# Heating and Cooling Energy Cost Comparison in Victoria

## Solar Thermal vs. Natural Gas vs. Solar Electricity

**Synopsis:**

> **With respect to energy costs in Melbourne, Victoria, in 2019, the unit cost per GJ to provide heating energy from a solar thermal system for existing large-scale energy users (i.e. > 50,000 GJ p.a. with an existing gas boiler and water storage tank) is almost half that of solar electricity and natural gas solutions. The main reasons are the solar thermal system's inherently higher solar collector efficiency and much lower cost of energy storage.**
>
> **The payback period for adding a solar thermal system to an existing gas heating system can be as little as 5 years (including principal and interest).**

Free solar radiation can now be converted into useful energy at up to 80% efficiency by the latest generation of solar thermal (water-based) collectors. This cost-breakthrough energy solution is fast becoming the preferred energy source of choice around the world, and here's why.

The bulk of global energy requirements is for heating and/or cooling purposes, not electrical power[1]. Solar thermal systems can deliver hot water up to 95˚C, which may then be used for a multitude of heating applications - from heating buildings and greenhouse spaces, to process heating and supplying domestic hot water. Solar thermal systems, combined with supremely-efficient compressor-less absorption chiller technology, can deliver 7˚C chilled water for all manner of cooling applications, from cooling large buildings to process cooling applications in breweries.

In comparison with solar thermal systems, solar electricity systems only convert solar radiation into electricity at around 15% efficiency. If they are combined with historically popular air-source heat pumps, the overall efficiency still only increases to between 45% - 50%.

When amortizing the capital cost of a solar thermal system (with gas back-up), or a solar electricity driven heat pump system (with grid electricity back-up) over say, 20 years, at a 5% interest rate, the cost of 1GJ of natural gas energy can be compared to the equivalent level of thermal energy from solar thermal and solar electricity systems.

Outlined below are various energy cost comparisons for the three key industry heating energy options in Victoria. Each energy source is examined with respect to three different usage time scenarios – i.e. night time usage, day time usage, and mixed day & night usage.

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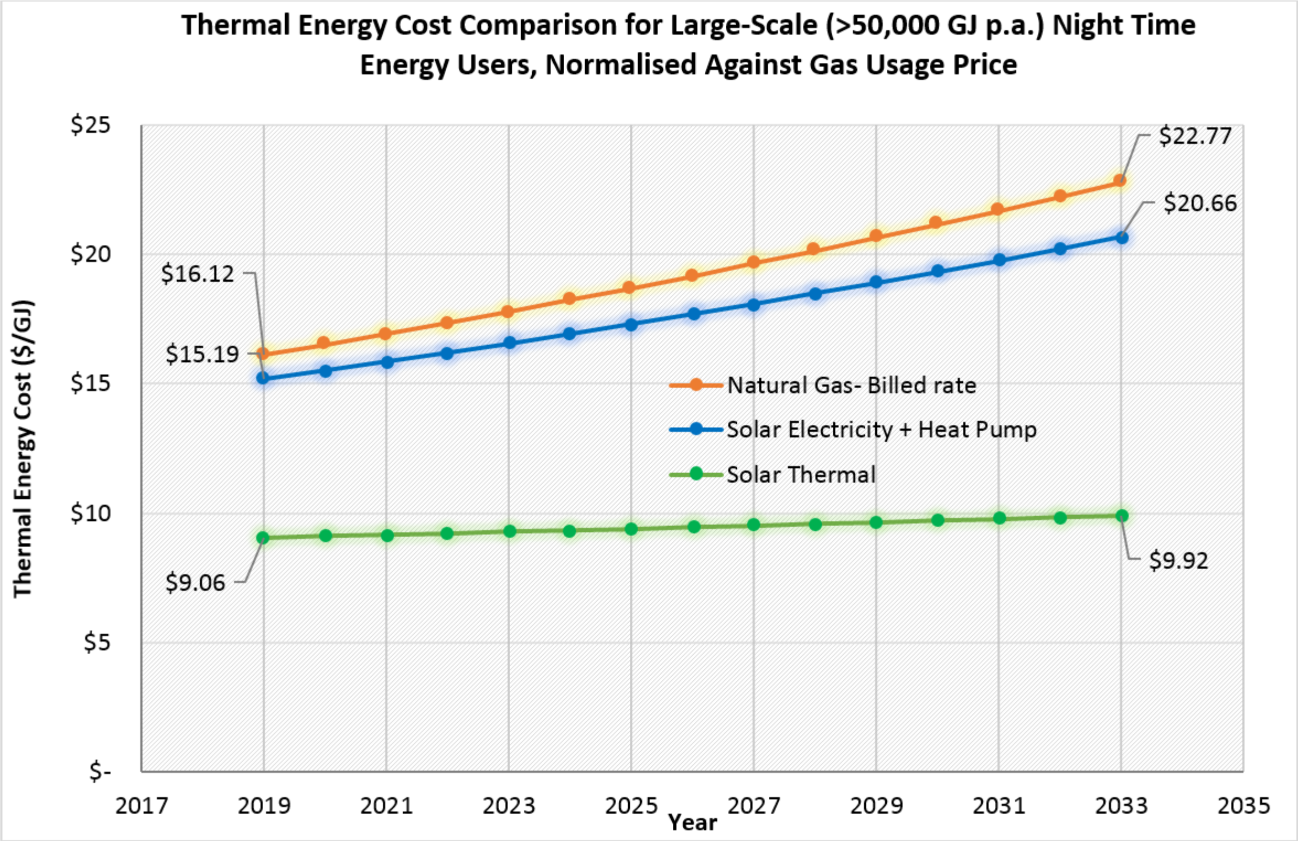
[1] International Energy Agency, publications, Market report Series 2018

## Night Time Heating Energy Users

For a night time energy user (such as a commercial greenhouse) that consumes more than 50,000 GJ of natural gas per annum at the cooler Melbourne latitude, the current and forecast comparative system thermal energy unit costs are shown below, normalized against the gas usage price.



*Note that the Natural Gas price billed rate is based on ASX Natural Gas price of $10.66/GJ plus gas supplier margin (20%) plus network charges (26%).*

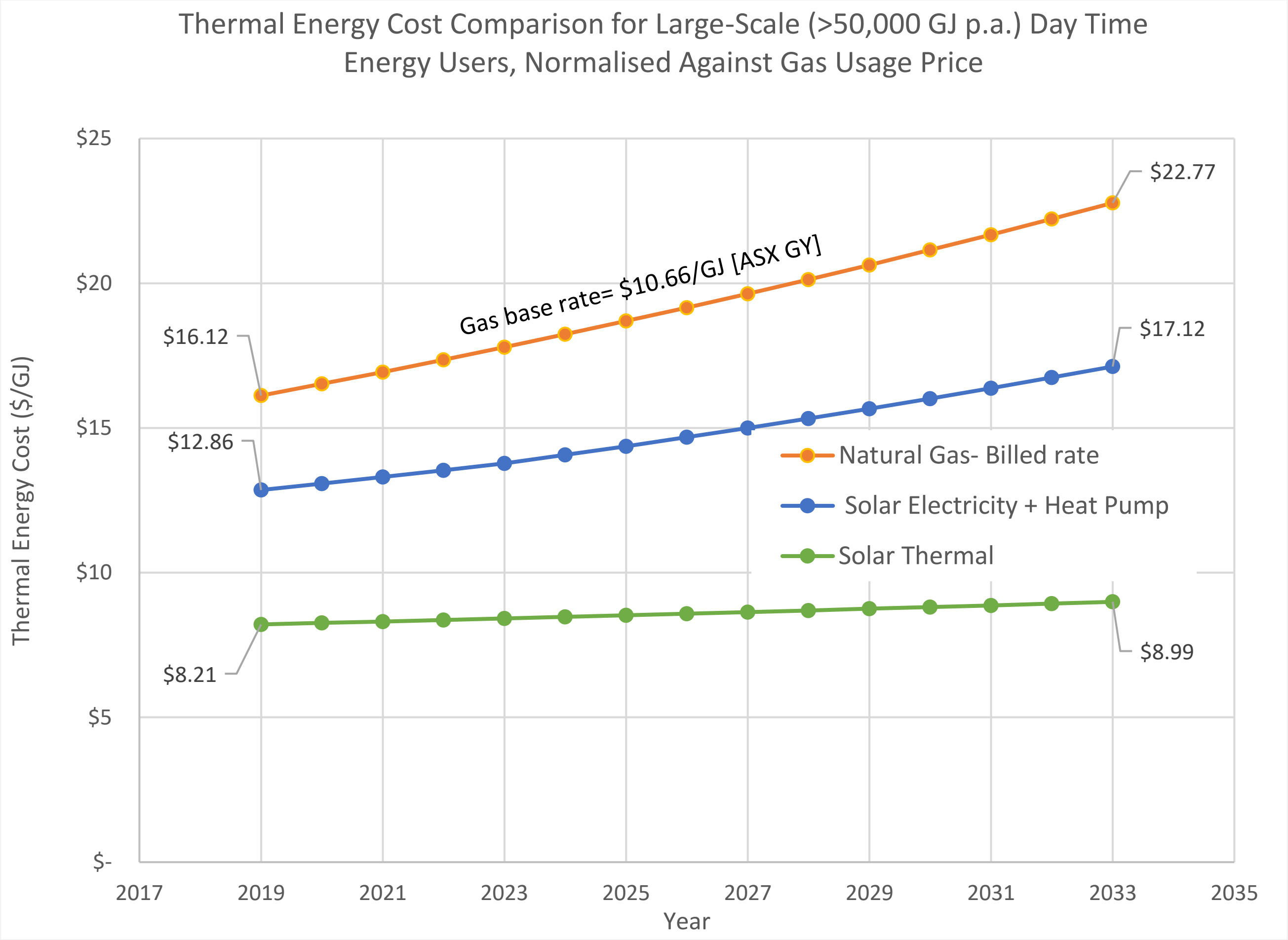
From the above graph, the large-scale night time gas consumer will spend $806k p.a. ($16.12/GJ in 2019) on 50,000 GJ of natural gas. The normalized cost of providing an equivalent amount of thermal heating energy using solar electricity + heat pump system is $759k p.a. ($15.19/GJ), and for a solar thermal system $453k p.a. ($9.06/GJ).

This night time usage scenario is representative of many applications where hourly energy demand is not synchronized with hourly solar energy generation. Applications such as greenhouses don't need much heat during the day but require significant heating during the night. The solar thermal energy is simply stored in insulated water storage tanks such as those typically used at greenhouses, whereas energy from solar electricity driven heat pumps cannot be viably stored (read more about thermal energy storability below). Cost-effective energy storage and much higher efficiency in transforming solar light into solar thermal energy is the key difference between solar thermal and solar electricity energy systems.

## Day Time Heating Energy Users

At the other end of the energy generation/usage cycle spectrum, a dairy farm and abattoir scenario is representative of applications where hourly energy demand is synchronized with hourly solar energy generation, and most of the solar energy generated is used instantaneously.

For a day time heating energy user such as an abattoir, that consumes more than 50,000 GJ of natural gas energy per annum at the Melbourne latitude, the current and forecast comparative system thermal energy unit costs are shown below, normalized against the gas usage price.



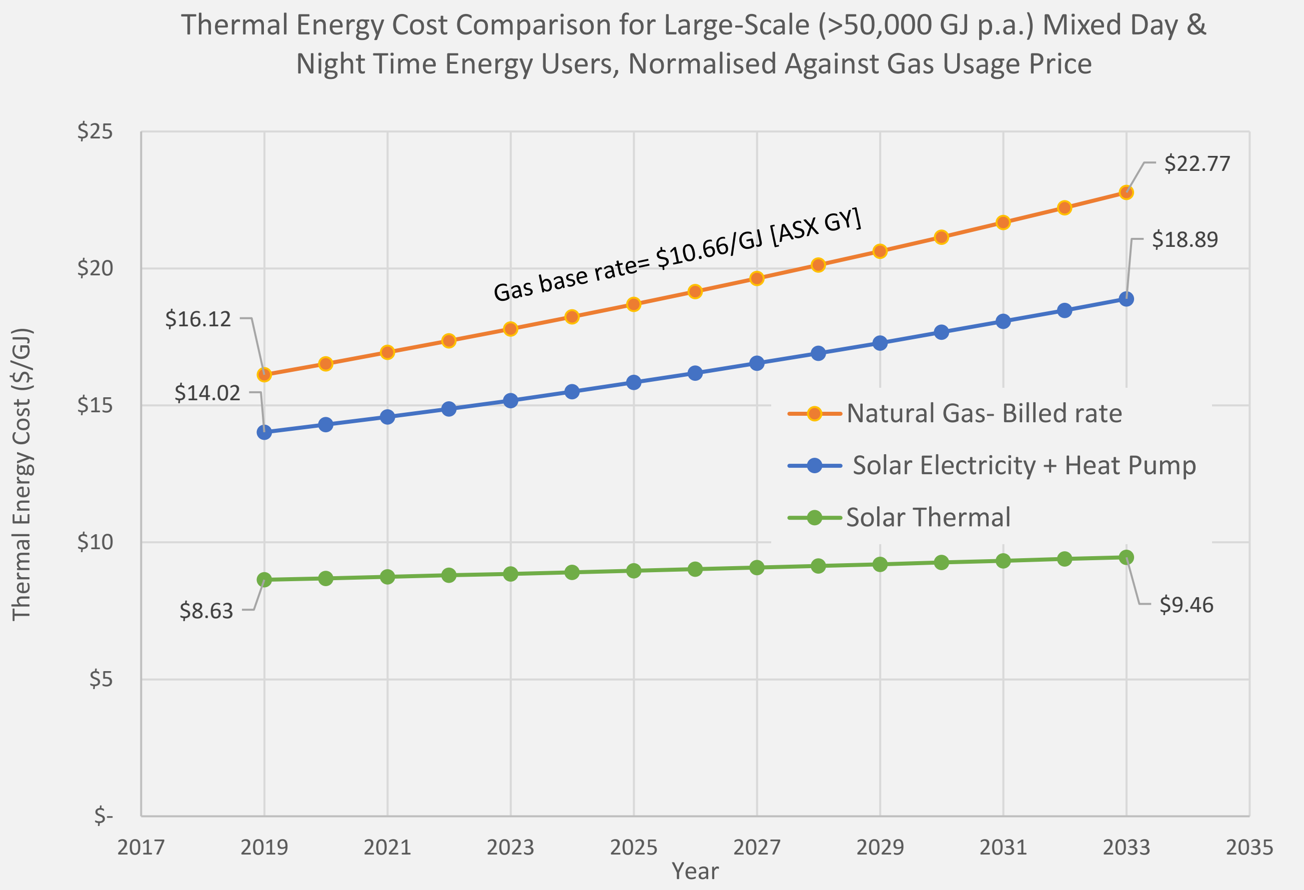
*Note that the Natural Gas price billed rate is based on ASX Natural Gas price of $10.66/GJ plus gas supplier margin (20%) plus network charges (26%).*

For a large-scale day time thermal energy user such as a dairy farm or abattoir (consuming 50,000 GJ of gas at a cost of $806k p.a. ($16.12/GJ)), the normalized cost of providing an equivalent amount of thermal heating energy using solar electricity + heat pump system is $643k p.a. ($12.86/GJ), and for a solar thermal system just $411k p.a. ($8.21/GJ). The cost-benefit between solar thermal and competing heating solutions is even greater at locations with warmer latitudes, such as New South Wales and Queensland.

## Mixed Day & Night Heating Energy Users

For large-scale mixed day and night energy users, such as for new residential estate developments or retirement villages that use a district heating and cooling distribution system, or Council swimming pools/gym facilities, energy consumption is roughly evenly distributed during the day and night time.

For such users consuming more than 50,000 GJ of natural gas per annum at the cooler Melbourne latitude, the current and forecast comparative system thermal energy unit costs are shown below, normalized against the gas usage price. This graph is the arithmetic average between night time heating energy users and day time energy users.



*Note that the Natural Gas price billed rate is based on ASX Natural Gas price of $10.66/GJ plus gas supplier margin (20%) plus network charges (26%).*

From the above graph, the large-scale day & night time gas consumer will spend $806k p.a. ($16.12/GJ in 2019). The normalized cost of providing an equivalent amount of thermal heating energy using a solar electricity + heat pump system is $701k p.a. ($14.02/GJ), and for a solar thermal system $432k p.a. ($8.63/GJ).

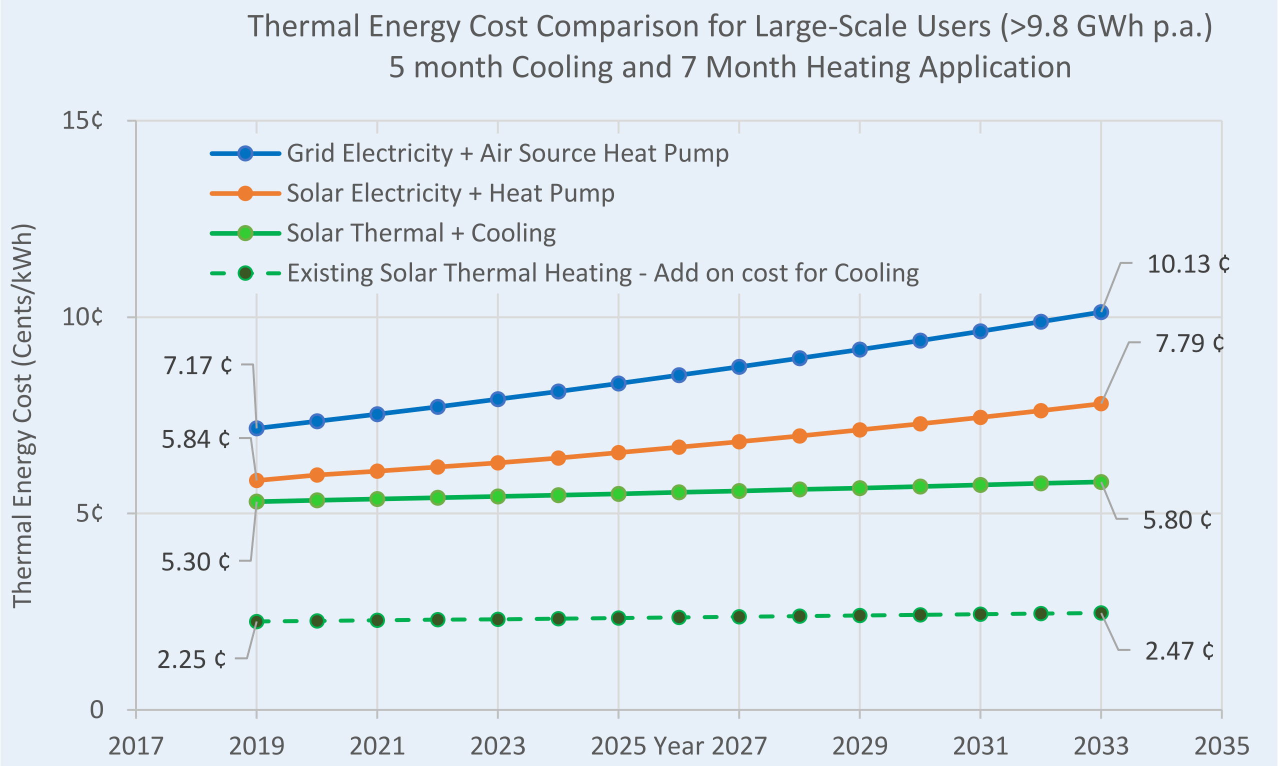
## Day Time Cooling and Heating

The demand for cooling typically peaks during the day time when solar energy is readily available. As mentioned above, solar thermal energy systems have the capacity to also provide cooling by simply adding an absorption chiller to the existing solar thermal heating system.

Consider the example of a large greenhouse that predominantly calls for night time heating in winter, but has a very large cooling demand for its cool rooms during summer. The excess seasonal heat generated by the solar thermal system during summer can be used to provide free cooling energy during summer.

For large-scale thermal energy users, the capital cost of absorption chillers are a fraction of the cost of conventional electric chillers (i.e. ~70% cheaper!) and can be readily added later to an existing solar thermal heating system, allowing the provision of virtually free (i.e. near zero operating cost) cooling during the day. An absorption chiller can also work with a back-up gas water heater when there are less than planned periods of sunshine.

For an application that requires 5 months of cooling and 7 months of heating, with a combined demand of more than 9.8 GWh cooling and heating energy at the Melbourne latitude, the current and forecast comparative system thermal energy unit costs are shown below.



From the above graph, it is clear that solar thermal absorption chiller systems deliver the least expensive combined heating and cooling energy, compared with grid electricity and solar electricity systems.

## District Heating and Cooling Distribution Solutions

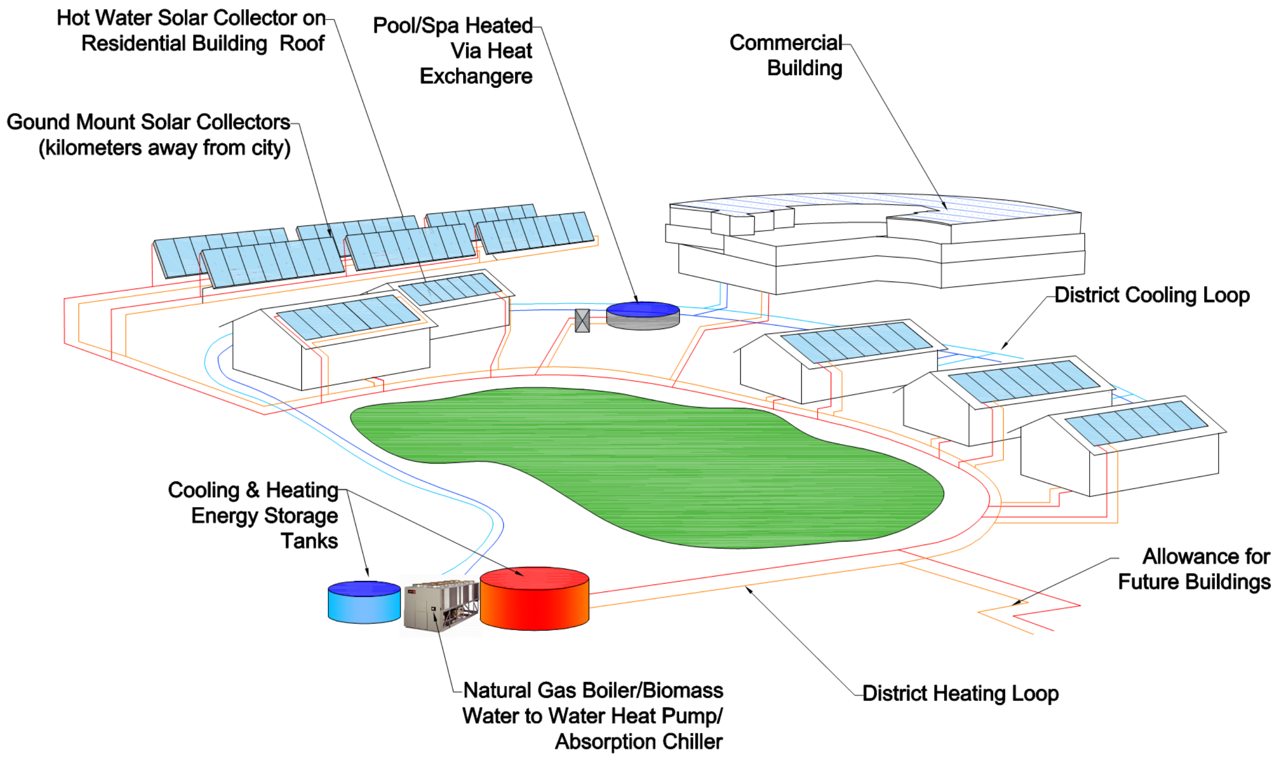
In Europe, district heating and cooling systems are very popular. District heating and cooling systems can service from two buildings to thousands of buildings, such as in a big city. For example, more than 80% of the buildings in Stockholm are serviced with district heating systems.

Instead of each building having its own standalone heating or cooling system, the energy is delivered to geographically separate buildings from a central plant (such as with grid electricity). The water-based distribution system guarantees that heating and cooling arrive efficiently and safely to the end users.

District heating is more energy and cost efficient due to its scale, and it can also take advantage of land resources that might not otherwise be productively used.

The centralized thermal energy plant can have a renewable thermal energy generator, such as a solar thermal system. Centralized solar thermal systems utilise a thermal storage tank (i.e. a large steel insulated hot water tank) to provide heating and cooling during the day and night, and is backed up by a single gas or biomass water heater on the occasion when the excess stored hot water runs out after the sun has goes down.

Each building is provided with a pair of insulated hot and cold water supply & return pipes from the street that is metered separately.



The district heating and cooling network's coverage can easily be extended in line with the real estate development stages, by laying more pipes, often in combination with adding more thermal energy generation.

Geoflow Australia is the local partner to Savosolar from Finland – the award-winning manufacturer of the world's most efficient solar thermal collectors. They jointly design and deliver large-scale turnkey solar thermal heating and cooling solutions.

Since each customer's business is unique in its energy requirements, Geoflow uses sophisticated TRNSYS hourly modelling software (as used by the Clean Energy Regulator) to accurately inform clients of their calculated energy cost savings.

## Thermal energy storability: Solar thermal versus solar electricity systems

Heating applications such as greenhouses, have a low heating demand during the day and a high heating demand during the night. Solar based solutions need to store the sun's free energy during the day for night time use.

The minimum acceptable temperature for any greenhouse hydronic heating system is 50-60$^{o}$C. A solar thermal system is capable of generating and storing heat in the form of hot water up to 95$^{o}$C in cost-effective, insulated, commercially sized storage tanks.

In the case of solar electricity driven commercial heat pump systems (at a Mega Watt scale), the maximum hot water generation temperature is 55$^{o}$C, which is barely 5$^{o}$C higher than the minimum temperature required.

The difference in water delivery temperatures between the two technologies means that solar thermal systems can store 800% more energy than solar electricity driven heat pump systems, for the same sized storage tank.

Energy from solar electricity systems can be stored in batteries and transformed into heat during the night, when needed. However, while this approach is occasionally used, it is nowhere near as financially viable. For example, a Tesla Powerwall 2 that offers 13.5kWh storage and useable energy, costs more than $12,000. When coupled with a heat pump, however, it can only generate approximately 40kWh of heating energy in a daily cycle. In comparison, for the same upfront cost of an electric battery, an 8,000L insulated stainless steel storage tank can store 370 kWh of heating energy from a solar thermal system – that's more than <u>nine times</u> the storage capacity for the same price!

## Key Data and Assumptions

The key data and assumptions used in the above cost comparisons for heating and cooling applications are as follows:

*System sizing*

- The sizing of the renewable solar thermal and solar electricity systems has been optimized for the greatest Return on Investment (ROI) for each heating/cooling demand scenario.

*Solar Thermal heating (with gas back-up)*

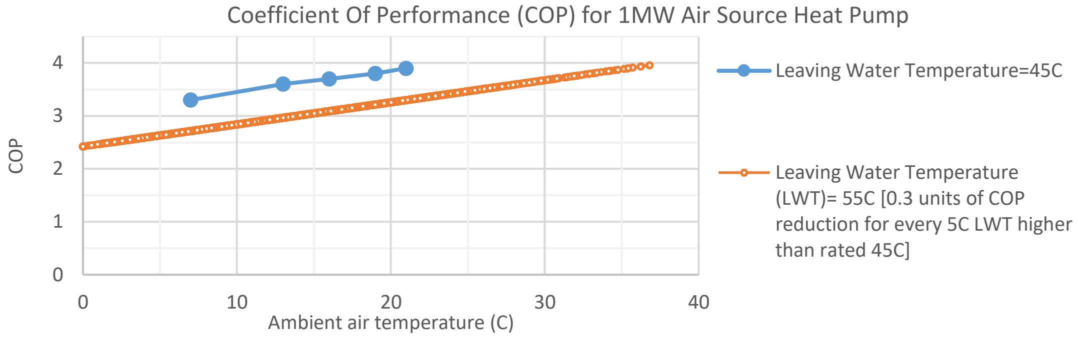
- Solar thermal size and cost:
  - Night time and day time heating: Savosolar collector with the 13,000m2 gross surface area.
  - 5-months cooling & 7-months heating: Savosolar collector with 13,000m2 collector gross surface area plus 3.3MW absorption chiller & cooling tower.
- Solar thermal collector model and area: Savosolar SG12, installed on the ground with 4.4m c/c spacing between collectors, with collector facing true north and collector slope equal to location latitude.
- Solar thermal performance modelling: hourly with TRNSYS software
- Warranted maximum performance degradation of solar thermal collectors: 0.4% p.a.
- Finance term and interest rate for capital cost of supply & installation: 20 years @ 5% p.a.
- Solar thermal maintenance expense: 0.75% of capital cost p.a. increasing by inflation
- An existing business uses a gas boiler and thermal storage tank(s)
- No subsidies, grants, CO2 reduction rebates from local or federal governments are included to lower solar thermal system costs.

*Natural Gas*

- Wholesale gas base price: ASX Victoria Gas Strip (GY) future (as of 12th March 2019): $10.66/GJ
- Retail gas supplier profit margin: 20%, leading to a contract gas rate of $10.66 x 1.2 = $12.80/GJ
- Average additional gas network charges: 26%, leading to an actual gas price of $12.80 x 1.26 = $16.12/GJ
- Gas price inflation rate: 2.50% p.a. (RBA target inflation)
- Existing gas boiler system efficiency: 80.0%
- Metered gas adjustment (UAFG): 4.17%. All commercial gas users are charged this amount.
- Gas boiler maintenance costs are not included for conservative cost comparison purposes.

## *Solar Electricity + Heat Pump heating (with grid electricity back-up)*

- Solar Electricity size and cost for different applications:
    - Night time heating (e.g. Greenhouse): 1MW DC at $1.35 million (installed on the ground with 4.4m c/c spacing between collectors with collector facing true north). Installing more solar electricity in this scenario will simply increase the grid export headworks charge and worsen the feasibility of solar electricity plus heat pump system.
    - Day time heating (e.g. Abattoir): Solar Electricity size and cost: 2.7MW DC at $3.64 million (installed on the ground with 4.4m c/c spacing between collectors with collector facing true north).
    - 5-months cooling & 7-months heating, Solar Electricity size and cost: 2.0MW DC at $2.7 million (installed on the ground with 4.4m c/c spacing between collectors with collector facing true north). In this scenario, 80% of the generated solar electricity is used onsite.
- Heat pump size and cost for different applications:
    - Night time heating (e.g. Greenhouse): 1.8MW Carrier 30 XQ at $660k installed, a heat pump is sized so that the combination of solar electricity plus heat pump plus grid electricity back-up can replace the same amount of required natural gas (50,000 GJ) from competing heating technology.
    - Day time heating (e.g. Abattoir): 3.8MW Carrier 30 XQ at $1.39 million installed.
    - 5-months cooling & 7-months heating 3.3MW Carrier 30 XQ at $1.21 million installed.
- Air source heat pump variable efficiency in heating mode:



Adopted cooling mode average efficiency (COP): 3.0.

- The solar electricity system is assumed to be connected to the main electricity grid at no cost, to enable exporting any surplus solar electricity not directly consumed on site. For the sake of simplicity for this analysis, no cost allowance has been made for any necessary grid upgrade and connection works (i.e. for any new poles and wires to handle the increased electrical load), which can vary widely from thousands to millions of dollars.
- Backup electricity from Grid:
- Contracted peak rate: 9.6 cents/kWh, and contracted off-peak rate 6.2 cents/kWh increasing by inflation.
    - Billed peak rate: 24 cents/kWh, and billed off-peak rate 15.5 cents/kWh.
    - [Billed rates are calculated by dividing the annual cost of electricity by annual consumption (in kWh) for a 2,800 MWh p.a. demand case. Hence the peak and off-peak rates include all costs such as daily supply charges, etc.].
- Solar electricity performance modelling: hourly with SAM software
- Warranted maximum performance degradation of solar electricity collectors: 0.74% p.a.
- Finance term and interest rate for capital cost of supply & installation: 20 years @ 5% p.a.

- Solar electricity maintenance expense: 2.1% of capital cost p.a. increasing by inflation
- Solar electricity + heat pump maintenance expense: Allowance made for replacing inverters twice and heat pump once over 20 years, in line with typical design life.
- Grid Feed-in tariff is 6 cents/kWh and assumed not to decrease in the future.

*Common assumptions*

- Heating water minimum temperature = 55˚C.
- Cooling chilled water fixed temperature = 7˚C
- Estimated national Inflation rate: 2.5%
- Heating and cooling demand patterns for each scenarios:
  - **Night time heating users (such as greenhouse heating applications):** Based on the heating demand pattern of an actual commercial greenhouse in regional Victoria (>10ha glasshouse). Total annual heat delivered by both solar thermal and solar electricity systems is equivalent to the heat from 50,000GJ p.a. of natural gas burnt at a boiler efficiency of 80% and UAFG = 1.047.
  - **Day time energy users (such as abattoir and dairy farm heating applications):** Based on an application requiring 2.67MW per hour of heating demand. Both solar thermal and solar electricity systems deliver heating equivalent to the heat from 50,000GJ p.a. natural gas burnt at a boiler efficiency of 80% and UAFG= 1.047.

    All solar electricity generated onsite is primarily used onsite to power the proposed heat pump system for instantaneous heat generation. Any solar-generated electricity that is excess to requirements is exported to the grid. Under the Daytime Energy User scenario, only 16% of generated electricity is exported to the grid. The heat pump is sized to maximize the return on investment.
  - **Day Time Cooling (5-months) & Heating (7-month) Demand Pattern:** 3.3MW per hour cooling demand from the beginning of November to the end of March (3.8 GWh p.a.), and 3.3MW per hour (11.91GJ per hour) heating demand for the remainder of the year (6.0 GWh p.a.).

    Both solar thermal and solar electricity systems are sized to cost-effectively deliver a minimum of 9.8 GWh (≈35,000GJ) per annum.

    All solar electricity generated onsite is primarily used onsite to power the proposed heat pump system for instantaneous heat generation. Any solar-generated electricity that is excess to requirements is exported to the grid. Under the Day time Heating and Cooling Energy User scenario, only 0.2% of generated electricity is exported to the grid. The heat pump is sized to maximize the return on investment.

**Disclaimer: The modelling here represents four generic types of heating and cooling applications. Each business has its own unique heating and cooling demand. For the most accurate heating and cooling unit cost comparison, the business's hourly heating and cooling loads should be used for cost comparison purposes.**