A guide for business:

# Replacing steam with electricity technologies to boost energy productivity

***Capturing business benefits using high energy productivity, Industry 4.0 enabled, electric technologies***

**AUTHORSHIP OF THIS REPORT**

This report is published by the Australian Alliance for Energy Productivity (A2EP). A2EP is an independent, not-for profit coalition of business, government and environmental leaders promoting a more energy productive and less carbon intensive economy.

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**ACKNOWLEDGEMENTS**

A2EP would like to thank the NSW Office of Environment and Heritage, Sustainability Victoria, Clean Energy Finance Corporation and Climate-KIC Australia for funding this work.

A2EP would also like to thank the many stakeholders who generously gave their time to provide valuable input and insights in the preparation of this report.

*Note: Acknowledgement of this support does not indicate stakeholders' endorsement of the views expressed in this report.*

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## Why address process heating?

Steam was a valuable medium for heating in the past, providing excellent heat transfer and energy density. But central steam systems are a poor match for the requirements of the Industry 4.0 world – which requires digital control, accurate measurement, and great flexibility.

This guide aims to assist businesses to replace central boilers and steam reticulation systems with distributed (point of end use) alternatives to steam heating, which are more responsive to changes in plant conditions and can be readily digitalised for integration with Industry 4.0.

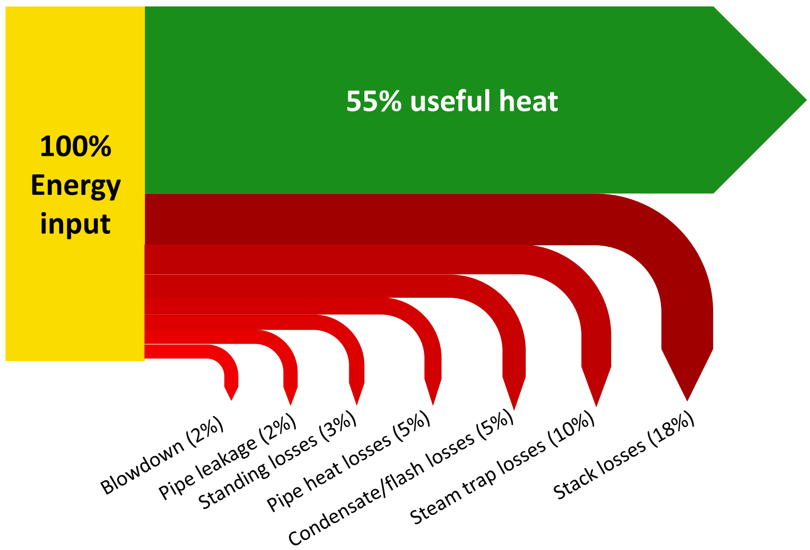
By doing this it is possible to substantially improve energy productivity - not just through energy savings, but also increased value through better reliability/less downtime, improved working conditions, reduced maintenance costs and reduced water use.

Food, beverage, textile and other facilities use steam in a range of processes from boilers fuelled by natural gas (or other fossil fuel), with steam circulation and condensate return.

Often the end process heating requirement is at a much lower temperature than the steam is supplied at. And often the actual process requirement is for heating to a temperature well below 100°C.

Central steam systems are much less efficient than what most operators believe. The large scale of losses is generally hidden by the lack of measurement – steam flows are expensive to measure and often inaccurate. The diagram below shows the sources of losses in a typical system running at full load, **excluding** the large standing losses of a standby boiler. At part-load operating conditions, the efficiency rapidly falls further due to the large fixed losses, resulting in less than 35% of the energy in the gas burned delivering useful heat to the process.

***Central steam systems waste a lot of energy even operating at full load***



## Process heating applications

If we want to consider alternatives to steam systems, we need to understand the purpose of providing heat to each process where it is used. Steam heating is typically used in:

- Food processing for removing water (concentrating, crystallising, drying), preserving, cooking, and cleaning.
- Other industries for forming, melting, or to promote chemical reactions.

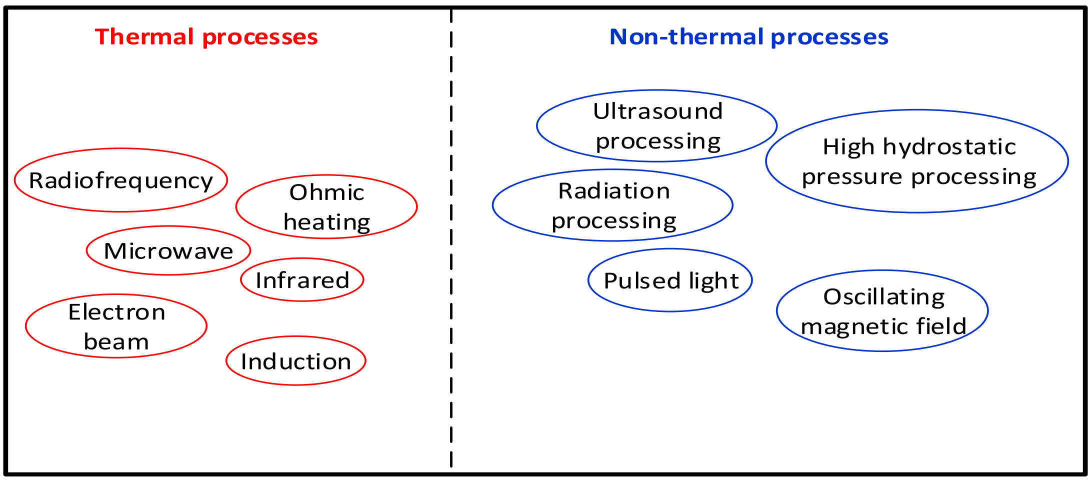
This guide is primarily focused on process heating in food/beverage processing.

[1]The food and beverage sector consumed 14.5% of total energy consumed by manufacturing in 2015-16 and generated 33% of the total value. Note that food and beverage processing activities extend well outside the manufacturing sector as measured by Australian Bureau of Statistics.

Both thermal and non-thermal alternatives to steam heating may be used to achieve the ultimate outcomes that are desired on food processing sites:

1. **Dewatering** - the most energy efficient way to remove water is natural/forced evaporation, followed by mechanical dewatering, and the least efficient is boiling off water.
2. **Preserving** – thermal preservation requires heating to over 70°C and up to 100°C to kill pathogens in food. Preservation can also be achieved by using non-thermal processes to kill bacteria. Non-thermal processes tend to be more energy efficient and may result in a better-quality product because thermal processing may alter the product characteristics.
3. **Cooking** generally needs to raise the food to 100°C+ and often involves some level of dewatering.
4. **Cleaning process plant** – requires heating to over 70°C and up to 90°C to kill pathogens.

***Alternatives to boiler systems: Thermal and non-thermal processes***




[1]https://www.energy.gov.au/sites/g/files/net3411/f/energy-update-report-2017.pdf

## Alternatives to boiler systems

The diagram on the previous page shows there are many electric technologies that can replace fossil fuel-based steam systems. These are point of end use technology applications, which are matched with a specific process need, and thus may only operate when that process is operating. The choice of technologies to best address a process need requires careful examination of each specific process.

In this guide, we are not able to address all electricity technologies and applications, but instead focus on the most generally applicable options:

1. **Mechanical dewatering technologies to reduce the drying task**
2. **Electro-technologies to replace thermal processing for preserving**
3. **High energy productivity electro-technologies for heating/cooking**
4. **Heat pump technology - waste heat recovery and co-producing heat and cold**

Once high productivity electricity technology options for displacing steam heating that are cost effective are applied, if there are still some applications that need steam then consider:

5. **High efficiency localised packaged boilers.**

# 1. Mechanical dewatering to reduce drying

Evaporating water uses large amounts of energy. Evaporating one litre (1 kg) of water requires about 2.3 MJ (0.64 kWh) of thermal energy. In practice, taking into account dryer efficiency, much more energy may be consumed.

Removing water using free ambient energy or mechanical methods can be far more energy efficient. Options may include ambient forced evaporation using an efficient fan system, microfiltration using membranes to separate water from product, centrifuging (high speed rotation), and crushing. Combinations of technologies can be used in series, and partial dewatering can be done before cooking.

Energy productivity improvements associated with these technologies may include:

- Reduced energy use
- Reduced capital costs of equipment
- Improved quality and consistency of product, e.g., improved extraction of juice from grapes increases wine production, while capturing more flavour
- Reduced quantities of material to be transported and processed, if dewatering can be conducted earlier in the value chain.

Note that a dewatering process could be used in tandem with a heat pump drier to achieve high energy productivity.

**Example: Concentrating milk using reverse osmosis**

Normally milk is transported with its full water content and dewatered thermally at the processing plant using spray dryers. An alternative, membrane dewatering, is far more energy efficient than thermal drying.

Reverse osmosis technology is suitable for on-farm use where a large farm is a substantial distance from the processing plant (noting care must be taken to maintain low bacterial levels in this additional process step), for inter-factory transfers of milk and milk products, and for sales of bulk milk products interstate and internationally.

It has been demonstrated that milk can be concentrated to 50% of the original volume without adversely affecting the quality of the milk.

This process can be used at the milk processing plant before the driers, but then loses the transport energy saving benefit.

***Reverse osmosis at Yanakie Dairy Farm, Vic***

*Image: https://www.clearwater.asn.au/*

## 2. Electro-technologies for preserving food

Pasteurisation is common in industrial processing to kill bacteria, by heating to a temperature of 65-75°C for a specified period: the higher the temperature, the shorter the period required, but the greater risk of changing flavours or textures.

**Alternative options replace heat with other mechanisms to kill pathogens**

These technologies reduce or avoid the need for heat. Fuel consumption is thus displaced with electricity, often at much higher energy productivity. The net impact on energy cost and loads on energy infrastructure needs to be considered. Alternative processes may offer value-adding benefits, such as extended shelf life or maintenance of more attractive texture or taste.

***HPP for pasteurising fruit juice***

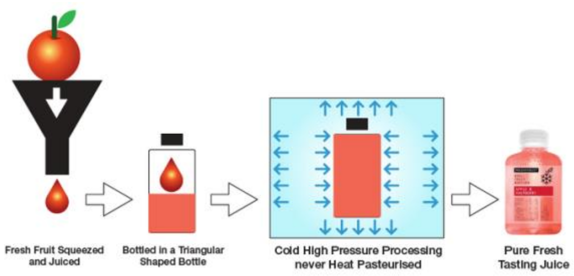



*Image: http://www.preshafruit.com.au/process.html*

Technologies that avoid traditional thermal heating are emerging, though some have been available for many years. They include:

- High pressure processing
- Microwave
- Ultrasonic
- Irradiation (electron beams, X-rays),
- Ultraviolet light (especially suitable for sterilising containers).

In some cases, it is possible to maintain sterile production conditions so that pasteurising is not needed when the product is to be consumed fairly soon, and the cold chain can be well managed, or advanced packaging is used.

**Example: High pressure processing (HPP)**

HPP uses very high pressures in the range of 300-600 MPa instead of heat processing to kill yeasts, moulds and bacteria. It can be used across a range of product categories such as juices, meat, poultry, seafood, fruit and vegetable products, meal solutions, dips and sauces.

HPP technology has the potential to extend the shelf-life of cooled perishable products, e.g. juices produced using HPP can be stored up to five times longer than other chilled juices. HPP also provides improved safety, taste, texture, quality, fresh-like characteristics and nutritional value, without having to use chemical preservatives.

# 3. Electro-technologies for heating and cooking

Convection-based heating using hot gas or a flame relies on conduction of heat through the bulk of the material. Electro-technology processes, such as microwave and radio frequency, can more accurately target and deliver energy to the point of use volumetrically.

In radio-frequency (RF) heating, material with polar molecules content is conveyed between two electrodes with alternating polarity. The alternating polarity makes the polar molecules, like water, re-orient continuously. The friction caused by this molecular movement rapidly heats up the material throughout.

RF heating can be employed in a large number of thermally driven processes:[2]

- Drying textiles, fabric and garments
- Drying hydrophilic foams
- Post baking drying and moisture control of food products
- Drying water-based coatings, ink, and adhesives
- Heat treating, de-infestation of bagged products
- Pasteurisation of food products.

Ultrasound processing uses interaction between materials and sound waves with high frequency not audible by the human ear. This technology can be used across a range of applications in industry including crystallisation, drying, degassing, extraction, filtration, homogenisation, meat tenderisation, oxidation, and sterilisation[3].

**Example: Microwave radio-frequency**

Microwave RF generates heat in snack food mainly in areas with more moisture content.


*Image: www.radiofrequency.com*

**Example: Ultrasonic extraction**

Ultrasonic extraction from herbs.

*Image: www.hielscher.com*

[2] http://www.radiofrequency.com

[3] http://www.dolcera.com

# 4. Heat pumps

Industrial heat pumps use a refrigeration cycle to very efficiently upgrade low temperature heat from the environment to useful, higher temperature levels.

Heat exchangers, which are cheaper than heat pumps, can be used when the waste heat stream is at a high enough temperature to be recovered for use at a lower, but still useful, process temperature. But where the temperature needs to be raised, heat pumps can be used.

The most economically attractive applications occur where heat pumps can be used to upgrade heat from waste streams (e.g. condenser heat from refrigeration systems) and/or capture latent heat (e.g. hot humid air from dryers), and where simultaneous heating and cooling duties can be delivered.

The efficiency of a heat pump is denoted by its 'coefficient of performance' (COP), e.g. a COP of 3 means three times as much heat energy is delivered as the amount of mechanical work input from the compressor. The COP is higher where the size of the temperature 'lift' is lower and when heat exchanger area or heat transfer efficiency is greater.

**Example: Hot water for sterilisation and cleaning using heat pump**

Lobethal Abattoir in South Australia installed a two-stage ammonia heat pump in 2012 as an alternative to heating water with a gas-fired boiler.

The heat pump utilises waste heat expelled by the condensers of the freezer plant, heating approximately 250,000L of water per day from 11°C to 75°C.

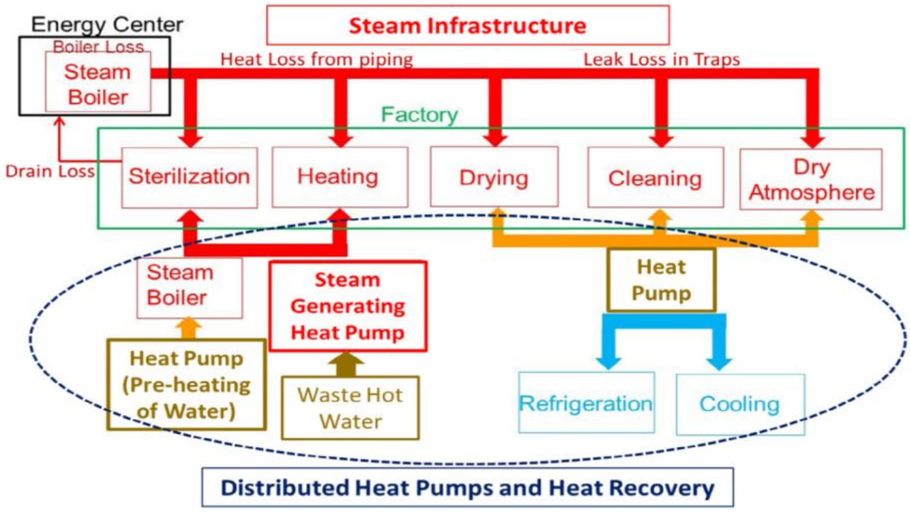
Hot water produced is delivered to a thermal storage tank and is used partly during the night for sterilisation and cleaning purposes and partly during the day for processing e.g. sterilising knives.


*Image: www.ampc.com.au*

***Typical heat pump applications***

| Application type | Features | Typical Industries |
|---|---|---|
| Dryers | Capture sensible and latent heat from exhaust streams | Milk, pasta, noodles |
| Food washing | Capture sensible and latent heat (water vapour) from exhaust streams | Potatoes, vegetables, fruit |
| Water heating for process and cleaning | Capture waste heat from process or refrigeration (or air) compressors | All food |
| Pasteurisation | Can be heating and/or cooling role | Milk, juices |
| Combined process heating and cooling | Ideal applications use the condenser for heating and evaporator for cooling simultaneously | An example is bread - product cooling and proving |

***Replacing central steam system with a series of local heat pumps***




## 5. High efficiency localised packaged boilers

Once we have identified ways to replace most of the process heating load with electric technologies, there may be some applications which still require steam, or it is too expensive to convert existing plant.

Small packaged steam/hot water boilers can be installed near the end point of use on the site to cater for these needs.

These boilers can lead to a higher energy productivity because they:

- can be independently shut down when the process is not operating
- have rapid start –up and fast response to transient conditions
- can be individually sized and selected according to a particular end use
- each one can independently operate at a specific temperature/load condition
- allow for higher reliability if packaged boilers are connected.

Note: The recently released report "Gas efficiency: A practical guide for Australian manufacturers" is a useful guide for sites to achieve gas savings by improving the efficiency of existing equipment. In this report we are focused on transformative change rather than incremental change.

***Compact electric steam boiler***

*Image: www.cleaverbrooks.com*

# Integration of renewable energy to reduce electricity costs and emissions

Deployment of more energy productive, digitally-controlled electricity technologies provides additional opportunity for using renewable energy to reduce carbon emissions.

The renewable energy can be supplied from on-site PV or other options such as biomass, and/or a renewable power purchase agreement from an off-site generation plant.

Either way, by managing the timing of electricity usage, the application of renewables can be optimised to get the best benefit. This is done through making electricity efficiency improvements, focused on loads operating at peak price times, utilising energy storage (thermal storage such as chilled water tanks, material storage or batteries) and use of demand management controls.

Energy storage can be added to heat pumps (hot and chilled water depending on the application) to improve the ability to use the systems preferentially in low energy price periods/avoid peak demand charges.

The control of electricity use to optimise usage patterns based on increasingly cost reflective real-time electricity supply prices is enabled by digitalisation.

Increased use of renewable energy and demand management controls can have additional benefits for manufacturing sites including:

- Improved energy security
- Improved ability to participate in and receive revenue streams for demand response programs
- In some cases, reduce the need for power supply infrastructure upgrades
- Reputational benefits of improved corporate sustainability.

# Implementation Planning

This guide suggests steps to replace central steam/hot water systems with energy productive electricity technology.

### A. Technical feasibility assessment

**1. Is there much to gain from moving to point of end use energy application?**

There may be a good case if:

- the existing boiler is close to its end of life.
- hot water, not steam, is the main heating requirement.
- the site is moving to an Industry 4.0 model, where central steam systems will not suit flexible operating requirements.
- the boiler is oversized for duty, hence operating mostly at part load.
- the reticulation system is in need of major maintenance.
- significant waste heat is available, but at a temperature too low for heat exchange for process us (e.g. from refrigeration compressors)
- there are existing large cooling towers
- boiler fuel prices have increased relative to available electricity (including on-site generation or PPA).

If the answer to one or more of these questions is yes, go to step 2.

**2. Define the actual requirements of process heating loads**

Carry out research to find out the precise customer product specifications that drive the process heating demand.

- What are you specifically trying to achieve with the heating task, and what are all potential options to achieve that objective?
- Is heat definitely required? If so, what is the specific temperature versus time requirement, and the heat transfer characteristics of the product? Note that the temperature of the supply line (e.g. steam pipe) should not be relied on as a guide to process temperature needs.

**3. Consider upgrading incrementally**

Are there parts of the steam system that are remote from the rest of the reticulation system, or have different operating hours (e.g. operate on a weekend when other plant is off)? In these cases, there may a case to consider closing off one section of the steam system in incremental steps to replace steam. Note that this is generally not the most energy productive option, as the rest of the system losses remain, and it further reduces load on what might already be an underloaded main boiler. However, if it provides significant incremental benefits, it gets the process of boiler replacement started.

## 4. Technical feasibility analysis of displacing steam

Now, thermal requirements and energy flows across the plant need to be quantified.

**4.1.** Assess any non-thermal technology replacement options first.

This guide and the accompanying text provide options.

If economical, this will reduce the remaining heating requirement.

**4.2.** Conduct a plant heat balance.

The heat required by each process heating application needs to be quantified and checked against a balance between heat into and out of the system.

**4.3.** Are there sources of waste heat?

Identify types of rejected heat sources across the plant.

- At what temperatures and quantities are they available?
- Does the amount of heat vary with throughput, the product, season, etc?
- Does the timing of heat being available coincide with applications that can use it? If not, can it be stored?
- Is it located close to the potential sink?

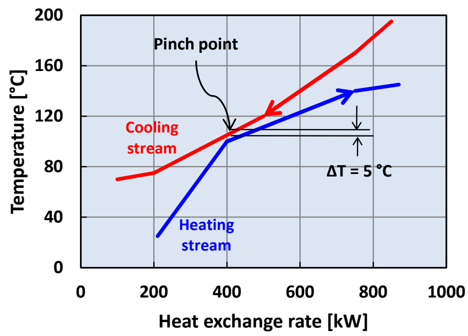
**4.4.** Can I simply meet key process heat demands with a heat pump or two?

If it is a relatively simple application without multiple heat sources and sinks, a heat pump might be the best option, and in that case, you might proceed straight to a technical and economic feasibility study of that project.

**4.5.** Do I need to conduct a pinch study?

Pinch analysis is used to systematically identify optimal heat inter-change opportunities within a plant that has many heat sources and sinks at different temperatures.

An exothermic process can transfer its rejected heat to an endothermic one (see the figure below). The point with minimum temperature difference between the two streams is called the pinch point.




Pinch analysis helps to:

- Identify the amount of reusable thermal energy in a complex plant
- Match the available and required thermal energy at exchange points
- Size and locate suitable heat exchangers for heat recovery
- Identify the necessity optimal positioning and size of heat pumps to upgrade low temperature heat sources for use in particular processes.

Pinch analysis is not necessary for plants with simple processes.

Further explanation can be found at http://www.industrialheatpumps.nl/en/applications/pinch_analysis/.

See also 'Pinch Analysis and Process Integration' by Ian C Kemp.

## B. Economic feasibility analysis

### Energy cost of heat pumps vs steam from boiler/steam system

The primary factors influencing the economics of heat pumps to replace boiler systems are:

- The **relative price of electricity and available fuels**
- The relative overall system efficiencies of heat delivery
- The **lift temperature** of the application (between the waste stream temperature and the process).

The relative electricity to gas price ratio has a significant impact on relative heat costs from heat pumps and boilers. This ratio is commonly between 1.5 and 4 around the world.

Typically, the price of electricity and gas in the east coast of Australia in 2017/18 is about 15-17.5 c/kWh ($42-49/GJ) and $10-12 /GJ respectively[4], which means the ratio is about 4. But the large difference between system efficiencies can change this ratio to under 0.7 – that is, the cost of heat supplied by the heat pump can be much cheaper than that of the gas boiler system.

The diagram below provides an indication of the relative cost of a heat pump and gas heating for different lift temperatures.

**Example 1**: An advanced heat pump can generate 65°C useful heat from 25°C waste heat, with a $COP_{Heat}$ of 4. This means that by consuming 1 kWh of electricity, 4 kWh of heat will be delivered at 65°C. For this case, the cost of heat from the heat pump will be about $10/GJ. A boiler/steam system with 75% efficiency can deliver the same heat at $13-16/GJ. But if that boiler/steam system is only effectively 35% efficient, the delivered heat from the gas systems would be twice as expensive.

**Example 2**: Heat pumps deliver heat at the condenser side by cooling the evaporator side. This is how they can co-produce cooling and heating which is a significant advantage, particularly for the food industry.

The combined $COP_{Heat+Cool}$ of heat pumps can be much higher than their $COP_{Heat}$ if the cold side (the evaporator) is also utilised.

***Heat pump temperature lift vs cost of delivered heat***

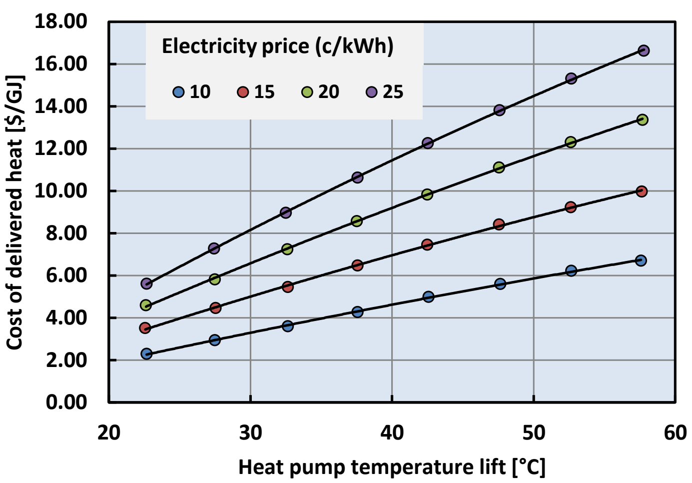



Chart basis:
At pump evaporator temperature = 55°C
Efficiency of heat pump cycle is 65% of thermodynamic maximum
Information intends to present trends and does not apply to all cases.

[4] A2EP, 2017. High temperature heat pumps for the Australian food industry: Opportunities assessment

An advanced $CO_2$ heat pump can lift a stream temperature from as low as 12°C to 90°C with a $COP_{Heat}$ of 3. This heat pump can also deliver cold water at 7°C at the same time. When you include the production of chilled water the combined $COP_{Heat+Cool}$ = 5.1. This plant can generate 90°C hot water at a cost of about $14 - 16 /GJ which is on parity with heat from a 75% efficient gas fired boiler/steam system. PLUS, for every kW of heating power, 0.7 kW of cooling is also available.

The economic attractiveness of heat pumps is even greater when:

- boiler and steam system efficiency is lower, and this is generally the case.
- renewable PV electricity is available onsite. PV power is often coincident with plant operation hours. Heat pumps can convert PV power into hot and cold thermal energy, which may be stored in hot/cold water tanks to be used when PV is not available.
- the electricity to gas price ratio is lower e.g. when off-peak tariffs are applicable, and/or LPG at >$20/GJ is the only accessible fuel.
- the process has variable load with significant duration of part load operation. Heat pumps are less sensitive to part load conditions than boilers and can maintain ~80% of their peak COP for much of the operating range, whereas the efficiency of boiler systems can drop from 75% to 50% at 50% load. This means that the cost of delivered heat

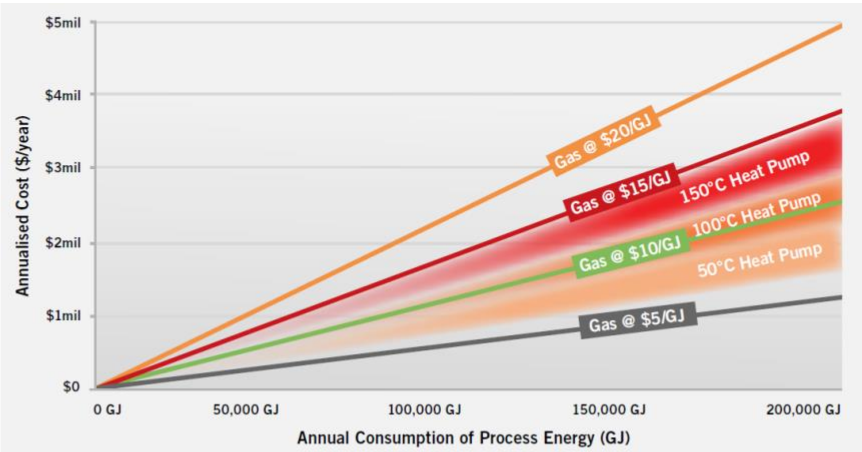
  increases from $16/GJ to $24/GJ whereas heat from a heat pump only increases from $10/GJ to $12/GJ.

**A very common scenario:** A plant has an average steam/hot water efficiency of 45% for producing cleaning hot water at 65°C. The plant uses LPG at $20 /GJ and has access to electricity at 15 c/kWh.

The cost of heat for this application will be $44/GJ from the boiler. This can be reduced to $10/GJ if a heat pump is adopted.

If this plant uses 5m$^3$ of cleaning water per day, the cost saving on fuel will be about $8,500 over 300 days of operation.

The capital cost of such industrial high temperature heat pumps is estimated to be about $1000 /kW of heat output installed. However, this can change with varying site and application specifications.




***Comparing the annual cost of heat pump system with existing gas boiler*** *(annual cost includes the running and capital cost of heat pump system)*

**Economic issues of boiler replacement with heat pumps and other electricity technologies**

An economic assessment for a complete replacement of a boiler and steam system with alternative electricity technologies, requires analysis of all the costs and benefits from this transformative change in energy systems.

Some of the issues that should be considered include:

- The **capital and installation cost of the alternative technology** as a new project or retrofit:

  (i) Timing of installation to match equipment retirement, plant expansion, development of new plants helps the economics.

  (ii) The capital cost is impacted by the need for redundancy for plant reliability. One strategy to achieve at least partial redundancy without a cost penalty is to install multiple smaller standard units instead of one large piece of equipment.

  (iii) The potential cost for upgrading the electricity connection or substation for large consumers may need to be included in the financial estimation to account for increased electric load, although addition of energy storage and/or smart management systems could limit peak demand within limits of existing supply infrastructure.

  (iv) Alternative technology costs are declining as economies of scale and standardisation are captured, and supply chains mature.

- **System utilisation factor**

  High return on investment for a new capital project is facilitated by high operating hours - ideally 3 shifts/7 days (i.e. 24/7 operation).

- **Importance of fully capturing all indirect energy productivity benefits**
  - Improved plant reliability (partially dependent on redundancy)
  - Reduced system maintenance (particularly where alternative technology displaced all or a significant part of steam reticulation system)
  - Enhanced controllability leading to improved product quality
  - Facilitating increased throughput
  - Reduced water bills, e.g. where a heat pump condenses water that can be utilised on-site
  - Reduced environmental management costs e.g. boiler blowdown and chemicals
  - Space savings compared to a boiler and steam system
  - Improved working conditions – less noise and heat.

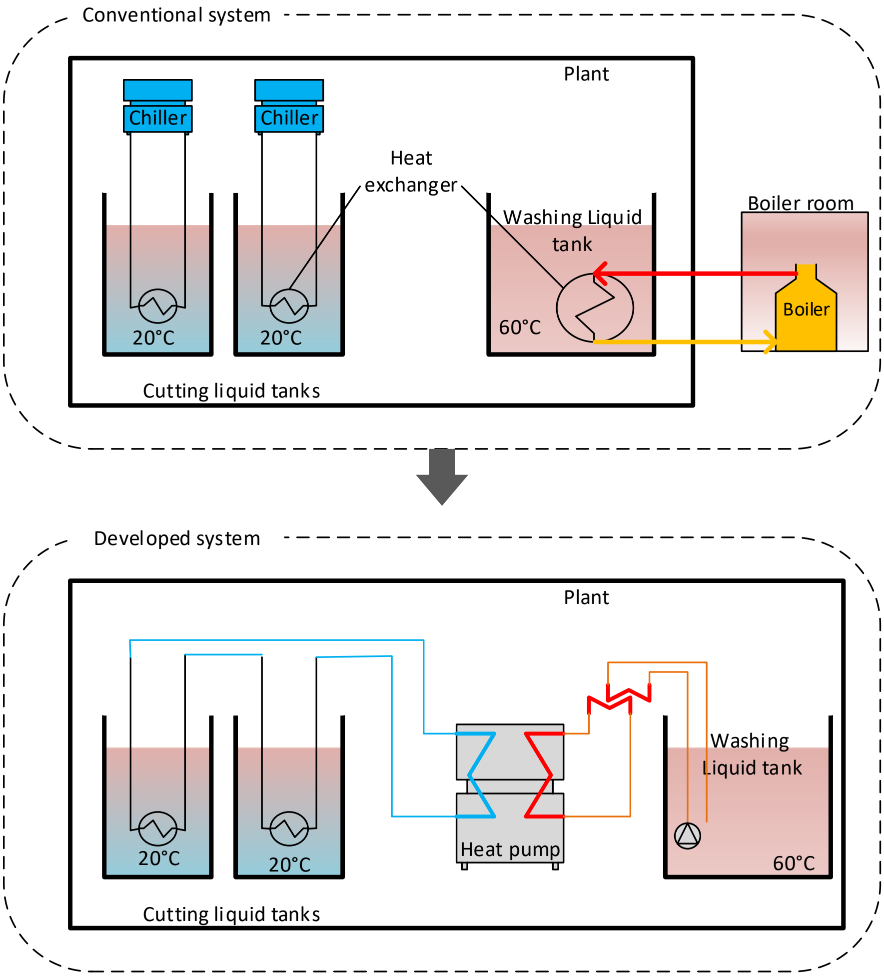
**Funding and financing options**

Financiers are becoming more interested in financing energy productivity and on-site renewable energy projects as they improve their understanding of them. The Clean Energy Finance Corporation has played a major role in the change, and partners with financiers to offer attractive finance packages.

## Example case study: boiler replacement with heat pump

Aisin AW CO. Ltd., is a Japanese Automotive part manufacturer. The company needs to wash parts once they are manufactured.

***Replacing central steam system point of use heat pump in a manufacturing plant manufacturing plant***




This was conventionally carried out using washing liquid being heated to 60°C by a central steam system. The steam was produced by a boiler running on heavy oil. The boiler was located at considerable distance from the plant leading to poor thermal efficiency of the long steam lines.

Installing a small boiler within the plant was not feasible at the time. The company installed a heat pump within the plant, close to the point of use for heating the washing liquid.

The heat pump was also coupled to the exhaust of the onsite chiller, which is used to cool the cutting tools. The rejected heat from the chiller exhaust used to be lost to the atmosphere as low grade waste heat.

The heat pump delivered the required heat for the washing liquid as well as boosting the chiller performance.

Since 2010 and after the technology had proven its effectiveness, 13 more heat pumps were installed for the same manufacturer.

These 14 heat pumps were comprised of 6 cooling/ heating type heat pumps with a capacity of 22kW, and 8 heating-only type with a capacity 43kW.

With these 14 heat pumps, the plant realised a steam-less thermal system with no need for a central boiler.

After implementing the heat pumps, energy consumption, $CO_2$ emission, and running cost of the plant reduced by 73%, 76%, and 89% respectively.

Many more examples of offsetting steam consumption with the help of heat pumps have been reported by the International Energy Agency (IEA)[5].

[5] Application of Industrial Heat Pumps Final Report, IEA, 2014

## Glossary of terms

The following is a summary of terms used in this report.

**Coefficient of Performance (COP)**

The efficiency of refrigeration systems and heat pumps is denoted by the coefficient of performance (COP). The COP is the ratio between energy usage of the compressor and the amount of useful cooling at the evaporator (for a refrigeration installation) or useful heat extracted from the condenser (for a heat pump).

**Energy productivity**

Energy productivity (EP) refers to the value created from using a unit of energy.

**Electrification**

Eliminating combustion and replacing it using electricity driven processes/systems

**Levelised cost of energy**

The cost of supplying unit of energy throughout the lifecycle of the equipment/process including its capital and ongoing costs.

**High temperature heat pump**

Vapour compression heat pumps with heat delivery temperature of over 65°C.

The full detailed Transforming Energy Productivity in Manufacturing report is available here.

A guide for business to implement Industry 4.0 to boost energy productivity is available here.

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The Australian Alliance for Energy Productivity has been leading business transformation through activities including:

- Research and analysis that is identifying emerging technologies and business models and documenting case studies and issues relevant to progress towards doubling Australia's energy productivity by 2030.
- Reframing ways of thinking about energy, in particular:

  - Energy Productivity (increasing economic and business value from each unit of energy consumed).

  - Value chain thinking, which highlights the interdependence of industry sectors within a supply chain as well as the customers of intermediate products or services and end-consumers.

  - A systems and services focus, so that the fundamental services valued by consumers are identified, and the complex technical, financial, business and other systems that deliver these services are understood.

  - Information exchange, through sector working groups, and events such as a recent Innovation X-Change.

  - Advocacy and engagement with governments.

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