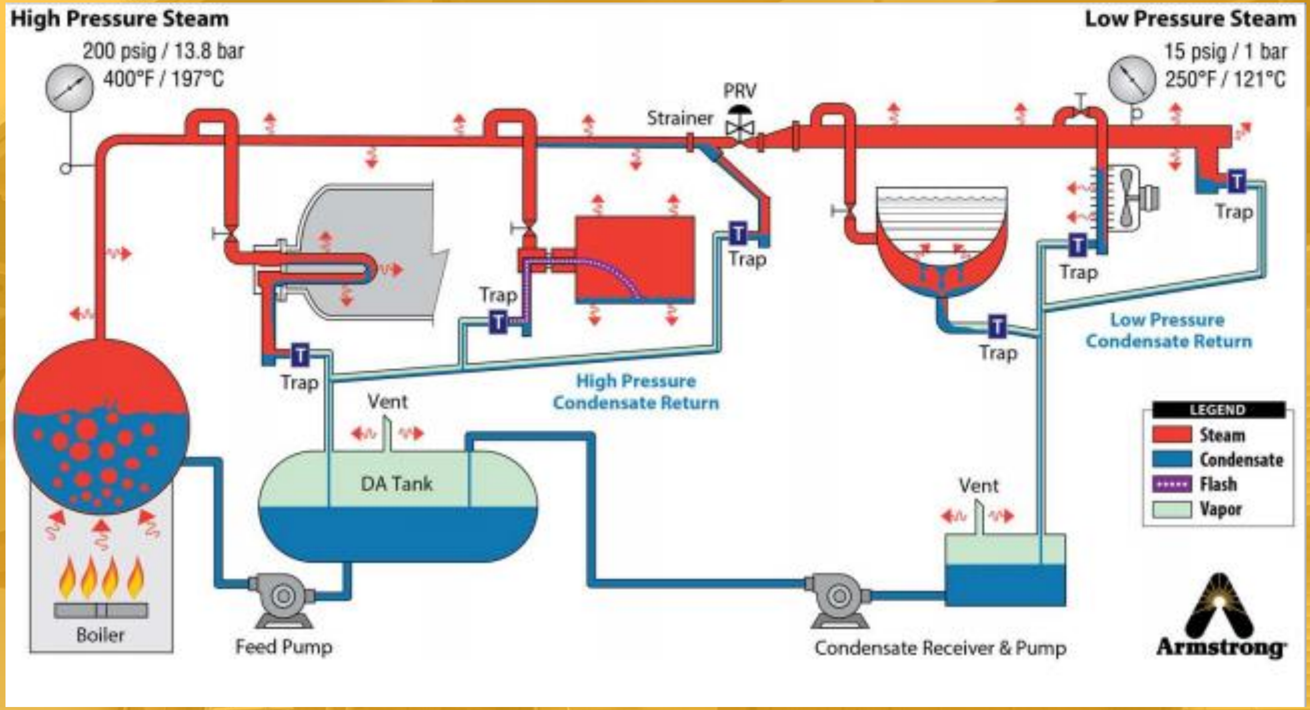
Condensing Boilers

Condensing boilers utilize condensing economizers which extract the available latent heat of the water vapor in the exhaust.

Due to the low exhaust temperature required for condensing to occur, the incoming water must be <100°F to recover heat.

Heat cannot be condensed if incoming water is >130°F

Steam Boiler System



Steam Trap Function

Remove Condensate to prevent water hammering and equipment damage.

Remove gases such as air and CO_2 that do not condense.

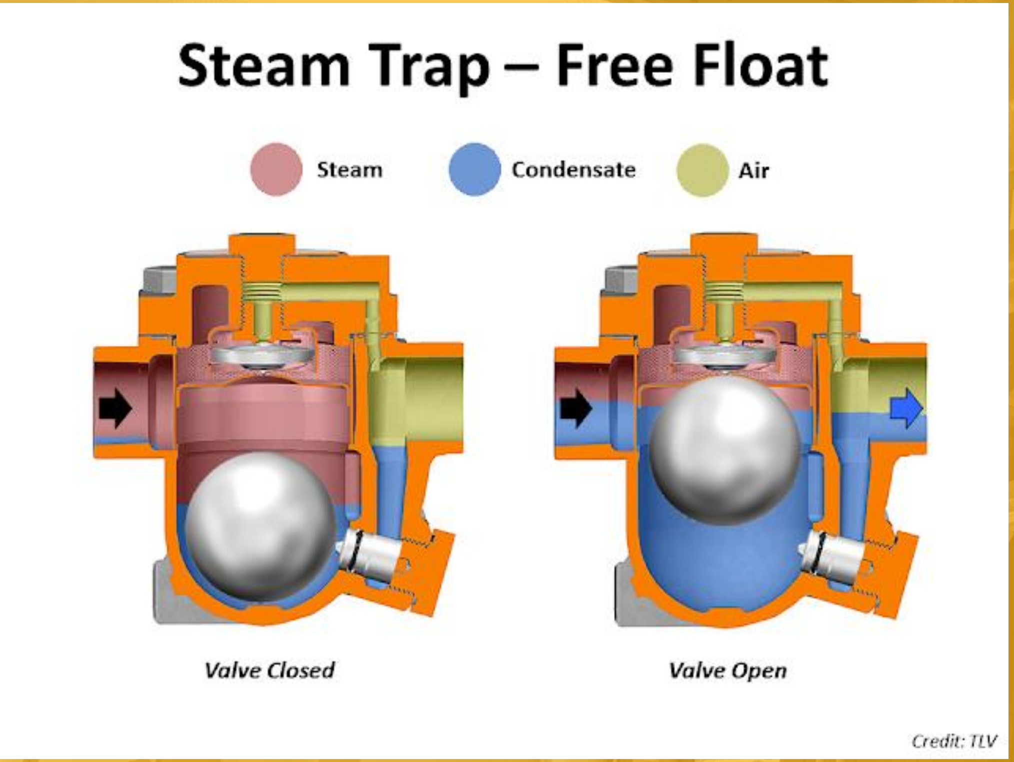
Retain dry steam.

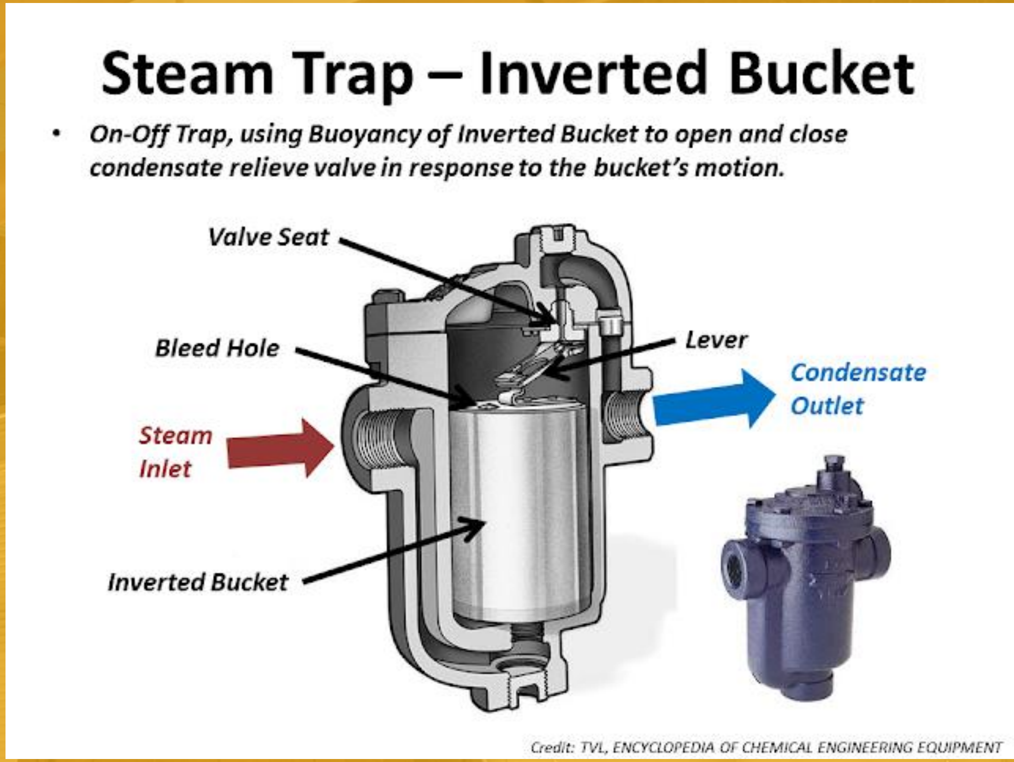
Traps fail open or closed.

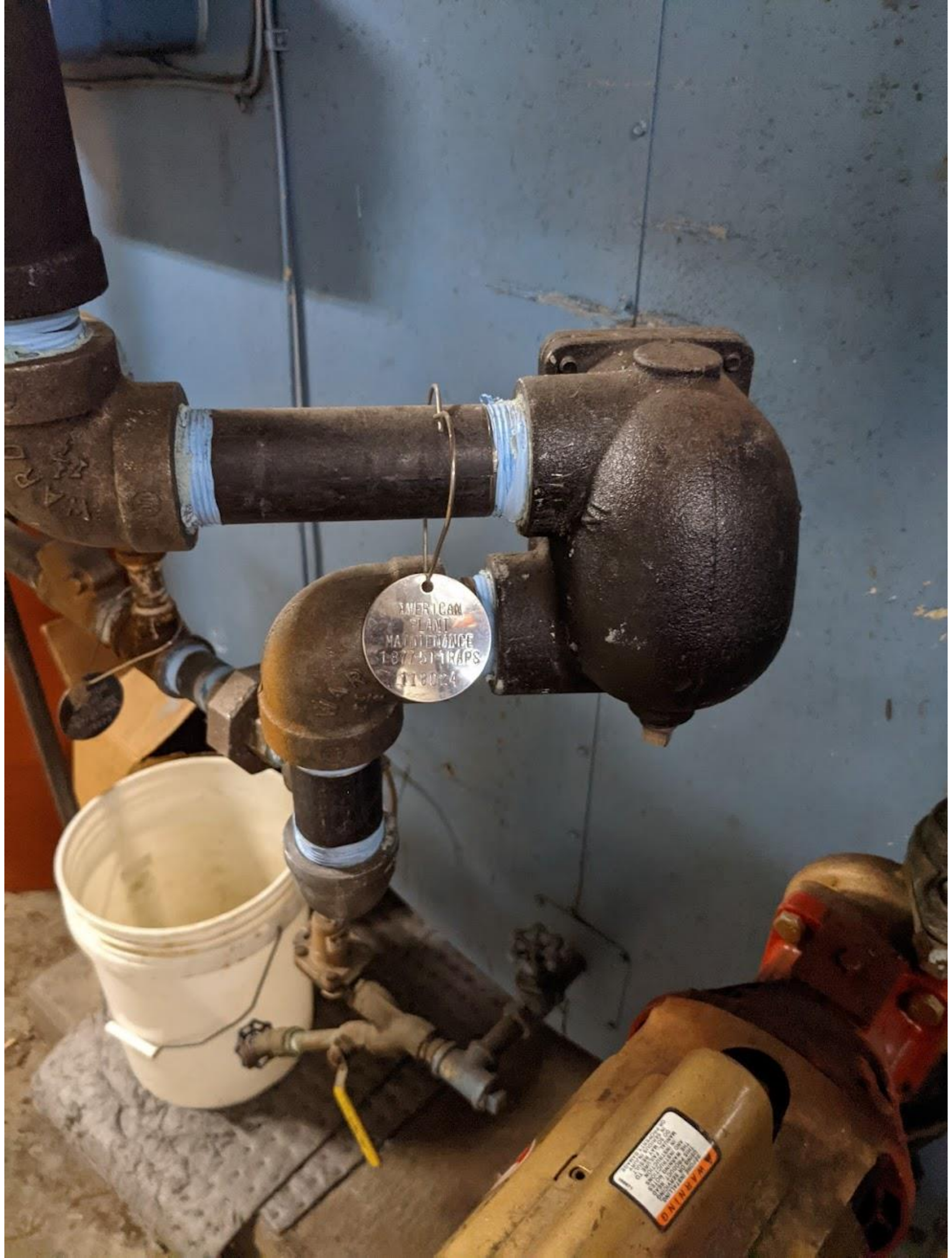
If they fail closed they are not removing condensate.

If they fail open, they are passing live steam.

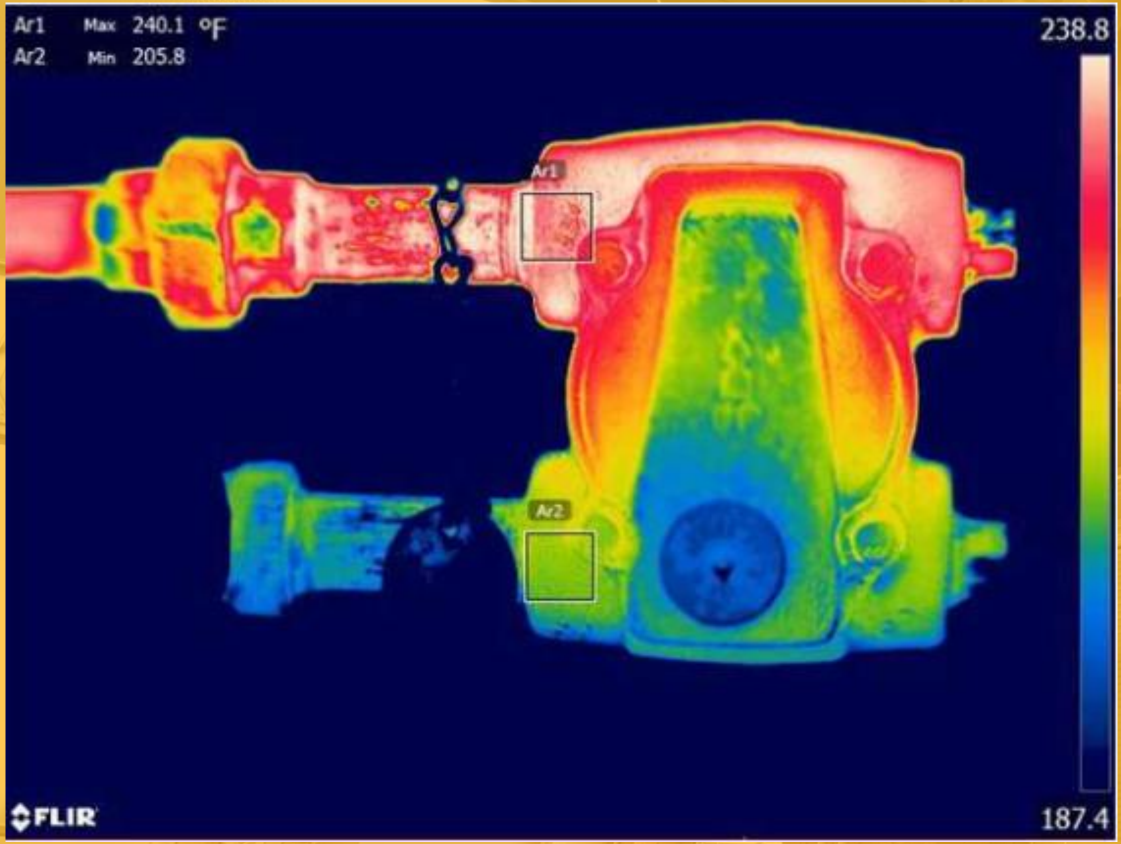
Steam Traps

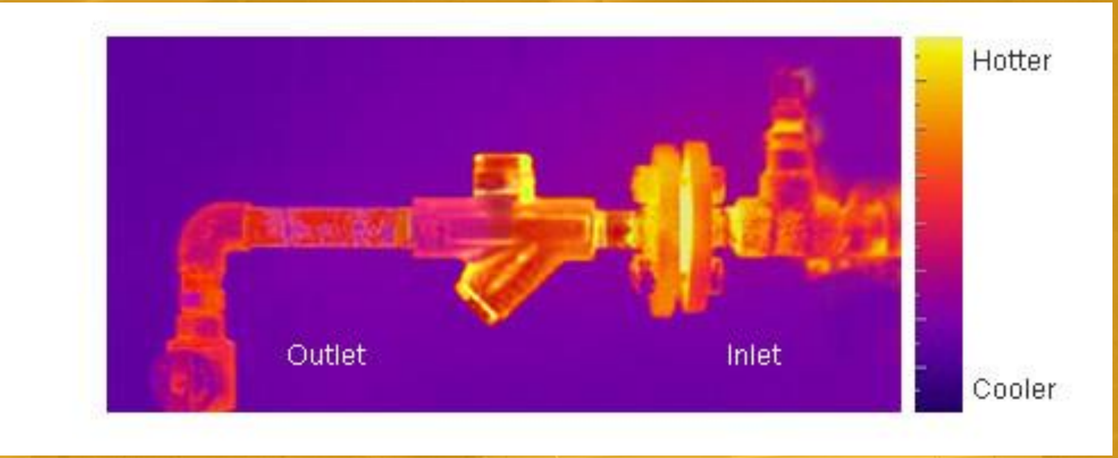

Steam Trap – Free Float
Steam
Condensate
Air
Valve Closed
Valve Open
Credit: TLV


Steam Trap – Inverted Bucket
• On-Off Trap, using Buoyancy of Inverted Bucket to open and close condensate relieve valve in response to the bucket's motion.
Valve Seat
Bleed Hole
Lever
Condensate Outlet
Steam Inlet
Inverted Bucket
Credit: TVL, ENCYCLOPEDIA OF CHEMICAL ENGINEERING EQUIPMENT


AMERICAN
PLANT
MAINTENANCE

Steam Traps


Ar1 Max 240.1 °F
Ar2 Min 205.8
238.8
Ar1
Ar2
FLIR
187.4


Hotter
Outlet
Inlet
Cooler


Industrial Systems

Pumps

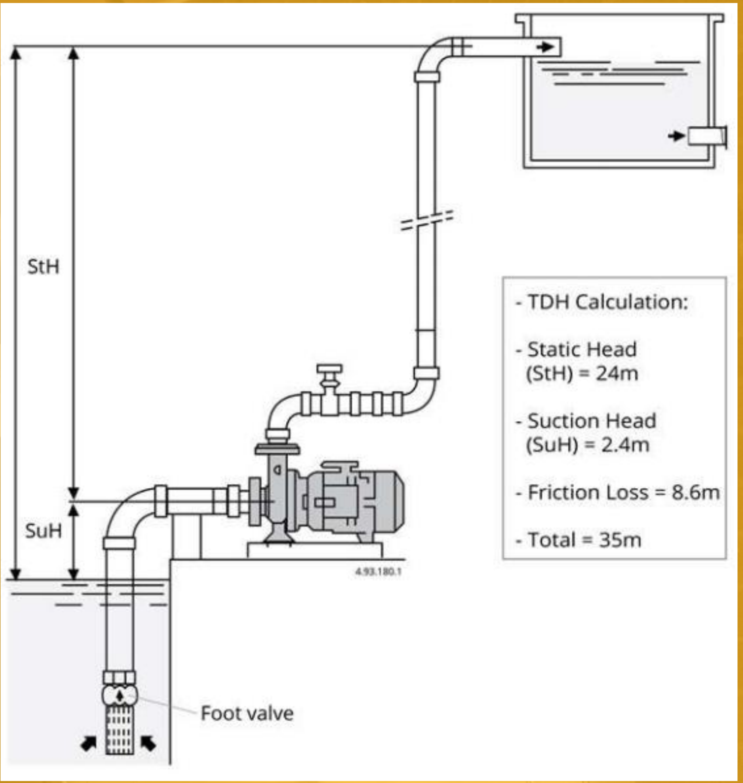
Pumps are usually oversized for the intended job and not managed well.

Installing a Variable Frequency Drive allows for savings to be had by throttling the power to adequately address the amount of flow.

Pump Equations

Brake Horse Power = Pressure * Flow

$$\frac{Head * GPM}{3960 * Pump\ Efficiency}$$



Optimizing Pumps

Use smaller pumps so unneeded capacity can be switched off.

If you hear a noise like the pump is pumping gravel, raise the suction liquid level or lower the pump.

Reduce pipe resistance by checking the losses at valves, elbows, and strainers, and determine what is providing increased resistance.

Compressed Air

Compressed air systems are used for pneumatic tools, conveyors, packaging, and a lot of production equipment.

Non-Flammable & High-Torque

Most systems are about 20-25% efficient, so seek substitutes when possible.

Reciprocating

- Smaller than 15 HP
- Up to 50 psig
- Used for small buildings and controls

Rotary Screw

5-500 HP

25-150 psig

Used for medium manufacturing

Compressed Air

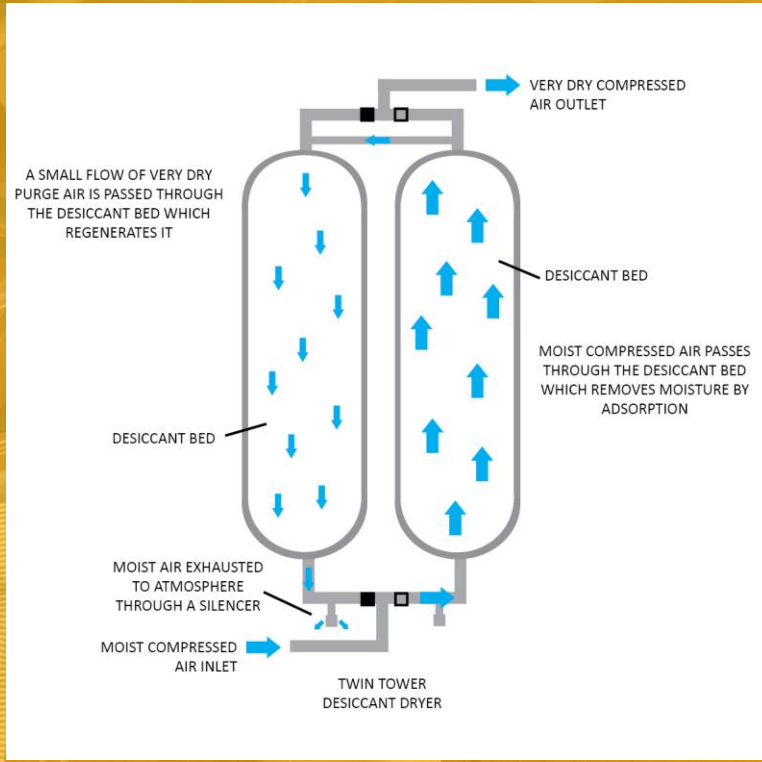
125-5000HP

125-10000psig

Used for large manufacturing

Compressed Air

Compressed air systems require a lot of electricity to keep the air dry and flowing.



Receiver Tanks

Function like a shock absorber and act as a buffer for pressure.

Prevents cycling of load/unload compressors.

Can be located before the dryer, after the dryer, throughout the plant, and at equipment that require large loads.

Saving Energy

1. Eliminate compressed air needs
2. Fix Compressed Air Leaks
3. Reduce Excess Pressure
4. Improve Controls
5. Intake outside air & reject waste heat
6. Replace Equipment

Saving Energy

Poor usages of compressed air can be substituted with more energy-efficient options.

Open Blowing/Drying → Engineered Nozzles

Aerating a liquid → Low Pressure Blowers or Mixers

Air Motors → Electric Motors

Saving Energy

	Losses From Compressed Air Leaks (kWh/yr) via SI and Imperial Units					
Leak Hole Diameter mm (in)	*Air Pressure in bar (psig)*					
	4 (58)	*5 (72)*	*6 (87)*	*7 (102)*	*8 (116)*	*9 (131)*
1 (0.04)	900	1,300	1,600	2,000	2,400	2,900
2 (0.08)	3,700	5,100	6,500	8,100	9,700	11,500
3 (0.12)	8,400	11,400	14,600	18,200	21,900	25,900
6 (0.24)	33,700	45,500	58,600	72,700	87,700	103,500
9 (0.35)	75,800	102,400	131,800	163,600	197,400	232,800

Sources- Woodroof, E., Mazzi, E. (2019), "Maintenance OutPerforms Wall Street by 10x", Buildings Magazine, Feb 2019; & the 2012 Compressed Air and Gas Handbook, Chapter 8, Table 8.21 and Table 8.25, Compressed Air and Gas Institute, for a 2-stage compressor and using orifice coef. of 0.6.

Saving Energy

Determine what pressure is needed to operate plant tools and make that pressure.

Each 2 psi of pressure reduction reduces compressor energy consumption by 1%

Isolate systems that absolutely require higher pressure with smaller dedicated compressors

Saving Energy

- Clean your intake filters
- Minimize unnecessary discharges
- Investigate operation strategies such as start-stop, load/unload, and sequencing of compressors
- Program a pressure set-back during times that you know the air isn't needed.

Saving Energy

Relocate air intakes to cooler positions*	
Air Intake Temp, °F	Power Savings**, %
30	7.5
50	3.8
70	0
90	(3.8)
110	(7.6)

*MD Oviatt and RK Miller, Industrial Pneumatic Systems, Fairmont Press, 1981, p. 49.

** Relative to 70ºF

Saving Energy

85%-90% of compressor input energy is lost as heat.

A fully loaded 100 HP compressor generates about 250 MBH.

For each HP, assumed 2500 Btu/hr is available to recover.

Waste Heat Recovery

Waste heat is almost always all around you in an industrial facility. To harvest it, it must be

- High Quality
- Near a location where it can be reused
- Be created when it can be used elsewhere.

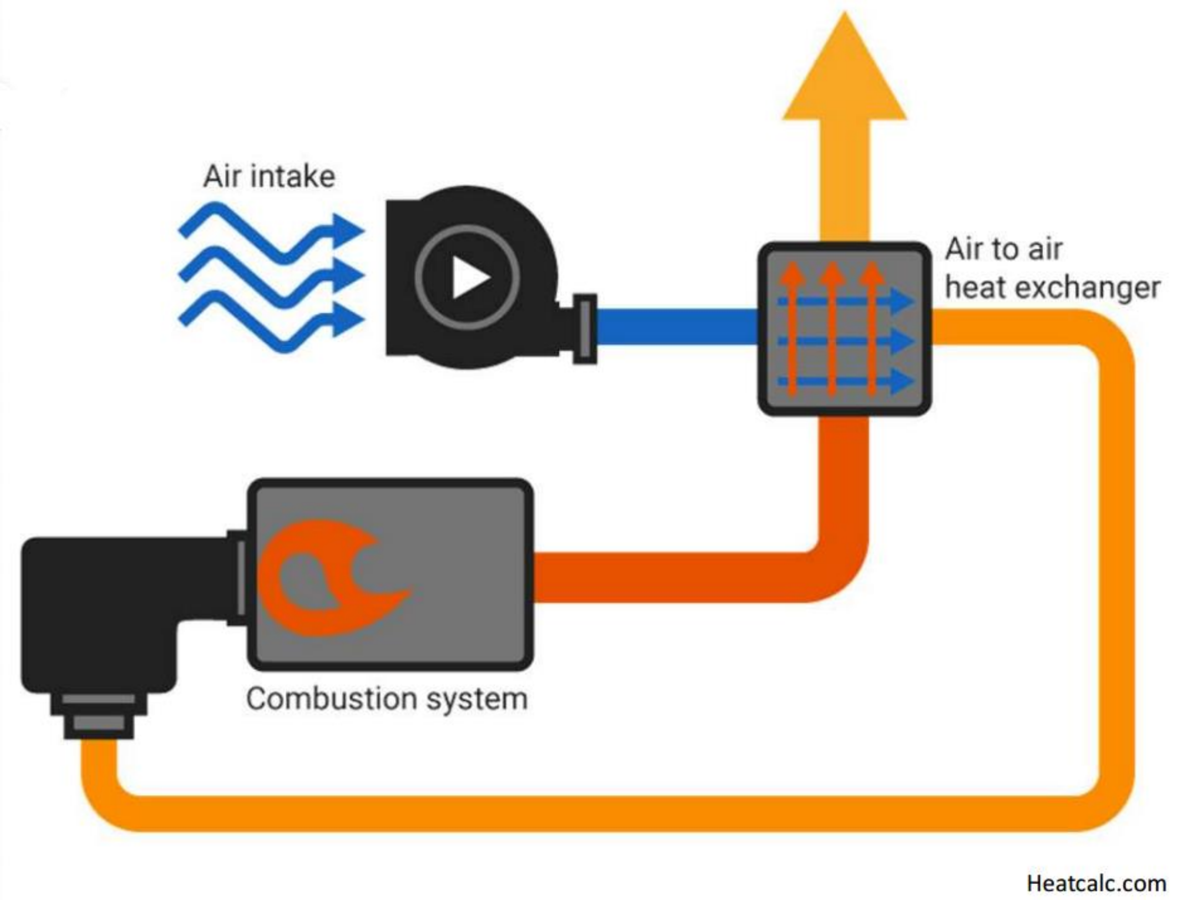
Waste Heat Sources

- Combustion flue gas
- Lost condensate
- Heat of compression from compressors
- Waste combustibles
- Condensing water

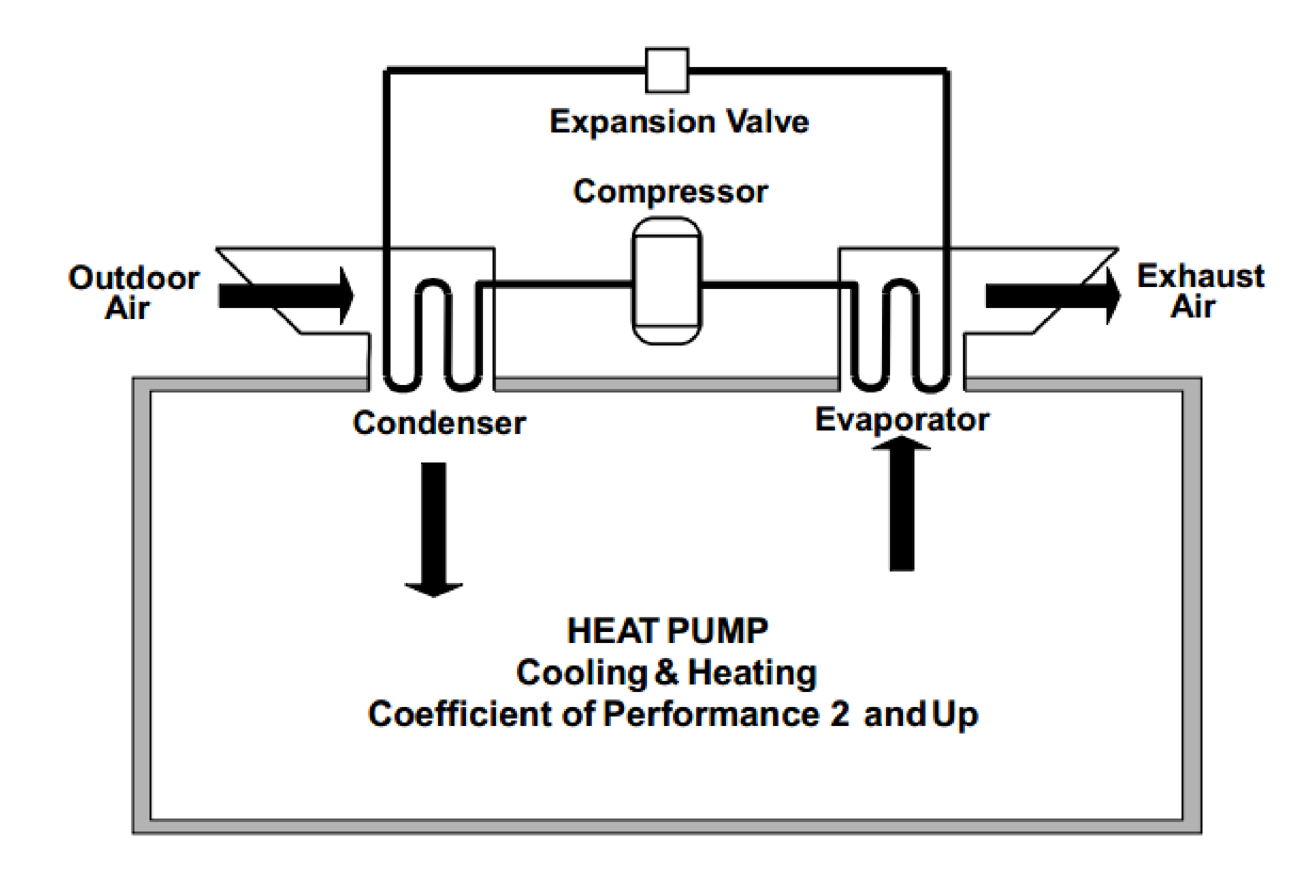
Waste Heat Uses

- Preheat combustion air or boiler feed water
- Preheat process flow
- Space heating
- Domestic Hot Water Heating

Air to Air


Air intake
Air to air
heat exchanger
Combustion system
Heatcalc.com

Heat Pump


Expansion Valve
Compressor
Outdoor Air
Exhaust Air
Condenser
Evaporator
HEAT PUMP
Cooling & Heating
Coefficient of Performance 2 and Up

Liberal Arts College

Solar hot water, steam traps, DI, steam trap jackets, controls, boiler replacement

125K Therms
$1.1M Total
$225K Incentive

Local Hospital

Pipe insulation

34K Therms
$126K Total
$126K Incentive

z

Local Hospital

DI and burner replacement

10K Therms
$75K Total
$21.8K Incentive

z

Questions?

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centerforecotechnology.org

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