

Hot Water Systems, Boilers, and Waste Heat Systems

Making minor adjustments to hot water systems, boilers and waste heat systems can improve their efficiency and result in significant savings with little capital outlay. This will not only save your business money but will also reduce greenhouse gas emissions.

In many industrial processes, a large proportion of the energy used ends up in the form of waste heat that often needs to be removed. Mechanical means, such as fans or cooling water circuits, are often required to remove this heat with a corresponding increase in energy use and costs. By recovering this waste heat and utilising it for other uses, you can reduce your energy consumption and costs.

Facts and Figures

- Energy recovery is the beneficial use of heating or cooling energy that would otherwise be lost or would need to be removed from a specific space.
- Only 55% of the heat produced by a typical boiler is recovered as usable steam, although up to 90% is often achievable.
- Small steam leaks can cost hundreds of dollars each year.
- Many boiler installations could be operated more efficiently. Fuel efficiency is often more than 5% below optimum.
- Water heating can account for up to 20% of energy used in many small businesses, such as restaurants.
- Hot water system temperatures are often set higher than necessary. For each 5°C reduction in water temperature, energy consumption can be reduced by between 3% and 5%.
- Heat can be recovered from boiler flue gases by using a heat exchanger to preheat boiler makeup water or boiler combustion air.



Photograph: Peter Garside, Alcoa

Hot Water Systems

Hot water systems are used in industrial and commercial facilities, either for general hot water use or for space heating. Regardless of what the water is used for, it is vital to ensure that the demand for hot water is as low as possible and that daily hot water demand is as uniform as possible.

The energy used to heat hot water can be reduced by ensuring that the heating process is as efficient as possible and losses that may occur in the distribution system between the heating plant and the load are minimised.

Types of Systems

The two main types of hot water systems available on the market today are instantaneous water heaters (continuous flow water heaters) and storage water heaters. When purchasing a new system, or modifying an existing installation, your decision should be based on the:

- requirements for hot water.
- efficiency and running cost.
- capital cost.
- life expectancy of the system.

Instantaneous (continuous flow) hot water systems

Water is heated as it is needed and therefore a storage tank is not required, saving on the purchase cost and energy losses. They can operate on natural gas, LPG or three phase electricity. As water is heated instantaneously, these systems do not run out of hot water.

Instantaneous hot water systems are generally smaller than storage systems. Smaller sized instantaneous units can be mounted on a wall or in a cupboard. They can be installed externally or internally. There are however, restrictions on installing gas hot water systems indoors. Some gas hot water systems need to have a pilot flame ignited at all times, which costs you money. You should consider turning the pilot flame off if you are going away for an extended period of time or look for a model with an electric pilot light.

Hot water from instantaneous systems is often delivered at a slightly reduced pressure and standard units can generally deliver adequate hot water to only one tap at a time. When a second tap is turned on,

the pressure and temperature of the water will drop. High-powered units are available which can service larger flow rates and several taps.

Storage hot water systems

These systems store hot water in an insulated tank ready for use throughout the day. Storage systems generally have only the one heat source, such as an electric element or a gas burner. They can however, use a combination of fuel sources, such as a solar thermal collector, with a booster inside the tank or with an instantaneous heater in line with the supply water.

Heat pump storage hot water systems use less energy than other storage hot water systems. They use a compressor and a refrigerant gas to extract heat from the air (in much the same way as heat is extracted from a refrigerator) to heat the water stored in the tank.

When purchasing storage hot water systems it is important to consider the size of the tank and you should discuss this with your supplier. If the tank is too small for the task, hot water can temporarily run out. If the tank is too large, your operating costs will be unnecessarily high.

Heat is also lost from the tank. These losses depend on the temperature setting, the tank size and the tank's insulation. The smaller the tank, the less your daily tank heat losses will be.

Typically storage heaters are best suited to situations where demand for hot water is relatively consistent. If the demand for hot water is inconsistent or infrequent, instantaneous heaters may be better suited.

Energy Rating Labels

All new domestic gas hot water systems (except gas-boosted solar hot water systems) display energy labels with star ratings for energy efficiency. Electric hot water systems currently are not required to carry energy rating labels.

For a given size, the more stars (six is best) the less gas used and the lower the operating cost. This also means reduced greenhouse gas emissions. Rating labels will also tell you the expected annual energy consumption in megajoules (MJ), based on a consumption of 200 litres per day. To convert MJ to kWh units as on your gas bill divide by 3.6.

Solar Water Heaters

Solar water heaters can be used as stand-alone systems or as boosters for existing systems. Those that are coupled with an efficiently controlled booster can significantly reduce energy consumption and costs. Over the life-time of the system, savings in the order of thousands of dollars can be made.

An efficient solar water heater can also reduce greenhouse gas emissions when compared with conventional water heating systems.

The size of the system best suited to your needs will depend on the size of your business, the amount of hot water usage and the temperature required. If you have large hot water requirements, it is recommended you contact a solar water heater manufacturer for advice on the cost and potential savings from installing a solar water heater at your business.

There are also State and Federal Government schemes that provide rebates for installation of solar water heaters. Your solar water heater distributor will be able to advise you of the rebates that are available.

More information on 'domestic sized' hot water systems is available from the Sustainable Energy Development Office's Energy Smart Line. Simply call **1300 658 158** or alternatively visit our website at www.sedo.energy.wa.gov.au

Hot water systems, boilers, waste heat systems and the environment

When fossil fuels such as coal or natural gas are burnt at power stations to generate electricity, they create greenhouse gasses that contribute to global warming. By reducing your energy use, you not only cut your costs but you reduce greenhouse gas emissions.



Boiler systems

Boilers and steam systems are a very common source of heat for a wide range of industrial plants. The actual cost of the steam produced by a boiler will depend on the path the steam follows from the boiler to the point of use.

Choosing a boiler

The boiler best suited to your business will depend on a number of factors, including the:

- demand profile of your heat requirements.
- fuel source.
- quality of the feedwater.
- space available for installation.

Determine how much you pay to make steam

Conducting a cost analysis will provide you with an account of the potential savings you can gain. You should look first at those areas of the system where improvements in boiler efficiency can be made relatively easily.

Boiler efficiency

Boiler efficiency is a measure of the energy into the boiler versus the energy contained in the useable heat out. This is represented below.

$$\text{Efficiency} = \frac{E_{\text{out}} - E_{\text{loss}}}{E_{\text{in}}}$$

Where; E = energy

The more efficient the boiler the less energy it consumes, hence the lower the cost to you and the lower the impact on the environment.

The most significant losses from boiler systems are due to:

- stack losses from excessive flue gas volume, (ie too much air) and heat in flue gas, (ie too high a temperature).
- combustion losses from incomplete combustion of fuel, (ie. insufficient air) or poor mixing.
- losses from poor insulation of the boiler and steam/water distribution system.
- excessive boiler blowdown, which effectively ejects useful heat from the boiler. Raw feedwater for boilers generally contains dissolved solids, including minerals, which is removed during conversion to steam. If the total dissolved solid (TDS) levels in the boiler get too high, operation or maintenance problems can occur. The TDS level is controlled by 'blowing down' a quantity of water from the bottom of the boiler and replacing it with clean feed water, effectively lowering the TDS levels.
- boiler short cycling, which occurs when an oversized boiler quickly meets the process or space heating demands and then shuts down until heat is again required. There is a decrease in efficiency because fixed losses are magnified under lightly loaded conditions.

- leaks in the distribution network and poorly maintained steam traps. Malfunctioning steam traps allow the condensate to drain out from the equipment.

Optimising your boiler system

It is important to establish your current level of combustion efficiency before you begin to improve the effectiveness of your boiler. Opportunities to improve the efficiency and reduce the costs of running your boiler and steam system can often be made in the following areas.

Reduce Stack Losses - operating your boiler with an optimum amount of combustion air will minimise heat loss via the stack and improve combustion efficiency. In some cases it may also be effective to recover heat from the boiler flue gases to heat the boiler makeup water or the boiler combustion air using an economiser or air pre-heater designed for this purpose.

Reduce combustion losses - these are generally low for gas or oil-fired boilers with sufficient combustion air. For fuel oil, poor atomisation increases unburnt fuel loss. In solid fuelled boilers unburnt fuel can be a significant factor.

Reduce radiation losses - the amount of heat lost from bare pipes and surfaces can be minimised by considering a number of factors, including the:

- physical condition of the surfaces. A rough texture will have a greater surface area to diameter ratio and hence higher losses than a smooth surface.
- temperature of the surface. High surface temperature means high heat loss.
- surrounding conditions. Minimising air or water flow across surfaces will reduce losses.

Ambient/Pipe Temperature Difference	50°C	75°C	100°C	150°C	200°C	300°C
Pipe O.D						
25 mm	43	90	147	285	455	910
75 mm	97	200	340	640	1,000	2,150
125 mm	148	320	500	980	1,560	3,300
250 mm	260	550	740	1,750	2,900	6,000

Table 1: Losses (watts per linear metre) of un-insulated pipe.

- insulation of boiler and pipework. The optimum insulation thickness is a balance between decreasing the heat loss and increasing the insulation cost. The most economic insulation thickness is where the total cost (the sum of the cost of the insulation and the cost of the lost heat) is at a minimum. As a rule-of-thumb, a 90% reduction in bare pipe heat loss (watts per metre) is used as an initial estimate of the heat loss reduction from installing insulation. The table above shows typical losses in watts/linear metre of un-insulated pipe.

Optimise production pressures

- Ensure that pressure at the process is reduced to the lowest possible useable value. Less energy is used producing steam at lower pressures.
- You can also minimise distribution losses by producing and delivering steam as near to system design pressure as possible.
- Latent heat can be lost in the moisture in the steam. To prevent this heat loss, steam must be as dry as possible.

Reduce Boiler short cycling - if possible, shift loads from a large boiler to a smaller one. Fuel savings can often be achieved by adding a smaller boiler sized to meet average loads at your facility. If possible, the plant could be re-engineered to consist of multiple small boilers. Alternatively, consider the feasibility of re-scheduling loads to help optimise boiler system performance.

Minimise boiler blowdown and condensate loss - for improved efficiency, boiler blowdown must be optimised. Too little blowdown will build up sludge and reduce heat transfer efficiency and water flow in boiler tubes, resulting in operational problems. Conversely, too much blowdown results in the loss of too much hot water with consequent increases in fuel costs, boiler feedwater consumption and water treatment chemicals.

The most effective way of reducing boiler blowdown is to maximise the amount of condensate return as condensate is typically free of minerals. This reduces the amount of fresh feedwater and thus the amount of dissolved solids entering the system. It also helps reduce the thermal load on the waste water system and provides the potential for using low pressure flash steam from the condensate with no additional thermal energy input. Other ways of maximising condensate return include:

- slope piping down to appropriately located drainage points so that all condensate is efficiently drained.

- check to see if the feed water tank is insulated and covered adequately to prevent evaporation.
- identify and quickly repair steam leaks in your steam system.

Maintain steam traps and check for leaks - regularly check your boiler and distribution pipework and fittings for leaks. This can be undertaken as part of the facility maintenance program. Well maintained steam traps will not only save you money through more efficient use of the steam but will also assist the removal of air from the steam system. Air mixed with steam reduces steam temperature and, consequently, heat transfer. Correctly operating valves will also reduce the maintenance requirements of the system as this will reduce water hammer.

Distribution Systems - hot water systems typically include a distribution system to transport hot water from the heater to the point of use. You can minimise energy losses by:

- reducing the distance hot water has to travel from the heater to the point of use.
- regularly checking for pipe leaks.
- repairing or installing insulation on the piping system.





Waste Heat Recovery

Recaptured waste energy can be used for water heating, space heating or cooling and for other energy using processes, such as heating incoming process streams. An alternative method for utilising waste energy is to match a process stream that requires heating against a process stream requiring cooling.

Depending on the type of process, waste heat transfer can be in a form of a positive heat flow (heating) or a negative heat flow (cooling). The potential benefits from heat recovery can include:

- reduced operating costs through reduced energy consumption.
- lower capital costs for heating or cooling plant (e.g.; smaller boilers, smaller and chillers).
- reduction in pollutants and greenhouse gas emissions due to lower overall fuel consumption.
- conservation of non-renewable energy resources.

Applications of Waste Heat Recovery

In most cases, recovery of heat requires additional equipment and a detailed analysis will be required in order to evaluate the potential benefits of a project. Heat recovery is best suited for continuous operations and can be used:

- to heat incoming process streams (e.g. preheating boiler feed water or domestic hot water).
- as a heat source for processes requiring a lower temperature (e.g. cleaning water).
- for preheating the combustion air of boilers, dryers, ovens and furnaces.
- for cooling streams by extracting energy from the disposal of chilled water or other fluids.

Considerations for utilising waste heat

When assessing the viability of using waste heat some important factors to consider other than the temperatures of the source and process streams are:

- What are the operating hours of the heat source and heat load? Typically high operating hours (e.g. greater than 3,000 hrs per year) are required for a project to be economically viable. Fuel costs must also be considered.
- Are the source and load close to each other? The shorter the physical distance between the waste heat source and the heat requirement area, the more attractive the project.
- The nature of the mediums (e.g. corrosiveness, presence of solid matter) can have a significant impact on a project. Corrosion resistant exchangers cost more.

- An optimised system will have the heat producer and the heat user 'in phase', rejecting only low grade heat to the atmosphere. Continuous steady-state operation is the ideal condition for the economic viability of heat recovery.
- For non-continuous process operations, the waste heat may have to be stored before use. A full feasibility study is likely to be required to assess the benefits of heat storage systems.

To fully ascertain the potential for utilising waste heat at your business it is recommended that you contact an engineer or waste heat specialist.

Merging Heating Requirements

System optimisation involves getting the best out of your system – making sure it doesn't waste valuable energy through neglect, wastage, or poor management. There are synergies between the production of steam and hot water and the utilisation of waste heat. Evaluate your site using all energy inputs and outputs to determine how you can save money.

Hints to improve energy efficiency

- Explore opportunities to reduce hot water use.
- Maintain your system in good condition.
- Install properly designed flow restrictors. These can be applied to hand basins and showers to regulate the amount of hot water deliverable from that outlet.
- Keep hot water pipe runs as short as possible to minimise system heat losses.
- Storage vessels should all be insulated. Insulating all hot water pipes is not always cost effective but should be considered where long pipe runs occur, where pipe runs are in exposed situations or in areas with colder winters. If distribution pumps are needed, locate them on the return leg.
- If purchasing a 'domestic sized' gas hot water system, check the star rating labels - the higher the stars the more energy efficient the hot water system.
- Set appropriate temperature limits on gas instantaneous hot water systems. Some have electronic temperature controls which can be adjusted from a remote control unit.
- Electronic ignition units use no gas at all when not being used. However, be aware that mains electricity ignition systems may not supply hot water during power 'blackouts'.
- Use gas-fired systems if installing a storage system. Gas storage systems usually reheat water more quickly than electric systems, so the tank size can usually be smaller than for an electric system.
- Keep storage temperatures to a minimum and consider installing a timer to turn storage hot water systems off after hours. High settings increase heat losses and accelerate equipment failure. Note that because storage water heaters can harbour Legionella a temperature setting of 60° Celcius is generally recommended. For more information check with your local health authority or the Department of Consumer and Employment Protection.
- If solar hot water collector panels are used, these should be installed to face as close to north as possible.
- Size your unit to meet the requirements of the maximum number of hot water outlets likely to be used simultaneously.
- Use stand-alone systems for general hot water use, as this will reduce standing losses, unless boilers operate year-round to meet base load heating.
- Where there is a limited requirement for higher temperature water, use a separate high temperature water heater to service that demand.
- Use off-peak energy to heat your water. This will reduce costs, but not energy consumption. If you have an electric water heater install a time clock on your unit. Check with your electricity supplier to find out if it offers time-of-use rates for small business customers and, if so, what the rate schedules are.
- If you have a suitable waste heat source, use it to preheat your hot water.
- Turn pumps off outside of normal operating times.



Photograph: Griffin Group

More Information

If you would like more information regarding hot water systems, boilers, and waste heat systems you should contact an engineer or consultant. To find one in your area visit the website www.energysmartdirectory.com. Information on choosing domestic-sized hot water systems and other energy saving advice for business is available from the Sustainable Energy Development Office's Energy Smart Line. Simply call **1300 658 158**. Alternatively, visit our website at www.sedo.energy.wa.gov.au

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