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Energy Efficiency Best Practice Guide

Steam, Hot Water and Process Heating Systems

Sustainability Victoria

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1 Introduction

This document is a step-by-step guide to improving energy efficiency in boilers, steam systems, hot water systems and process heating and achieving best practice that will lead to benefits for your business. There are several questions and issues covered by this guide, including:

- What are the basis components of industrial steam, hot water and process heating systems?
- How can I tell if the system is functioning efficiently?
- What are the areas where systems can be improved to operate more efficiently?
- What energy source should I use?

By following this guide, you will be able to determine what changes can be made to improve the operation and performance of equipment, reduce operating costs and improve environmental outcomes. The guide has been developed to lead decision makers and service providers through system changes; it is not intended to be a thorough technical guide. References for more detailed technical information are provided.

2 The business benefits of steam system, hot water system and process heating system efficiency

Steam, hot water and process heating are all essential resources of many industries. They often provide convenient, reliable and cost effective energy with which to undertake the processes that are fundamental to your business. As such an indispensable tool, there are great benefits to be gained from running these systems at their optimum efficiency, providing the best performance, safety and energy efficiency possible.

Figure 1 illustrates that the cost of energy consumption in a steam system is almost the entirety of the system's cost (based on data for boilers with a high rate of capacity utilisation over a 20-year life). It makes good business sense, therefore, to run an energy-efficient system.

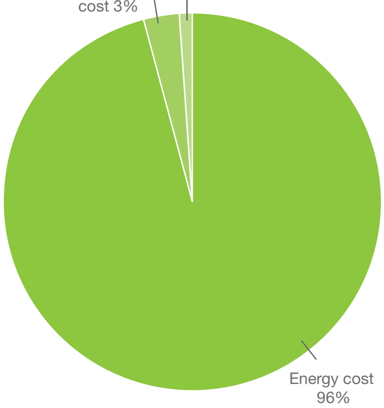


Figure 1: Typical lifecycle costs of a steam system.[1]

Not only is energy cost a large part of the overall cost of owning a steam system, but steam generation systems in the US typically account for 34% of all energy used in production.[1] In addition, process heating systems can account for 17% of total industrial energy use.[2]
In the UK, up to one third of all energy consumption is used to heat water.[3] These statistics show that running an energy-efficient steam, hot water or process heating system will greatly improve your business' energy consumption, bringing benefits both for your bottom line and the environment.

3 What is your opportunity?

Delivering the best outcomes for your business requires a whole systems approach to the design, installation, operation and maintenance of your steam, hot water or process heating system.

Defining the limitations of your current system is the key to finding the best solution to achieving energy efficiency for your business:

- How do I make my existing system more efficient?
- Do I need some new system components?
- How do I expand my existing system?
- What do I need to know to install a new system?

This guide offers step-by-step solutions to help you identify the opportunities to implement best practice to achieve energy efficiency of your steam system, hot water system or process heating system.

Solution 1: Improve the efficiency of your existing system
Is your steam, hot water or process heating system fulfilling needs but could run more efficiently? Perhaps your system is struggling to meet the plant needs at particular times of the day or week? This process may only involve a small investment, but can provide significant savings and costs.

Solution 2: Design a new system
If you are planning a new steam, hot water or process heating system, this process outlines the steps required to ensure you achieve excellent design and to help you understand where to spend your valuable capital.

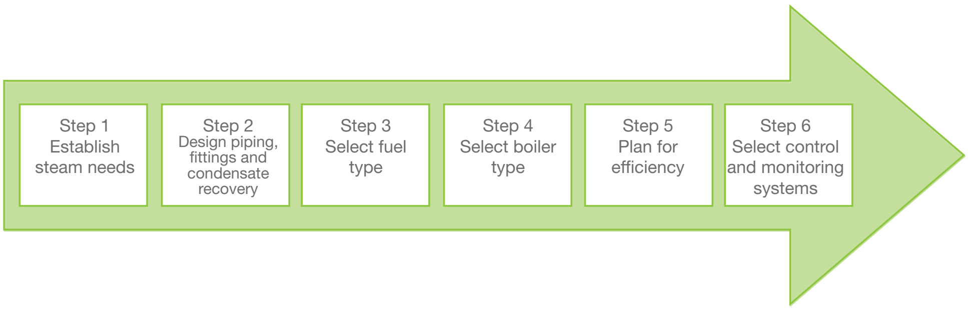
If your requirements have changed, for example, if there have been significant upgrades to the process plant or equipment, you may need to install more efficient equipment or expand your current system. This will involve elements of both solutions. Firstly, ensure your existing system is running efficiently (Solution 1) and secondly, design the new components of the expanded system (Solution 2). Following this process will ensure that you are not wasting money purchasing more than you actually need. Additionally, information gained from reviewing efficiency may guide the selection and design of the new components of the system.

4 Steam systems

4.1 Solution 1: Improve the efficiency of your existing system

There are many practical and proven methods for improving the efficiency of your existing steam system, and it is important to choose the ones appropriate to your circumstances.

A suggested process to follow for improving the efficiency of your steam system is summarised as follows:



4.1.1 Step 1: Review how you use steam

The first step to improving your steam system is to review how you use steam and why you need it. Ask yourself the following questions for each of your processes that use steam:

- What pressure, temperature and flow does it require?
- How do these requirements match with your steam supply conditions?
- Could you lower the temperature of your steam supply?
- Could you use another source of heat, such as waste heat from another process or piece of equipment?
- Can you alter the times at which steam is needed in order to create a more constant load at the boiler?
- Could you use steam storage and therefore a smaller boiler?
- Is steam being used for unsafe or inappropriate uses, such as heating water directly (the energy and cost spent in treating the steam is then lost as compared to returning the condensate)?
- Is the steam use very small and the distance from the boiler large?

Your steam system may not be meeting your needs efficiently, in which case a steam service provider can be consulted to suggest how your system may be improved. Request that they take a systems approach and keep your business needs in mind.

4.1.2 Step 2: Review boiler efficiency

Heat and energy losses in a typical packaged boiler can be illustrated by the following diagram, along with typical energy saving initiatives.

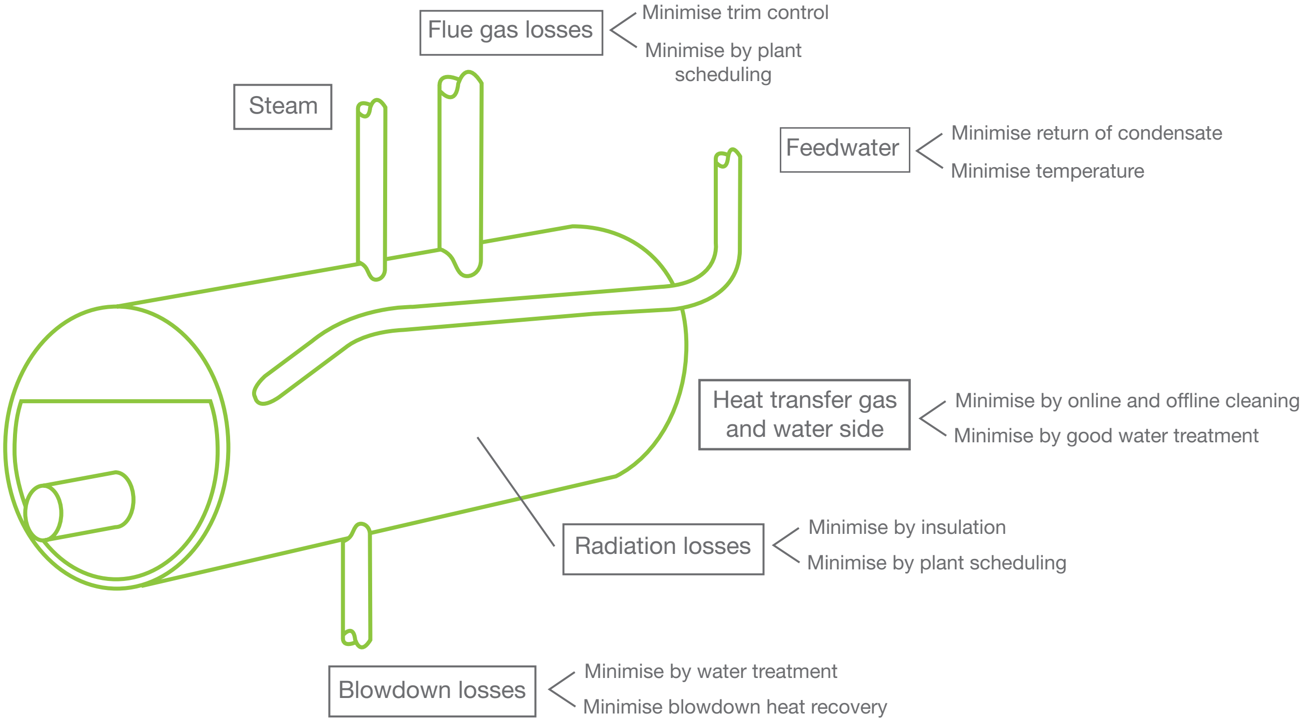


Figure 2: Typical boiler losses for a shell boiler.[4]

Opportunities for efficiency improvement are therefore related to reducing losses in these areas. Table 1 illustrates some boiler energy efficiency improvements and the expected energy saving potential.

Table 1: Some quantified energy saving opportunities for boilers.[4]

Technique/ Method	Energy Saving Potential
Improved operation and maintenance of boilers	Up to 5%
Improved water treatment and boiler water conditioning	Up to 2%
Total dissolved solids (TDS) control and boiler blowdown	Up to 2%
Blowdown heat recovery	Up to 3.75%
Boiler and burner management systems, digital combustion controls and oxygen trim	Up to 5%
Variable speed drives (VSDs) for combustion air fans	–
Flue gas shut-off dampers	Up to 1%
Economisers	Up to 5%
Combustion air pre-heating	Up to 2%

Note: Individual energy savings measures are not usually cumulative, and doing one will reduce the potential savings of another.

Key steps to improving boiler efficiency[5]

1. Improve operation and maintenance

The first step to running a more energy-efficient boiler is to measure its current efficiency as a baseline and determine if its efficiency is within a good operating range as compared to the boiler specifications.
With some simple measurements of steam temperature and pressure, feedwater temperature and pressure, steam flow rate and fuel consumption rate you can accurately determine boiler efficiency.

Secondly, you could investigate the boiler shell for hot spots. The presence of boiler hot spots can indicate an unhealthy boiler. Hotspots can lead to accelerated deterioration of boiler parts and a decrease in efficiency and performance of the boiler. Techniques such as infrared imaging can be used to detect hot spots.

2. Investigate opportunities for feedwater quality improvement

Improving the feedwater quality will lead to a decreased blowdown rate and other benefits throughout the steam distribution system. However, any opportunity that will require higher energy or cost in treating the water should be carefully evaluated against boiler blowdown energy losses to ensure the lowest energy and lowest cost solution is found.

3. Determine boiler blowdown rate (% of feedwater flow, kg/h)

Boiler blowdown is an important part of maintaining boiler performance. Too frequent and you are wasting high value energy; too infrequent and you risk the steam quality and boiler condition. Determine the optimum blowdown rate based on the energy and cost required for blowdown compared with water treatment costs, and then consider automating it based on acceptable concentrations of total dissolved solids (TDS).

4. Investigate blowdown heat recovery opportunities

The blowdown water contains significant energy that can be recovered. Two main methods are used. Flash steam is created when blowdown occurs and if the blowdown stream is directed to a flash steam vessel, the flash steam can be recovered for low-pressure steam applications or sent to the de-aerator. Blowdown water from either the blowdown stream or the liquid drain of the flash steam vessel could also be used to pre-heat feedwater (or other water) using a heat exchanger. Since the water has a high concentration of dissolved solids, the heat exchanger should be resistant to fouling and able to be easily cleaned.

5. Boiler combustion management

Minimising excess air in combustion is one of the key energy efficiency initiatives for boilers. The more hot oxygen and nitrogen that escapes from the flue, the more energy you lose. By analysing the oxygen concentration of the flue gas (%), you can easily determine if too much excess intake air is being used. This can then be controlled through regular checking and adjustment, or through an automatic oxygen trim control.

The flue gas exhaust temperature is also a good indicator of the efficiency of your boiler. By measuring the flue temperature daily and seeing how it changes as compared to steam load, ambient temperature and the oxygen content, you can quickly pick up any efficiency problems with the boiler. Keeping the flue gas temperature as low as possible is important in maintaining energy efficiency.

The concentration of combustible material in the flue gas is not only an efficiency matter but also one of safety. High concentrations are dangerous and may show that there is insufficient combustion intake air. Combine this measurement with that of the oxygen concentration to determine if the combustion intake air amount should be changed. Problems may also be due to insufficient time for the reaction, temperature or insufficient mixing of oxygen and the fuel.

Unburned carbon loss is generally a problem in coal-fired and other solid fuel boilers. By analysing the carbon concentration of the ash it is possible to see if your unburnt carbon levels are within a normal range. High levels are a sign of inefficient combustion, which is increasing your fuel costs. Changes may need to be made to your stoker or grate arrangements.

6. Economiser

Consider the application of an economiser.
This equipment recovers heat from your exhaust for pre-heating of boiler feedwater or other process water.

4.1.3 Step 3: Reduce steam distribution system losses

While the boiler itself is an important area for improvement, the rest of the steam system is just as important for improving energy efficiency and performance.

Key steps to reducing steam distribution system losses

1. Find and repair steam leaks

Steam leaks are a big cause of energy loss from steam systems. Leaks generally occur in pipe sections or connections and steam traps that drain condensate. Table 2 shows the cost of steam leaks at various pressures and hole sizes.

Table 2: Steam leakage rates.[5]

Hole Diameter (mm)	Leak Rate (kg/hour) at Steam Temperature 260 °C Steam Pressure (kPa above atmospheric)						
	345	**689**	**1034**	**1379**	**1724**	**2068**	**2413**
3.2	12	21	30	39	48	60	67
6.4	46	82	118	153	191	239	268
9.5	103	183	265	347	430	538	604
12.7	183	326	470	616	764	956	1073
19.1	411	733	1058	1387	1719	2151	2413
25.4	731	1303	1881	2465	3056	3824	4290
31.8	1143	2036	2938	3851	4776	5975	6703
38.1	1645	2931	4231	5546	6877	8604	9653

Leaks can be detected by sight and hearing, while ultrasonic leak detection can be used for smaller leaks. The most effective repairs on steam pipe leaks can be made when the steam system is not operating, as the maintenance crew gets extensive and safe access to the piping. If the leak is a safety hazard or system downtime will not occur for some time, then repairs can be made while the steam system is online. However, only trained technicians should do the work and the repair may not be as effective.

2. Implement a steam trap management program

Steam traps are devices that collect condensate in the steam line. Once a sufficient amount of water has been collected, the trap will drain to the condensate return network. The act of draining the condensate unavoidably means loss of steam from the system. If a trap is operating properly, this loss will be minimal. Normal wear and tear, debris in the steam system, or improper application of steam traps can lead to trap failure. If the trap fails while open, steam will be vented continuously, leading to a large energy loss from the system. If a trap fails while closed, condensate can back up within the steam system, damaging equipment and reducing the performance of your steam system.

Faulty steam traps that are leaking badly must be replaced to avoid large leaks. Typically, a well-maintained steam system will experience failure in 10% of its traps within a one-year period[5] To avoid large energy losses, a steam trap management program should be put in place that:

- trains personnel
- inspects every steam trap at least annually
- assesses its operating condition
- maintains a database of all steam traps, both operational and faulty
- acts on the assessment findings.

Green fact

Even in a well-maintained steam system, 10% of steam traps will fail every year

3. Investigate potential areas for condensate return

Condensate is the condensed water that has dropped out of the steam system as it loses energy through the distribution system. This water is then drained by steam traps. In the vast majority of cases, this condensate is returned to a receiver, where the water is pumped to the boiler feedwater system and recirculated through the steam system. The advantages of returning this water are:

- Less energy is required to heat the feedwater as the condensate is still at a relatively high temperature.
- Less water is drawn from the main supply and so you save water.
- Effort, energy and money have already been invested in treating the feedwater that is no longer lost.

Maximising the percentage of your condensate returned to your boiler will raise your energy efficiency. Unavoidable losses exist in certain steam applications, such as sparging steam into a tank. Opportunities for increasing your condensate return should be identified, including:

- running return lines to distant parts of the system
- ensuring the size of condensate return piping is sufficient for changing plant heat loads
- identifying and fixing leaks in the condensate return system.

4. Check insulation

Maintaining your insulation in good condition is vital to an energy efficient steam system. Without effective insulation on all piping, vessels and other equipment, you are constantly losing energy to the environment. Table 3 below shows the cost of uninsulated piping.

Table 3: Heat loss from uninsulated piping.[5]

Nominal Pipe Diameter (mm)	Heat Transfer from uninsulated pipe exposed to 0.4m/s wind and 21°C ambient temperature (MJ/h/metre) Process Fluid Temperature (°C)					
	93	204	316	427	538	649
12.7	1	3	4	7	10	14
25.4	1	3	6	9	14	20
50.8	2	5	9	14	22	32
76.2	2	6	12	19	30	44
101.6	3	8	14	24	37	55
127.0	3	10	18	28	44	66
152.4	4	11	20	34	51	76
203.2	5	13	25	42	66	96
254.0	5	16	30	50	79	119
304.8	6	18	34	58	92	139
406.4	7	21	42	71	113	172
508.0	9	26	50	86	139	211
609.6	10	30	59	101	164	250

Carrying out an inspection of all elements of your steam system, identifying and rectifying areas of no insulation, inadequate or deteriorating insulation will ensure that you can properly insulate you system. Ensure that you are using the correct type of insulation for your equipment.

5. Investigate opportunities to reintroduce flash steam

When water at a saturated temperature and high pressure is collected in a steam trap, a portion of it will be converted to steam when it is released to lower pressures. This is called flash steam. In most condensate return systems, flash steam is transported to the feedwater system with the liquid condensate. Even though the flash steam is at a lower temperature and pressure than the main steam system, this flash steam can still be useful in low-pressure applications. A flash steam recovery system can be installed to make use of this steam.

A flash steam recovery vessel allows the low-pressure steam to be separated from the condensate and creates a low-pressure steam supply line. The condensate liquid is pumped to the boiler feedwater tank. This flash steam supply can then be used in multiple ways. If the flash recovery vessel is located near the process, the flash steam could be used for additional heating of the original process to which it lost its heat. The flash steam may then condense and be drained back to the common condensate return line. Alternatively, the flash steam can be used in other processes for heating, or for cooling if there is a high-temperature process that needs cooling. If the flash steam cannot be used for a process, it can still be condensed and returned to the feedwater, as significant energy has been invested in treating it. However, condensing it may require large volumes of water and a cost-benefit study should be conducted.

4.1.4 Step 4: Undertake boiler maintenance

Boiler maintenance is essential in obtaining good performance, efficiency and longevity. A regular maintenance schedule, which involves logging of boiler efficiency indicators and thorough cleaning of heat transfer surfaces is essential. Inspection of boiler insulation and refractory is also key. The maintenance instructions provided by the boiler manufacturer should be followed closely and at the recommended intervals.

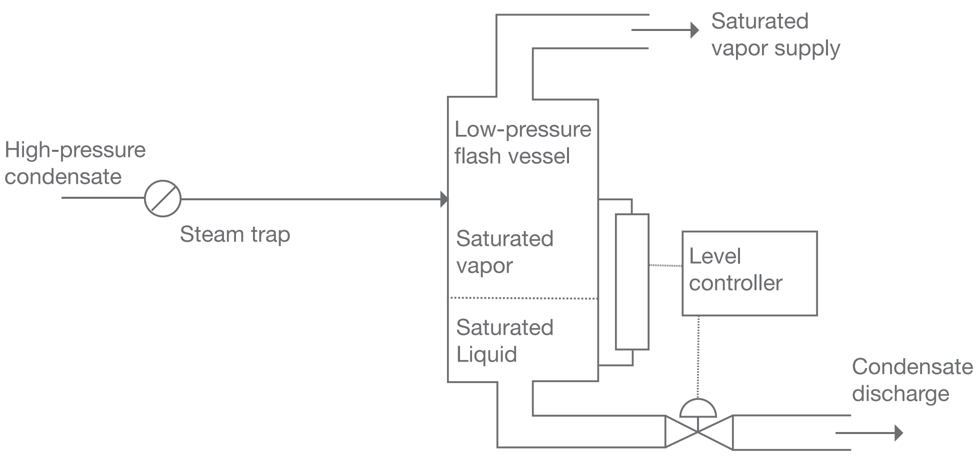
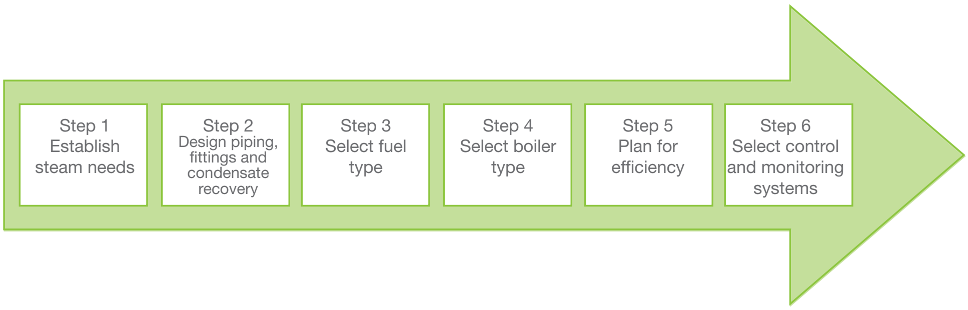


Figure 3: Flash steam recovery vessel.[5]

4.2 Solution 2: Design a new system

A suggested process to follow when designing a new steam system is summarised as follows:



4.2.1 Step 1: Establish steam needs

When planning a new system or boiler, it is important to take stock of exactly what you use steam for and how it is used to help meet your business needs. Compile a list of all end uses of steam, the temperature, pressure and flow they require, their location and their options for heat recovery. From this list, you can establish the correct temperature and pressure and the average flow required by your system. It is important to ensure that steam will not be used for unsafe or inappropriate uses for which other technologies are better suited and more efficient; after all, steam is a relatively expensive form of energy.

4.2.2 Step 2: Design your piping, fittings and condensate recovery

Once your steam needs have been identified, you can begin to layout your steam distribution and recovery system. This will consist of piping, fittings, valves, steam traps and possibly flash steam vessels and condensate receivers. The design of your heat recovery opportunities should also be considered at this stage. Particular thought can be given to the angling of your steam pipes to allow for more convenient condensate recovery through natural drainage, rather than requiring dedicated condensate pumps.

4.2.3 Step 3: Select the fuel type

Selection of the most suitable fuel for your boiler application is an important and sometimes difficult choice. Options may include natural gas, fuel oil, coal and others. You should also include waste heat from other parts of your plant, or from an on-site cogeneration system. Your decision should include considerations such as:

- boiler type required
- relative cost of fuels
- stability of the fuel costs
- changes to prices or your circumstances in a carbon-constrained world
- current/future government or company policies that may affect supply of the chosen fuel
- availability of a continuous supply of the fuel (for example, supply interruptions)
- the potential for fouling and the cleaning time required
- maintenance and downtime requirements
- efficiency
- net environmental impact.

4.2.4 Step 4: Select boiler type

There are two key types of boilers – water tube boilers and fire tube boilers.

Water tube boilers
Water tube boilers are usually used in large industrial and power generation situations where extremely high heat transfer rates are required to produce large quantities of steam. The water is heated in tubes and the fire (combustion process) is contained in the space around the tubes. [6]

Fire tube boilers
Fire tube boilers are used in the more typical industrial and commercial boilers, which generally require lower steam generation quantities, or have limited space. In this case, the fire, or the hot combustion gases, are contained inside tubes within the boiler and the water is circulated around these tubes.

Steam accumulators
Steam accumulators can be used to store steam for use at peak steam demand times. While the use of accumulators has declined recently, they should be considered when selecting a boiler, as the ability to store steam allows for the selection of a boiler that can supply average demand without needing to supply peak demand. Installation of a smaller boiler will mean both a cheaper installation and, more importantly, cheaper running costs.

Steam usage
The steam generated by boilers can be used in two ways:

- at high pressure (> 4200 kPa) to drive turbines or reciprocating engines
- at lower pressure (700–1400 kPa) to supply heat to heating coils and so on, or by direct injection into fluid

In some plants, a combination of these uses is employed. The resulting high-pressure superheated steam is used to drive a turbine for the generation of electricity, and the turbine exhaust steam is used for heat transfer applications. In these systems, the condensate is generally returned to the boiler for reuse and the overall efficiency is almost 80%.

In most industrial and commercial plants, steam is only used for process and environmental heating. It is important to optimise the efficiency of each part of such systems through proper selection, sizing, operation and maintenance.

The pressure at which you choose to distribute steam will be a balance between high pressures, which minimise pipe sizes and subsequent heat losses, and low pressures, which minimise the formation of flash steam from the discharged condensate.

In industrial processes, the decision to use either heating coils/jackets or direct steam injection is determined by the:

- required rate of heat transfer
- agitation of solutions
- nature of the product
- operating temperatures
- cost of feedwater treatment.

A typical steam system uses the steam for direct process heating in the injection vessel and for indirect heating through an indirect heating coil.

4.2.5 Step 5: Plan for efficiency

Integrating the boiler operation with the steam system demands is an important step towards obtaining the most energy-efficient steam system possible. Often, the operation of the boiler at higher capacity or for longer periods than are actually required by plant processes causes a large waste of energy. Scheduling plant processes to create as constant a steam demand as possible, over as short a time as possible, is ideal. This will reduce the time the boiler is operating at low capacity or the number of times that the boiler must be shutdown and fired up. The use of sophisticated monitoring and control systems will assist in implementing the most efficient system turndown when demand is low.

4.2.6 Step 6: Select boiler control and monitoring systems

Your boiler's control system will largely depend on your fuel selection. They can range from more simple mechanisms to complicated digital control and monitoring systems. Some of the essential control systems required are outlined below.

Combustion control system
This control system regulates the fuel air mixture. Systems range from simple physical linkage systems that vary the fuel and air intake with the steam pressure, to electronic systems that monitor the fuel and air intake and steam pressure independently. This system makes use of the intake dampers and the fuel regulating valve.

Burner flame safeguard system
This system ensures that the burner flame remains stable and safe by monitoring the flame, boiler pressure, water level and other variables. This system makes use of the safety shutoff valve on the fuel supply.

Water level control
This system controls the water level in the boiler by sensing the water level and controlling the pumping of feedwater into the boiler. More advanced systems also sense the steam flow rate and other factors.

Steam pressure control
This system regulates the pressure in the steam header around the set point by controlling the burner firing rate.

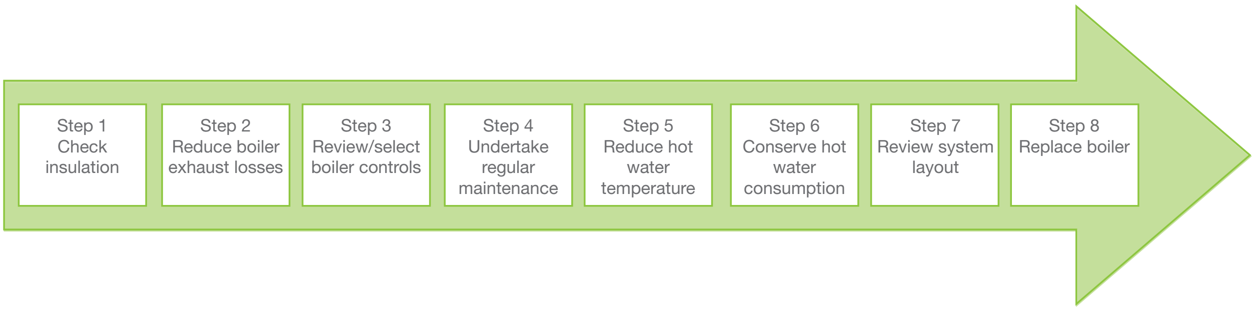
Safety valves
As well as the safety shutoff valve that ceases fuel supply, there is a safety release valve that releases excess pressure from the boiler and a non-return valve on the steam line that protects against steam flow back into the boiler.

Monitoring systems
As part of the boiler monitoring system, important variables that should be monitored include fuel supply, steam flow and feedwater flow meters. This enables a range of data to be analysed, boiler efficiency to be assessed and trends in efficiency to be analysed.

5 Hot water systems

5.1 Solution 1: Improve the efficiency of your existing system

A suggested process to follow for improving the efficiency of your hot water system is as follows:



5.1.1 Step 1: Check insulation

Insulation (or 'lagging') is essential in reducing heat losses from the boiler, pipes and valves. New boilers are often very well insulated, however, older boilers may require more insulation or the insulation may have degraded. Poor insulation can account for losses of up to 10%.[7] Adding or replacing insulation is a simple and cost-effective measure that can improve your hot water system's efficiency.

5.1.2 Step 2: Reduce boiler exhaust losses

The exhaust flue of a boiler is one of the major sources of heat losses. You can do things to reduce these losses. The flue draws air through the boiler, even when the boiler is not firing. This cools the boiler and, therefore, more energy will be required to get it back up to the correct temperature. A flue damper can be installed that will automatically close the flue when the boiler is not firing, thereby conserving heat.

While the boiler is running, a lot of heat is lost in the exhaust gases. Recovering this heat is a good way of improving efficiency. Condensing boilers have this feature built-in. The exhaust gas can be passed through a heat exchanger with either the return water (in a circulating system) or the intake air to the boiler in order to reduce the energy required by the boiler. Increasing the temperature of the intake air by 20°C will increase the efficiency of the boiler by 1%.[7] This sort of system is called a recuperative burner system, and may need special modifications to your burner and its controls.

5.1.3 Step 3: Review/select boiler controls

The effectiveness of your boiler control system is one of the key factors in running an efficient hot water system. Check which type of control your boiler is using and whether it suits the demands of your boiler. You may wish to consult a service provider on whether your system could be adjusted to run more efficiently. A number of special control features can be employed to improve efficiency.

Burner controls
Possible types of burner control are on/off, high/low and modulating, increasing in efficiency from the former to the latter.

Boiler interlock
By integrating the control of the boiler with thermostats on the heating distribution system, it is possible to avoid 'dry-cycling', which is the firing of the boiler while there is no demand for heat. This is quite a simple yet effective measure if your boiler experiences this problem.

Sequence control
If multiple boilers are used, it is possible to use sequence control to turn unnecessary boilers off and avoid running multiple boilers at part load.

Optimised start/stop control
Often boilers have time switches to ensure the boiler is only operating during the times that production is running, for example, 8am – 6pm. An optimiser can be installed which receives input from process thermostats, allowing the boiler to operate for the shortest length of day possible while still maintaining the required heating for the process.

5.1.4 Step 4: Maintenance

Regular maintenance of your hot water generator is essential to keep it running efficiently. A maintenance routine, maintenance manual and logbook for tracking are all important features in a maintenance plan.
A number of specific maintenance tasks should be performed to ensure the best performance and lifetime for your boiler.

Analyse flue gas
If using gas, an analysis of the flue exhaust gases and the concentrations of oxygen, carbon monoxide and carbon dioxide will give an indication of combustion efficiency, which can be compared against the specifications of how your boiler should perform. This is a good way of determining the health of your boiler.

Remove soot build-up
Gas boilers will create a build-up of soot over time. This soot is a layer of unburnt fuel particles that builds up on the fireside of the heat exchanger. This layer will insulate the water and reduce efficiency. A 1mm layer of soot will increase the energy required by the boiler by 10%.[7] Removal of this soot is an important maintenance task.

Lime-scale build-up
If the water supply is particularly hard water, then lime-scale build-up can occur on the water side of the heat exchanger. As with the soot build-up, this inhibits the heating of the water. Removal of lime-scale is best done with chemical treatment. Again, this task is important, as a 1 mm layer of lime-scale will create a 7% increase in the energy input to the boiler.[7]

5.1.5 Step 5: Reduce hot water temperature

The temperature set point of your boiler is a major factor in determining the heat lost throughout your system. By reducing the temperature of your hot water supply to the minimum required for your application, you can save significant amounts of energy.

5.1.6 Step 6: Conserve hot water consumption

A key efficiency measure is to stop hot water going down the drain. This can be done a number of ways.

Repair leaks
Any leaks in the hot water system are causing your system to lose water and waste energy. Find and repair any leaks as far as possible. The staff on the shop floor can act as your eyes and ears in detecting any leaks, so make use of them.

Use efficient fittings
Use efficient nozzles and taps wherever possible. It may involve an initial cost but will soon pay off in both water and energy savings.

Separate hot/cold outlets
Using separate hot and cold water outlets instead of a combined warm water tap may also save hot water if a manual outlet control is used, as no hot water will be used when only cold is needed.

Appropriate uses
While hot water is often easily available for use in jobs on the shop floor, a significant energy cost is involved in creating hot water, which means using hot water inappropriately is wasting energy. Ensure that hot water is not being used for jobs for which there is a more suitable alternative.

Consider higher system pressure
There is a trade-off between using higher pressure water sprays (which use more electricity, but less hot water and therefore heating energy), and low-pressure systems. Consider the application of high pressure systems for cleaning or other uses.

Pre-heating and reuse in clean-in-process (CIP) systems
CIP systems can require a lot of hot water. Through the use of multiple holding tanks, water and energy efficiency gains can be made as follows:

- Water from the first rinse: *to drain*
- Water from the second rinse: *store in a tank to be used in the first rinse of the next cycle*
- Third/final rinse water: *store in a tank to be used as the second rinse of the next cycle*
- Fresh water: *use as the final rinse only*

5.1.7 Step 7: Review system layout

Minimising the distance between your hot water boiler and the end uses of your hot water will save you significant heat losses from piping.

5.1.8 Step 8: Replace your boiler

While the above key energy efficiency measures will help your hot water system run more efficiently, if your boiler is quite old or is in poor condition, then it may be beneficial to replace the boiler. Typical boiler lifetimes are 15 years.[7] While replacing the boiler may appear to be a large cost, the potential savings in energy and maintenance costs of running the new boiler, as compared to the old, one could make it worthwhile.

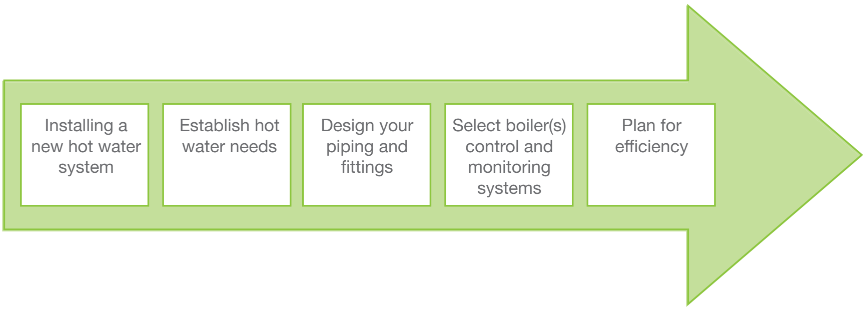
Replacing the boiler is not as simple as reading the specifications on the nameplate of the old boiler and ordering a new one with those specifications. A review should be undertaken that looks at your site's heating demand, with your business needs in mind. To ensure this review is thorough and accurate a boiler technician or specialist engineer should be consulted. Such a review should consider the following points:

- What is the site's heating requirements?
- What fuel supply will be used?
- Where will the new boiler be located?
- Is the new boiler a condensing boiler?
- Will it be compatible with the current site heating system?
- How will maintenance costs compare to the old boiler?
- Will there be the reduction in emissions of carbon dioxide, sulphur dioxide and nitrogen dioxide?

Condensing Boilers
Condensing boilers have an in-built second heat exchanger that extracts waste heat in the exhaust gases and returns it to the system. It also allows more water vapour in the exhaust to condense and also returns this to the system, reducing the water and energy consumption. Using a condensing boiler as the replacement can save between 10% and 20% of annual energy costs.[7]

5.2 Solution 2: Design a new system

You may need to install a brand new system, perform a major refurbishment, or conduct a major upgrade. In order to ensure that your new hot water system performs well and is energy efficient, a comprehensive review of your system requirements and the installation options is needed. Engaging a service provider to perform this role is advisable, as it will require considerable knowledge and resources. While all of the above information about hot water systems is applicable to new systems, a general outline of the review sequence is as follows:



5.2.1 Distributed and centralised systems

The generation of hot water can be performed in one central location and distributed to all the end uses, or the hot water can be generated with a number of smaller systems located close to where you need it. The choice between these two methods can be difficult and is different for each site. Some of the factors to consider are:

- Are the end uses of the hot water located within one building, or many?
- What is the distance over which you would need to distribute the hot water, and what would the thermal losses be?
- What is the volume of hot water you need and at which location?

5.2.2 Fuel selection

Gas
Gas is a common and convenient fuel used for hot water boilers. While natural gas is normally used, it is possible to use LPG. A burner provides heat via the heat exchanger. Air intake can be through natural convection or forced with intake fans.

Electricity
Electricity is another popular way of heating water. These boilers normally consist of a resistive element, which heats the water directly. Usually this is more expensive than gas, but can be more cost effective when used in a heat-pump system. If there is no natural gas available, then an electric heat pump should be considered as well as LPG or other fuel sources.

Steam

If you have steam generation on-site, you can use this steam to produce hot water. Steam and cold water are passed through a heat exchanger, with heat transferring to the water as the steam condenses. This can be an efficient method as you already have the steam generation system running and heat exchangers can be designed to operate quite efficiently.

Waste heat recovery

Waste heat from other processes (such as air conditioning, heat pumps or cogeneration systems) can be used to heat water. This may be in the form of flash steam, hot process liquids, flue gases from combustion, or air that has already passed through a process but may still have significant heat that can be transferred to water via a heat exchanger.

Solar

Solar hot water systems work by using the sun's thermal energy to heat water. These systems commonly run water through a series of pipes that are exposed to the sun, often on a roof. The water is then returned to a storage tank. Solar energy can also be supplemented by other fuels or heat sources in order to maintain a continuous flow of hot water during extended operation.

Heat pump

A heat pump works by extracting heat from the surrounding environment and transferring it to your hot water, much like a refrigerator works but in reverse.

Comparative analysis

The following table illustrates the relative advantages and disadvantages of some water heating systems. What is not taken into account in this table is the infrastructure cost to use the particular fuel source. This can have a significant bearing on the overall cost of the hot water generation.

Table 4: Advantages and disadvantages of various water heating systems.

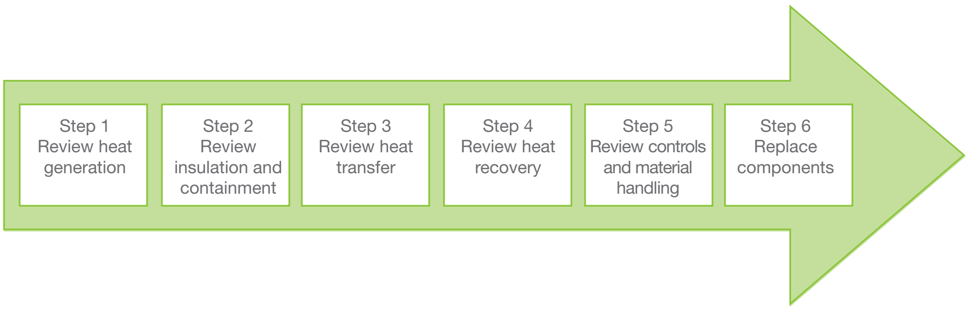
Energy Source	Fuel Cost (excluding cost of equipment)	Fuel Efficiency	Greenhouse Gas Emissions
Gas	$3–7/GJ	70–90%	Medium – gas has a lower greenhouse gas coefficient than electricity
Electricity resistance	$25–35/GJ	Up to 100%	May be high depending on your electricity supply characteristics
Steam	$4–10/GJ	50–80%	Medium if gas fired – gas has a lower greenhouse gas coefficient than electricity. High if electricity is used to raise steam
Waste heat recovery	Low	70–90%	Low
Solar	Free	70–90%	Low – there may still be pumping required in the system
Heat pump	$25–35/GJ	Up to 400%*	Medium – electricity is still required to run the heat pump

*It is difficult to represent overall system efficiency with a heat pump. The coefficient of performance (COP) of the heat pump may be as high as 4, meaning up to 4 units of heat are provided for one unit of electricity.

6 Process heating systems

6.1 Solution 1: Improve the efficiency of your existing system

While process heating systems can be complex, relatively simple improvements can be made with minimal investment or time but that yield significant energy savings and performance improvements. Note that, while most of the steps outlined here will be applicable to all process heating systems, some will apply solely to a combustion system as opposed to electricity-based heating technologies. A suggested process to follow for improving the efficiency of your process heating system is summarised as follows:



6.1.1 Step 1: Review heat generation

Air-to-fuel ratio
Like hot water generators and boilers, any direct combustion will need its efficiency managed. See Section 5.1.3 on boiler combustion controls and maintaining efficiency over time.

Pre-heat combustion air
A common method of pre-heating the combustion air is to pass the intake air through a heat exchanger with the exhaust gases from the furnace itself. In this way, heat that would otherwise be vented to the atmosphere is transferred to the intake air. Other methods would be to pre-heat combustion air with return steam or cooling water from another process in a heat exchanger. Intake air pre-heating can save between 15% and 30% of your energy costs.[2]

Oxygen enrichment
Oxygen enrichment has not been widely used in the past, but recent technology improvements mean that it is again becoming a useful technique. It involves supplementing the combustion intake air with oxygen, creating intake air with a higher oxygen concentration. This higher concentration leads to more efficient combustion and so less fuel is used. The saving from this technique can be between 5% and 25% of energy cost.[2]

Process temperature
Ensure the process temperature is set at the minimum required to maintain the desired product quality, thereby reducing heat losses from the system. Recent changes in your process or the materials you are using may now allow you to set a lower process temperature.

6.1.2 Step 2: Review insulation and containment

Insulation is vitally important in maintaining energy efficiency. Containing heat loss must be a priority in order to ensure your process heating system is running well.

Insulation
At the very least, ensure that adequate insulation in good condition is installed on the following equipment.

- furnace walls
- heat transfer pipes
- intake air pipes if pre-heated
- heat recovery piping.

Heat that is lost from the process is absorbed by the surrounding ambient atmosphere. If your process heating takes place within a building that is temperature controlled by a HVAC system, then poor or no insulation means that you are creating extra load for the HVAC system, and are losing money from two sources. Ensuring that your insulation is adequate can save up to 5% in energy costs.[2]

Air infiltration
The operation of a combustion system creates negative pressure within the furnace as the exhaust gases move out through the flue. While this ensures combustion gases do not escape to the surroundings, it may lead to the infiltration of ambient air into the furnace through leaks and openings. As this surrounding air is at a low temperature, it forces the furnace to work harder, therefore using more energy. To avoid this, the furnace should be regularly inspected and any cracks, leaks or openings due to improper seals on doors should be fixed. A pressure control system can also be installed to ensure that the furnace pressure does not encourage air infiltration. These measures can save up to 5% of energy costs.[2]

Hot spots
Regular inspection for localised hot and cold spots can help act as an early warning for problems with your furnace or boiler's health. Infrared imaging can be used to assist with this task.

Extended parts
Some furnaces of boilers may have parts that protrude from the body of the furnace, such as roller shafts. These parts cause heat to be lost to the surrounding atmosphere. If these parts cannot be removed or shortened, then perhaps insulation should be considered for them.

6.1.3 Step 3: Review heat transfer

The transfer of heat from combustion to the product is another area in which energy savings can be made.

Cleaning
Ensure that heat transfer surfaces are clean to allow for maximum transfer. Removing soot, scale, carbon and other deposits from furnaces, boilers, radiant tubes and heat exchangers will improve efficiency.

Burners
The correct and most efficient use of burners will assist in process efficiency and product quality. Ensure that in each location within the burner that the proper type of burner is being used, the layout is optimum for your process and that all burners are in proper working condition.

Recirculation
Recirculating fans or jets can be used to ensure that the temperature throughout the furnace or oven is consistent, increasing efficiency and improving product quality through consistent heating.

Furnace zone temperature
Zoning can be used within the furnace to apply different temperatures to the product at different stages of the process, by varying the temperature over time, as in a batch process, or by creating different temperature zones within the furnace, as in a continuous process. The proper use of zoning can allow a higher temperature to be applied in the initial stages, which will increase the rate of heat transfer while maintaining the product quality.

6.1.4 Step 4: Review heat recovery

Heat recovery is the best option for improving your process heating system efficiency. It is almost 'free' energy from gases or liquids that you would otherwise vent or remove. In high process-temperature applications, heat recovery is doubly important, as the higher the temperature of your combustion gases the more energy you are losing to the surroundings.

You may wish to consult a process heating service provider in order to gain an independent view of the best heat recovery system specific to your plant. Some of the more common heat recovery techniques are discussed below, most of which can save between 5% and 20% of your energy costs.[2]

Combustion air pre-heating
The simplest and yet one of the most effective techniques is to pass the exhaust gases through a heat exchanger to transfer heat to the intake combustion air, thereby reducing the fuel required to heat the process. This technique can save between 10% and 30% of your fuel cost.[2]

Product pre-heating
Where your process allows, it may be possible to use the exhaust gases (or other sources) to preheat the product before it enters the process furnace. As with combustion air pre-heating, this leads to significant fuel savings. This is particularly applicable if your product is a liquid, as a heat exchange can easily be utilised. It may also be possible to use the exhaust gases to aid the process heating itself by making a number of passes through the furnace.

Cascading
If you have multiple process heating applications, you may be able to cascade waste heat from one process to another. If you have exhaust gases from one process that are, for example, at 120°C, while another process is being heated to only 80°C, then you can use the waste heat of the exhaust of the first to assist in heating the second. This technique can be used to cascade waste heat through multiple different processes, either by using the exhaust of the original process in subsequently lower temperature processes, or by using the waste heat from each process in the next.

Hot water and steam generation
Waste heat from a process can be used to assist in the generation of hot water or even steam for your site. Using the exhaust gases of a process to preheat intake water for a hot water boiler, or the return steam of your steam generation boiler, is a very simple and yet efficient way to reduce your total energy costs.

Absorption cooling
As well as using exhaust gases for heating, it may also be possible to use them for cooling. You can use the exhaust to absorb heat and vent it to the atmosphere, thereby reducing the load on your cooling system and saving energy. The possibilities for absorption cooling are highly dependent on your processes and a service provider could be used to assess the viability of opportunities. Maintenance costs can be significant and should be investigated thoroughly.

6.1.5 Step 5: Review process control and material handling

Opportunities for energy savings through heat generation, transfer, containment and recovery have been considered. There are also opportunities for savings by optimising the process control, material handling and auxiliary systems of the process heating system. These will be dependent on your system – ensure that any efficiency improvement study takes a whole-systems approach.

Process control
A significant saving in process heating energy costs can be made by minimising the amount of starting and stopping of the furnace, and the amount of idle time between batches of the process. While the furnace is running with no product within it, you are using energy with no benefit. Additionally, each time the furnace is started, a very large amount of energy is required to heat the thermal mass of the furnace itself. This energy is then lost when the furnace is cooled. By optimising your process to run the furnace continuously with minimal delays between batches, for the shortest time possible, you can gain big savings.

Material handling
If your material handling system that loads product into your furnace is slow, you can waste time and energy in waiting for your product to move on. Upgrading this system to run faster can save energy.

Turndown
Process heating systems often have a minimum limit on the capacity that they can support before needing to be shut down. Turndown is the ratio of the highest capacity to the lowest. By increasing this ratio, you are making your process heating system more efficient.

Advanced materials
Many parts of a process heating system may need to be cooled to ensure proper functionality and longevity. With the advent of new materials, you may be able to replace these parts with new technology, which will provide the same function without requiring cooling, which saves energy. Also, many parts that are exposed to large amounts of heat have considerable mass in order to maintain integrity. Newer materials can be used that will withstand those temperatures while having a smaller mass, meaning that less energy is required to heat them during furnace start up.

Sensors
In order to obtain efficient process control, effective use of sensors is required. Ensure that your sensors are correctly placed and in good working order. New sensor technology is constantly being developed that may assist your control system in optimising your process. Accurate sensing of the furnace temperature (in various locations) and the oxygen and unburnt fuel content of the flue gases is essential.

Auxiliary systems
Process heating systems require many auxiliary systems, including forced draft fans, fluid pumps and material handling system motors. Effective and efficient operation of each of these systems is part-and parcel of running an efficient process heating system.

6.1.6 Step 6: Replace your equipment

If, after the key energy efficiency measures have been implemented, your process heating system is not performing well, due to either old age or poor condition, replacing your process heating equipment may be the best option. If so, it is a great opportunity to carry out a review of your process heating needs, rather than simply buying the same. Considering your heating requirements, material handling systems, heat recovery options and control systems is important in planning for the system that will give you the best performance with the lowest energy costs possible. Remember, the installation cost of typical industrial heating systems is only a fraction of their energy cost over their lifetime.

6.1.7 Performance improvement tools

A number of free software-based tools are available that can be used to assist in the assessment of your process heating system and identify options for energy-efficiency improvements. These tools are:

- Process Heating Assessment and Survey Tool
- NOx Emission Assessment Tool
- The Combined Heat and Power System Application Tool for the Process Heating Industry

For details of these tools, and where to find them, see Reference 2.

6.2 Solution 2: Design a new system

If you are planning a new process heating system you should plan for efficiency by considering the measures mentioned in this guide. A comprehensive study of your heating requirements, both at start-up and in the foreseeable future, should be undertaken. A process heating service provider can assist with this study and the design of the system in order to provide the most comprehensive options and the best energy efficiency achievable.

7 Selecting a service provider

Many of the suggestions made in this guide to improve the efficiency of your hot water, steam or process heating system can require substantial time, expertise, equipment and resources. In such cases, you may prefer to contact a service provider to perform some or all of the work for you. In either case, there are some questions you should ask before you begin.

7.1 Questions to ask service providers

Will the provider take a systems approach?
It is important that your service provider considers how to optimise your entire system, not only one or two of its components.

Will the provider examine the demand side as well as the supply?
While the supply side of equipment is an important consideration, the provider should also be investigating the demand side of your system.

Other questions:

- What analysis services do they offer (for example, boiler efficiency)?
- What training does the provider's staff have in energy efficiency?
- Are they qualified to work on all relevant equipment and install metering?
- Do they provide emergency service response?
- Will they take care of parts shipping?
- Will they contract out any of the work themselves?
- Do they have the capability to remotely monitor your system?
- Can they provide emergency rental equipment if required?

7.2 Database of sustainable service providers

Sustainability Victoria maintains a Sustainable Manufacturing Directory, which lists service providers for a whole range of industries, products and services. You can easily find a service provider to help you with your steam, hot water or process heating project by searching the directory, which can be found at: www.sustainability.vic.gov.au

Appendix A
Steam system overview

Steam systems are very common in industrial and manufacturing plants around the world.

Figure 4 shows a typical basic steam layout for an industrial plant.

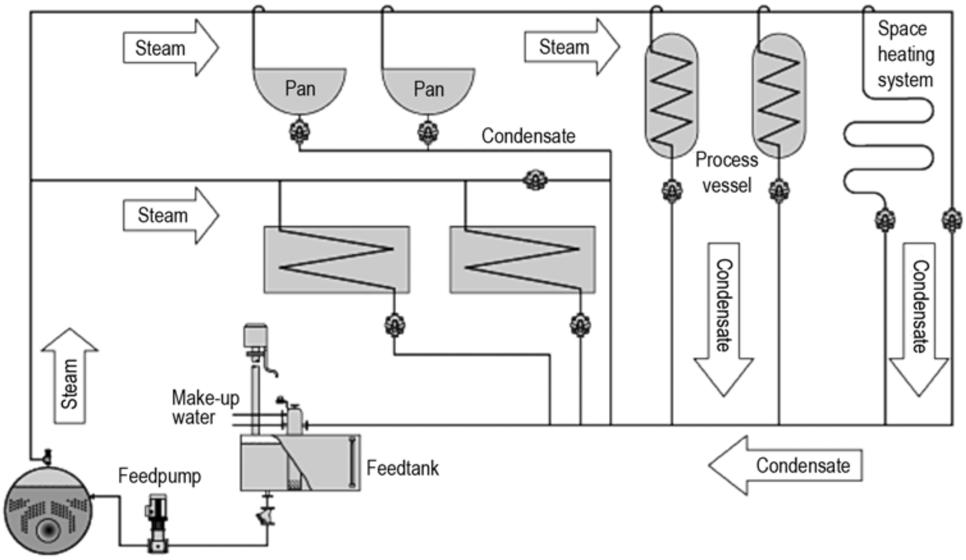


Figure 4: Typical basic steam circuit.[8]

A brief description of each component follows.

Gas burner systems: In typical packaged boilers that run on gas, burners mix the air and fuel in an appropriate ratio to support reliable and safe combustion. Too much fuel and there will be incomplete combustion and increased harmful emissions. Too little fuel (or too much air) and the air will carry away a lot of useful heat out of the flue. Burners come in different types including:

- pressure jet burners
- rotary cup burner
- gas burners (low and high pressure)
- dual fuel burners
- recuperative and regenerative burners.

Fire tube boilers: There are many different types of boilers and it is not possible to show them all here. Figure 5 illustrates the typical flow path for the combustion gases and the likely temperatures in a typical fire-tube boiler installation. In these boilers, the combustion gases from the burner flow through the inside of the tubes, with the water that will be boiled to steam on the outside of the tubes.

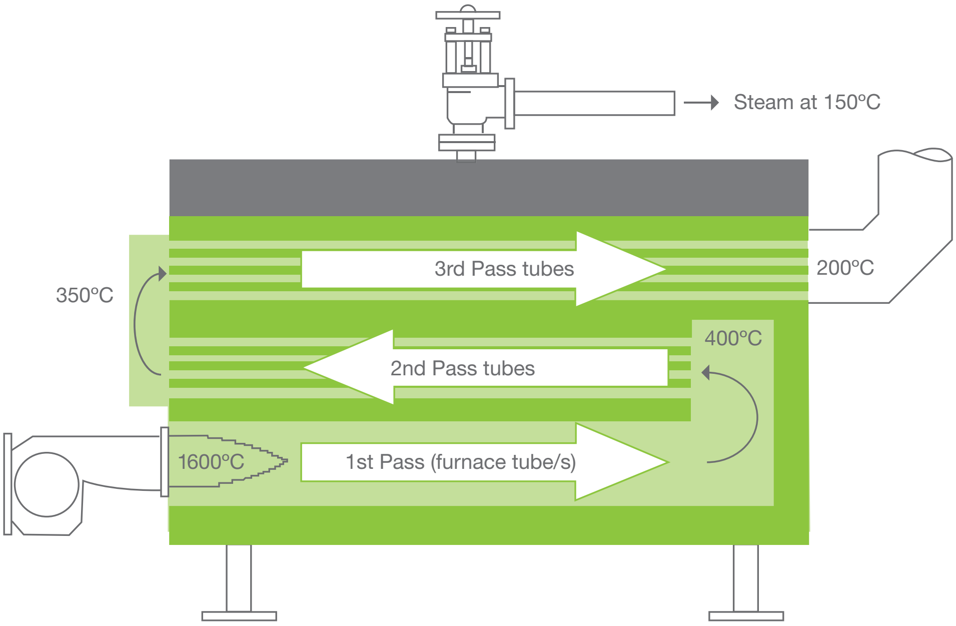


Figure 5: Typical flow path through fire-tube shell boiler.[8]

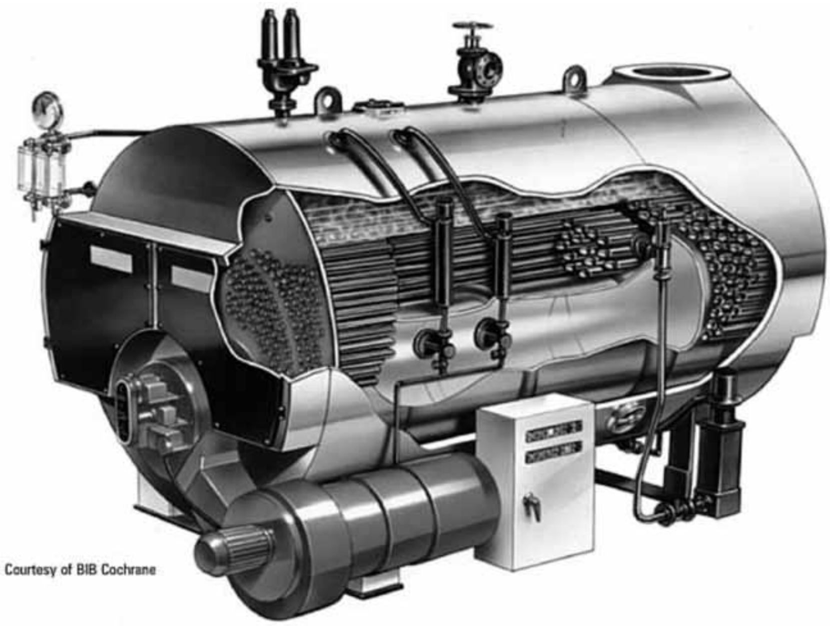


Figure 6: Modern package boiler.[8]

Water tube boilers: Water tube boilers are often used in larger boiler applications such as power stations and large industry. This is because the smaller diameter of the water tubes allows higher steam pressures to be generated, such as those required for power generation using steam turbines.

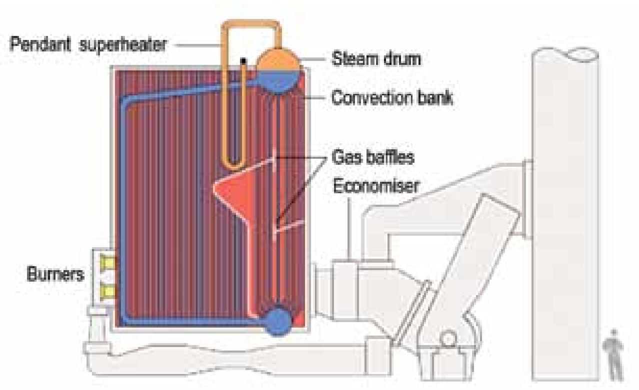


Figure 7: Water tube boiler.[8]

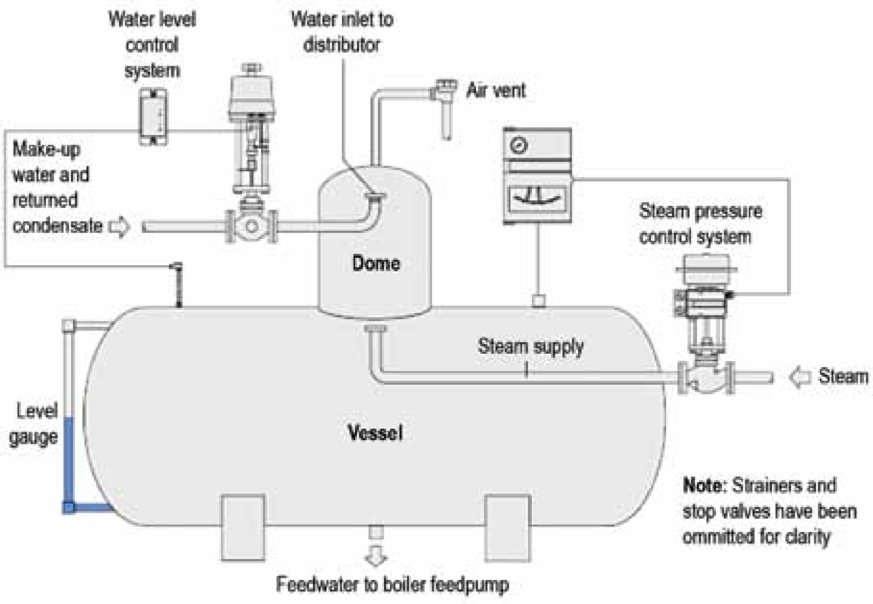


Figure 8: Pressurised de-aerator.[8]

Blowdown system: Over time, the water inside the boiler will accumulate sludge and suspended solids formed from the chemicals used in dosing of the feedwater, or dissolved solids naturally occurring in the feedwater itself. If not removed, these can accelerate corrosion and decrease the performance of your boiler and steam system. A blowdown routine should be implemented, which can be a manual or automated system.

De-aerator: The purpose of a de-aerator is to remove oxygen and other gases such as carbon dioxide, thereby reducing the potential corrosion in your steam system without significant use of chemicals. Whilst pressurized de-aerators require venting of steam with the oxygen, the reduction in the use of chemicals can reduce blowdown, prevent any contamination of foodstuffs in plant heat exchangers or direct use, and may be cheaper than chemical use.

Boiler feed pump: To overcome the pressure in the boiler created by the heating process, boilers are fed by boiler feed pumps. Sometimes they are driven by electric motors and sometimes by steam motors from the boiler itself. Flow from the boiler feed pump is usually controlled by a throttling valve that is connected to a water-level sensor in the boiler. As the water level drops due to steam production, more water is supplied with the boiler feed pump.

Economiser: Economisers have the potential to reduce your fuel consumption by around 4–6% through capturing the waste heat contained in the flue gas, and pre-heating the feedwater to your boiler. The main consideration (apart from cost) is the acidic conditions that may result from condensation of contaminants in your flue gas if you are using an oil-fired boiler. Economisers can be factory-fitted with a new installation, or retrofitted to some boilers.

Steam piping: International and national standards stipulate the material and wall thickness of steam piping. Generally, steam piping should be the minimum size required for the duty. This not only minimises the cost of the pipes, but also reduces the cost of insulation, fittings, flanges, supports and so on. Steam pressure is related to this, as generating steam at high pressures requires a lower pipe size to deliver the same amount of energy.

Insulation: To minimise heat loss from a steam system, it is common to insulate pipes, joints and fittings, but to leave safety valves uninsulated. Insulation comes in various types, including aluminium clad fibreglass, aluminium-clad mineral wool and calcium silicate.

Steam traps: The primary purpose of a steam trap is to discharge condensate, whilst not allowing live steam to escape. Due to the wide variety of applications under which steam traps are required to operate, they come in many shapes and sizes to suit those applications, including:

- thermostatic (operated by changes in fluid temperature)
- thermodynamic (operated by changes in fluid dynamics)
- mechanical (operated by changes in fluid density).

Strainers: High steam quality is usually important for your process equipment, and any solids contained in the steam can reduce its performance.

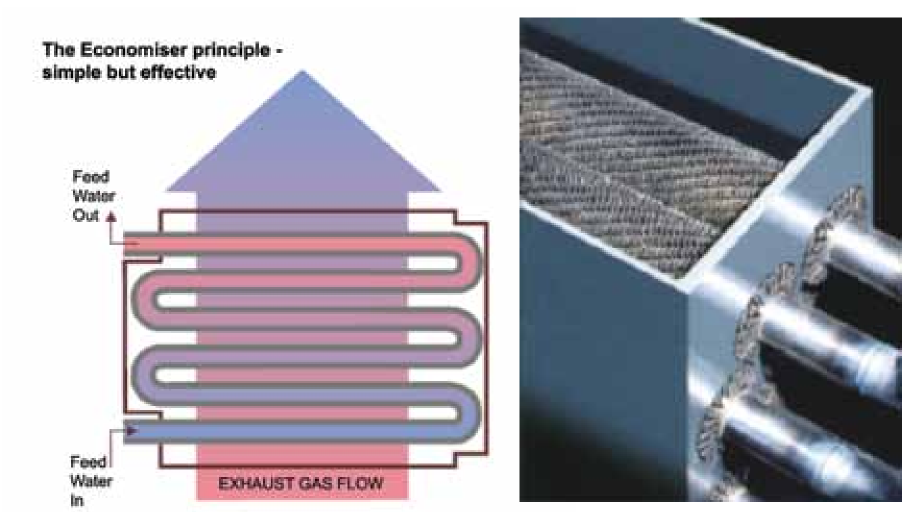


Figure 9: Economiser principle and example for a packaged boiler.[9]

Figure 10 illustrates a typical strainer, which acts like a sieve or filter. As such, it should be regularly cleaned to avoid blockage in your system.

Figure 10: Cut away section of a strainer.[8]

Separators: Separators are also part of the solution to maintaining high steam quality, which in turn minimises production downtime and reduces the degradation of your equipment. In particular, separators assist by removing steam that has condensed (condensate) from your system, as well as air. Air, when dissolved into condensate, is corrosive and an accumulation of condensate reduces the heat transfer performance of your steam system.

Figure 11: Cut away section of a separator showing operation.[8]

Condensate return system (return lines, return tank): Inevitably, as steam passes through your steam distribution network, it condenses, and in so doing gives up heat to pipes and steam equipment, your process and ultimately the atmosphere through heat losses. Bringing hot condensate back to your boiler (rather than discharging it to drain) will improve energy efficiency of your steam system, and reduce water make-up and water treatment costs (because the condensate will, by definition, be high-quality water). Several things could prevent condensate return, including contamination by the process or the cost of piping a small amount of condensate from part of the plant that is far away from the boiler. These costs should be weighed up against the benefits of recovering the heat.

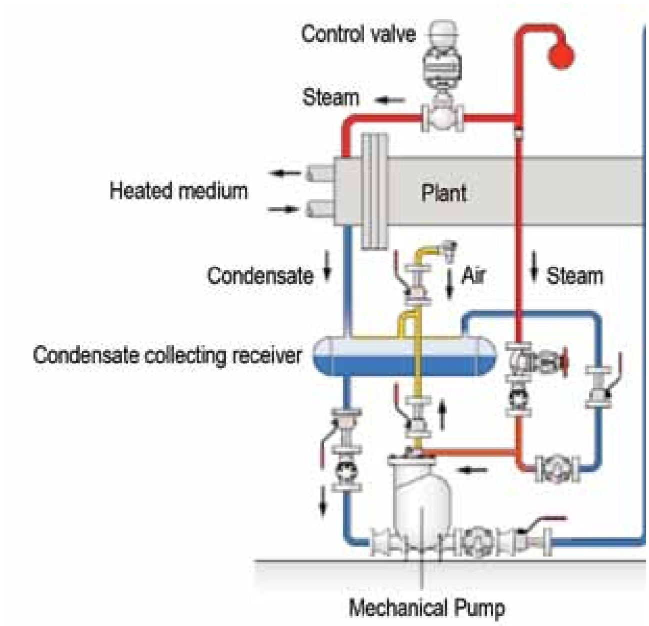


Figure 12: Condensate return system.[8]

Condensate return tank: When steam gives up its latent heat, it condenses to form high-pressure water, and when released through steam traps, can be returned to the boiler house for reuse. Sometimes, condensate is collected at the lowest point of a plant in a condensate return tank and then pumped to the boiler feedwater tank.

Steam accumulator: A steam accumulator is a method of storing steam for use during high-demand periods. Steam from the boiler is injected into the accumulator, which contains water under pressure at its saturation temperature. When the demand for steam exceeds the boiler's capability, the discharge valve opens and flash steam is created, as the discharge pressure is below that of the accumulator. In this way, the accumulator provides for the excess demand that the boiler cannot handle, allowing for a smaller boiler to be used but still providing for peak capacity. Also, when demand is low, the boiler will charge the accumulator with steam, providing extra demand on the boiler and so flattening its load profile.

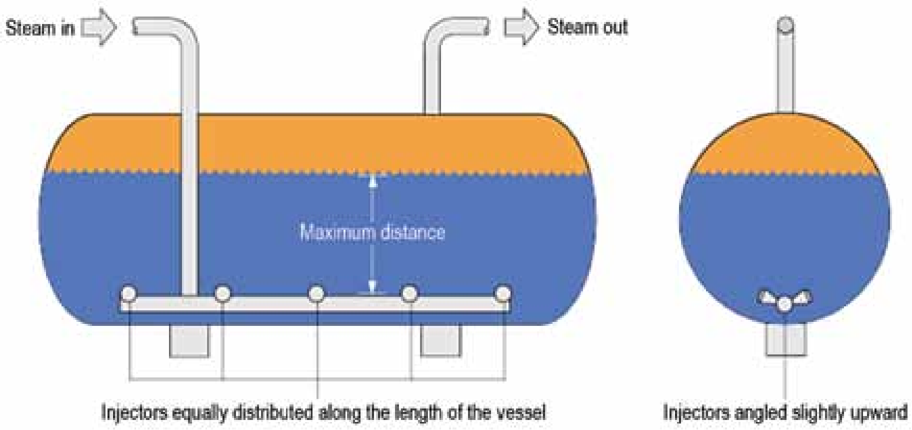


Figure 13: Steam accumulator (side and end view).[8]

Appendix B Hot water system overview

An industrial hot water system generally consists of:

- Hot water generator (sometimes called a hot water boiler): produces hot water at temperatures required by your process usually less than 100°C.
- Hot water pump: supplies hot water to the plant.
- Flue: extracts the exhaust gases from the boiler.
- Piping: carries the hot water around the plant.
- Insulation: (sometimes called lagging): reduces heat loss from piping and other equipment.

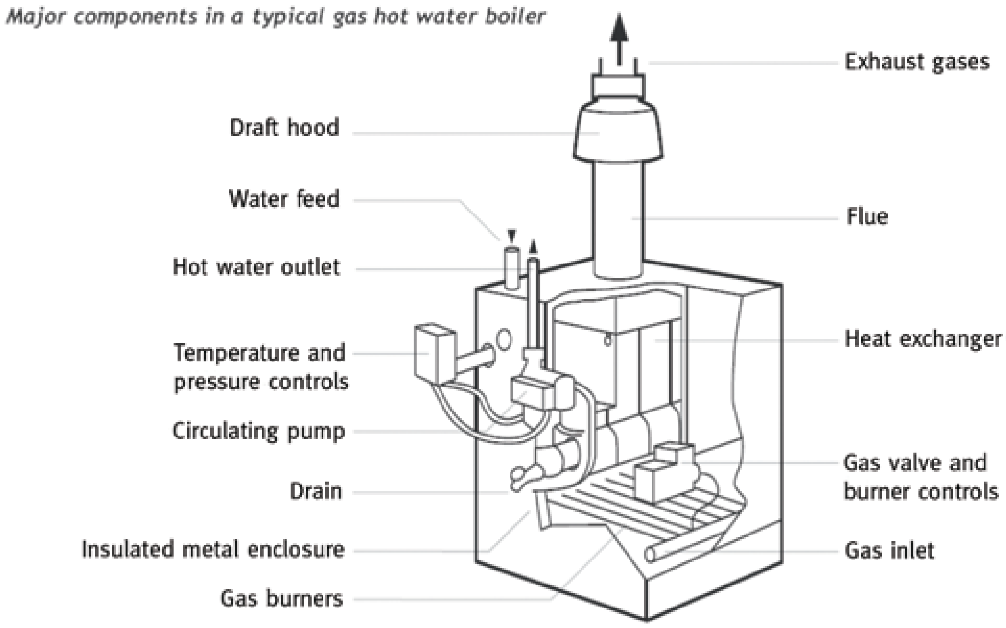


Figure 14: Typical gas-fired hot water system.[10]

Appendix C Process heating system overview

Process heating systems generally transfer energy from a fuel source to a product. The enormous range of industry-specific processes and technologies makes it impossible to consider all variants in this guide. A typical process heating system can be characterised as follows (Figure 15).

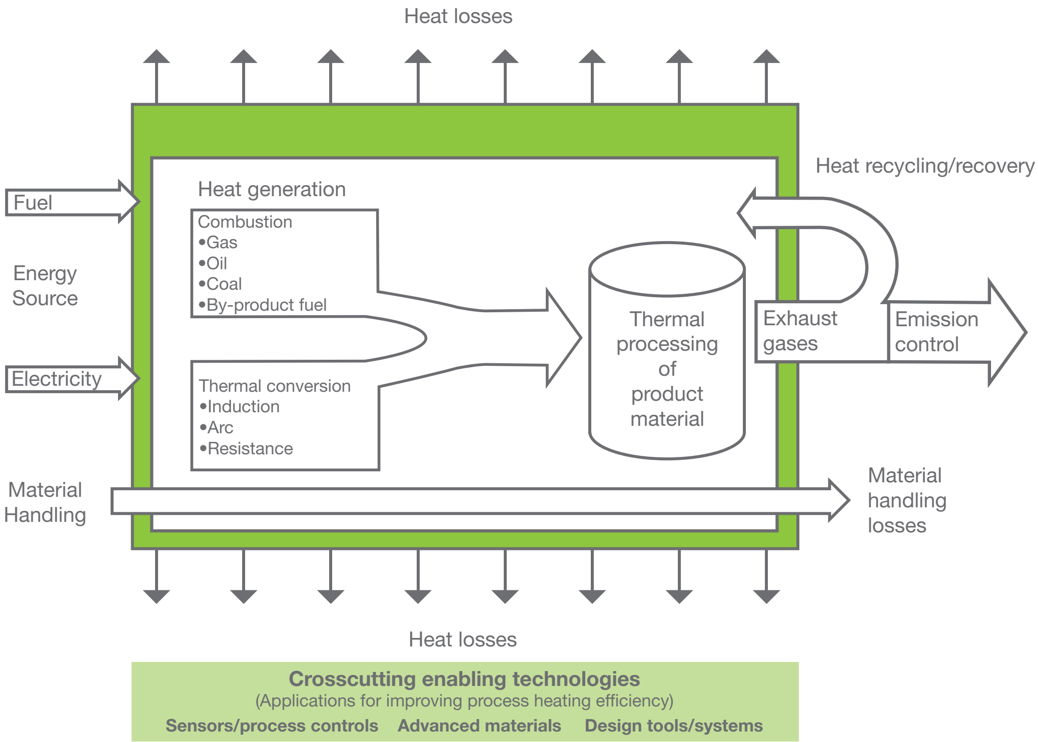


Figure 15: Key components of a process heating system.[2]

Key components in a process heating system are:

- fuel or electricity supply – gas line, electricity distribution board
- heat generation equipment – boiler, furnace, dryer, resistance
- heat transfer method – convection, radiation, fluid heat transfer
- material handling system – fluid, conveyor, roller, rotary heater
- heat recovery system – heat exchange between exhaust gases and intake combustion air
- exhaust emissions – furnace flue.

Process heating systems can be classified in a number of ways, as shown in Table 5 below. Two such classifications are the *mode of operation* and the *heating method.* The mode of operation distinguishes how the material is moved through the process:

- Batch: a set amount of material is processed at a time, before moving on to allow the next batch, in a start/stop fashion.
- Continuous: The material moves through the process at a constant rate.

The heating method is usually one of the following:

- Direct: heat from combustion is applied directly to the material, therefore, the combustion gases are in contact with the material and open burners or heating elements are used.
- Indirect: the material is separated from combustion. Heat is transferred using gases or liquids and heat exchange takes place with the material. Indirect heating equipment includes radiant burner tubes and covered electrical heating elements.

There are also a large range of energy sources and material handling systems used.

Table 5: Process heating classification.[2]

Furnace Classification Method	Equipment/Application Comments	Primary Industries
Batch and continuous		
Batch	Furnaces used in almost all industries for a variety of heating and cooling processes	Steel, aluminium, chemical, food
Continuous	Furnaces used in almost all industries for a variety of heating and cooling processes	Most manufacturing sectors
Type of heating method		
Direct fired	Direct-fired furnaces using gas, liquid or solid fuels, or electrically heated furnaces	Most manufacturing sectors
Indirect fired	Heat treating furnaces, chemical reactors, distillation columns, salt bath furnaces	Metals, chemical
Type of energy used		
Fuel fired	Process heaters, aluminium and glass melting furnaces, reheat furnaces, ovens	Most manufacturing sectors
Electrically heated	Infrared ovens, induction melting and heating furnaces, electric arc melting furnaces	Metals, chemical
Steam heated	Dryers, fluid heating systems, water or slurry heaters, tracing	Pulp and paper, chemical, petroleum refining, food
Other	Air heaters, polymerising heaters, frying ovens, digesters, evaporators	Chemical, food
Material handling system		
Fluid heating (flowthrough) systems	Gaseous and liquid heating systems including fluid heaters, boilers	Petroleum refining, chemical, food, mining
Conveyor, belts, buckets, rollers	Continuous furnaces used for metal heating, heat treating, drying, curing	Metals, chemical, pulp and paper, mining
Rotary kilns or heaters	Rotary kilns used in cement, lime, heat treating, chemical and food industry	Mining, metals, chemical
Vertical shaft furnaces	Blast furnaces, cupolas vertical shaft calciners, and coal gasifiers	Metals, petroleum refining
Rotary hearth furnaces	Furnaces used for metal or ceramics heating or heat treating of steel and other metals, iron ore palletising	Metals
Walking beam furnaces	Primarily used for large loads such as reheating of steel slabs, billets, ingots	Metals (steel)
Car bottom furnaces	Used for heating, heat treating of material in metals, ceramics and other industries	Metals, chemical, ceramics
Continuous strip furnaces	Continuous furnaces used for metal heating, heat treating, drying, curing	Pulp and paper, metals, chemical
Vertical handling systems	Primarily for metal heating and heat treating for long parts and in pit, vertical-batch and salt-bath furnaces	Metals, chemical, mining
Other	Pick and place furnaces	Most manufacturing sectors

Efficient energy sources

A number of different energy sources can supply your process heating application. These include:

- heat recovery
- natural gas
- electricity
- steam
- liquid propane gas
- diesel
- fuel oil
- coal
- cogeneration.

Heat recovery is the use of exhaust or return fluids from a process to heat a process or assist in making combustion more efficient. It should always be considered first as a supplement to your primary energy source. Examples of heat recovery are:

- Using furnace exhaust gases to heat intake combustion air via a heat exchanger.
- Using engine cooling water to heat a process.
- Using return low-pressure steam to heat a process.

While in some cases the ease of access to gas or electricity might make it tempting to perform heat generation solely with these fuels, the extra time and investment required to make use of heat recovery techniques may save you money in the long term.

Cogeneration is the generation of electricity and use of waste heat in the same step. Gas is combusted on-site to drive an engine. This engine is then used to drive an electric generator and so some electricity needs of the site can be met. The gas engine requires considerable amounts of cooling water and has hot exhaust gases. Through the cooling process, water may be heated to as high as 90°C. Steam can also be recovered. The cost effectiveness of this is very dependent upon the relative prices of gas and electricity at your business.

Your choice of the energy source for your process is a very important one and is worth reassessing at regular intervals. While your current energy source may have been suited to your business needs at the time of installation, a change in your process needs may mean that a different energy source may now be more appropriate, and more effective. Also, changes in the market price of different energy fuels may mean that is now cost effective to switch fuel source, despite the high installation cost. In order to make an informed decision on the best choice of energy source for your process heating application you may wish to contact a process heating service provider.

Appendix D Glossary

Term	Meaning
absorption cooling	A form of chilling to produce process cooling (cold air or chilled water) that uses heat as the predominant input energy source, as opposed to an electric chiller that uses electricity to drive a compressor
blowdown system	System for removing sludge and suspended solids that build up internally in a boiler system. Improves efficiency and increases life of boiler
boiler	Device that produces steam for use in a process
boiler interlock	Mechanism for preventing dry-cycling in a boiler
capacity utilisation	A ratio of the average output/throughput of a boiler (or other piece of process equipment) compared to the rated capacity/throughput
cascading	A method of using waste heat from the first process to be used in a subsequent process and so on
condensate	In the context of an enclosed industrial steam system, it is steam which has been converted from a vapour to a liquid, and in the process, has given up the majority of its heat
condensate return	System for recapturing condensate back to a boiler, and that allows the heat within condensate to be reused
coefficient of performance (COP)	A measure of the efficiency of a refrigeration system defined as cooling duty (kW) / input power (kW)
de-aerator	System for removing oxygen, carbon dioxide and other gases that could potentially increase corrosion in a boiler system
dry-cycling	Unnecessary firing cycles in the boiler when heating is not required in the process
economiser	System to capture waste heat from boiler exhaust to pre-heat feed water or some other process
flash steam	Saturated steam generated as a result of hot condensate going from a high pressure to a low pressure
flue	Exhaust for hot water boiler
heat pump	In industrial applications, hot water can be generated by a heat pump that moves heat from one process, or the atmosphere, to a hot water system
heat recovery	The capture of waste heat to be used in another processes (such as domestic hot water, preheating of boiler make-up water)
hot water pump	Circulates hot water around the plant for use in processes
pre-heating	The act of heating a product before the intake to the primary heating system

Term	Meaning
separator	Separators are used to removed condensate as well as air from a boiler system to help prevent corrosion
sequence control	Ability to control multiple boilers such that only required number of boilers are switched on
steam accumulator	A method of storing steam for use in high demand periods, which can help stabilise the boiler operation
steam piping	Pipe meeting national and international standards of material and wall thickness for carrying steam
steam trap	System for preventing live steam from escaping the steam system, usually by collecting condensate before ejecting as water
turndown ratio	The ratio of the lowest heating capacity to the highest heating capacity in a boiler

Appendix E Further Reading / References

Further Reading

More information about developing a business case for investing in your plant's energy efficiency, as well as detailed technical information about hot water, steam and process heating systems, can be found in the following resources available freely on the Internet.

Steam
Energy Efficient Operation of Boilers, Good Practice Guide GPG369, Carbon Trust, UK, March 2004
www.carbontrust.co.uk/publications

Fundamentals of Steam System Design: A Self-Directed Learning Course, American Society of Heating, Refrigerating and Air-conditioning Engineers, US
www.ashrae.org/education/page/761

Improving Steam System Performance – A Sourcebook for Industry, US Department of Energy – Office of Energy Efficiency and Renewable Energy, US, October 2004
www.eere.energy.gov/topics/industry.html

Is Oxygen Trim Worth the Price?, Blesi-Evans, US, November 2007
www.blesi-evans.com/techarticles.htm

Steam System Survey Guide, Harrell G., Oak Ridge National Laboratory, US, May 2002
www1.eere.energy.gov/industry/bestpractices/pdfs/steam_survey_guide.pdf

Hot water
Low Temperature Hot Water Boilers, Technology Overview CTV008, Carbon Trust, UK, March 2006
www.carbontrust.co.uk/publications

Steam and High Temperature Hot Water Boilers, Technology Overview CTV018, Carbon Trust, UK
www.carbontrust.co.uk/publications

Process heating
Improving Process Heating System Performance – A Sourcebook for Industry, US Department of Energy – Office of Energy Efficiency and Renewable Energy, US, September 2004
www.eere.energy.gov/industry/bestpractices/pdfs/proc_heat_sourcebook.pdf

Process Plant Insulation and Fuel Efficiency, Fuel Efficiency Booklet FEB019, Carbon Trust, UK, 1993
www.carbontrust.co.uk/publications

Case studies
There are many examples of businesses that have recognised inefficiency in their business processes and made an investment in becoming more energy efficient, with huge benefits for their bottom lines. Detailed case studies of the businesses can be found at Sustainability Victoria's website at www.sustainability.vic.gov.au

References

1 Improving Steam System Performance: A Sourcebook for Industry, US Department of Energy, pp 3 & 30, October 2004

2 Improving Process Heating System Performance: A Sourcebook for Industry, US Department of Energy, p 3, September 2004

3 Low Temperature Hot Water Boilers Technology Overview, Carbon Trust, UK, p 2, March 2006

4 Energy Efficient Operation of Boilers, Carbon Trust, UK, pp 4–6, March 2004

5 Steam System Survey Guide, Harrell G., Oak Ridge National Laboratory, pp 2-19, US, May 2002

6 Sustainability Victoria

7 Low Temperature Hot Water Boilers Technology Overview, Carbon Trust, UK, pp 2–18, March 2006

8 Spirax Sarco International website, November 2007 www.spiraxsarco.com

9 BIB Cochran International website, November 2007 www.bibcochran.com

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