HEAT PUMP
A BUSINESS CASE

For Nett Zero Emissions

Abstract

A case study introducing the application of a heat pump to heat water at the Noble Park Aquatic Centre, using verifiable empirical data to compare with existing gas usage, and producing a cost-benefit analysis.

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Heat Pump – A Business Case

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Product Development Evaluation

1 Executive Summary

What problem does this business case solve?

It is not as much a problem but an issue that stemmed from the need to reduce carbon emittance in the environment due to its harmful effect. A consequence of this is climate change, which is no longer a risk to the world but a real issue that threatens the way we live. Several countries around the world, governments and community bodies have recognised this danger and have started to put measures in place to reduce the emittance of harmful gasses into the atmosphere. The City of Greater Dandenong (Council) has also adopted this example and as a result it has adopted a policy which prohibits the use of natural gas.

Natural gas is used extensively within Council for several applications but predominantly for heating air and water. This business case uses the gas used by the boilers at the Noble Park Aquatic Centre as its model, comparing its heating energy to the heating energy generated by a heat pump, using electricity.

Putting the social, ethical, environmental and political issues and reasons aside the business case deals with tangible qualifications demonstrating how a change from gas to electricity is an opportunity that also makes commercial sense using solid empirical evidence backing up the payback analysis and long-term economic benefits.

Replacing direct electrical heating and gas heating with a heat pump is a clear win as heat pumps pave the way for efficient use of renewable energy sources, like solar or wind. In this sense, getting away from gas furnaces while promoting non-fossil electricity generation is the best ticket, especially when coupled with concerns over global warming.

The results of this study clearly demonstrate the commercial advantage of a heat pump versus the use of a gas boiler, even though the unit cost of gas is about 330% less than that of electricity.

2. Mindset Transformation

Opportunity

As with the psychological change that transformed the attitude toward coal in favour of non-fossil fuels the use of natural gas will mostly be replaced by heat pumps using a renewable source, electricity.

With the rising popularity of renewable energy sources, the use of non-traditional heating systems has witnessed an increasing interest around the country. Air source heat pumps are being suggested as an alternative to gas boilers for space and water heating (UK Committee on Climate Change), even proposing the banning of gas boilers in new homes from 2025.

The rationale behind the current hike in popularity of heat pumps and solar panels especially is contingent on the cost-efficiency these can deliver, if used wisely. In this context not all renewable energy technologies are equal, and some are better than others and the selection of the right solution is based on preferences, property characteristics and budget allowance.

3. The Heat Pump

3.1 Description

The main goal of a heat pump is heat generation. It is a more complex device compared to a boiler. The heat pump's operation is based on the absorption and transfer of a certain amount of thermal energy from a low-grade source, air, to a heating element, the pump's coolant, with a higher temperature. A heat pump, rather than creating heat, simply moves heat. It may move thermal energy from cooler outdoor air into the warmer inside, or from the cooler refrigerator interior into the ambient air. It pushes heat in a direction counter to its normal flow (cold to hot, rather than hot to cold), thus the word *pump*. A heat pump is used to extract far more energy from a heat source than it consumes, and if the heat pump is connected to a solar PV system most of the energy it generates is free.

Significantly, unlike an electric coil or a flame, the heat pump does not create the thermal energy, it moves thermal energy that already exists. A heat pump is always moving thermal energy from a cooler environment to a warmer one. That means that a heat pump heating a house in the winter is grabbing heat from outside and pushing it inside. This may seem counter-intuitive, but even freezing air has plenty of thermal energy, being hundreds of degrees above absolute zero. Capturing some of that energy and moving it can take a lot less energy than creating it directly.

Heat pumps are measured according to their Coefficient of Performance (COP). A heat pump with a COP of 3 means that for every 1kW of electrical energy it uses it delivers 3kW of heat, making it competitive in the right circumstance with fossil fuel sources that may initially appear cheaper.

3.2 Sensitivity Analysis

The competitiveness of heat pumps vs fossil-based conventional technologies is sensitive to the price of electricity compared with the price of natural gas.

The upfront capex cost can vary across technologies, hence not all heat pumps are equal, and the price per kW decreases with an increasing heat pump capacity size.

4. SWOT Analysis

Heat Pump technologies SWOT analysis

<u>Strengths</u>

Can be highly energy efficient compared to existing conventional heating options. High COP potential with further efficiency gains anticipated.

Can be used for multiple purposes: heating and cooling of both water and air. Highest efficiency if simultaneous provision of heating and cooling is required.

Can be coupled with on-site renewals fully supplemented by net-zero grid electricity.

Potential to reduce GHG emissions and no local air pollutants.

Mature technology already used at various scales from individual buildings to localised heating.

Heat pumps can be controlled so that they exploit periods of low electricity prices thereby reducing operating costs. They can also provide flexibility services to the grid by switching on/off when needed.

Weaknesses

Higher upfront CAPEX and longer payback periods compared to conventional heating options.

Limited public awareness of the technology and a lack of skilled technicians.

Many heat pump refrigerants have a high global warming potential.

Permits may be needed to install ground or water-source heat pumps.

Opportunities

Regulatory support specifically for heat pumps exists all around Australia.

Increasing implementation of supportive policies – such as the move toward zero emissions and zero energy buildings – increase the competitiveness of heat pumps.

New financing models could reduce the risk and high up-front CAPEX costs heat-pumps, e.g. energy performance models.

Threats

Deep renovation rates are relatively low, hampering the uptake of more heat pumps.

5. Success Factors

Selection of geography-appropriate Heat Pump technology:	Air Source Heat Pumps are more suitable for mild climates; for colder climates (<0°), ground or water sourced heat pumps are needed for optimal performance
Policies & Commitments:	Policies such as carbon neutrality, removal of fossil fuels, considering heat pumps as renewable energy and valorising the provision of demand side flexibility validate the heat pump business case
Finance Models:	Availability of financing models to reduce high upfront CAPEX costs, e.g. energy performance contracts and ESCO models.
Electricity vs fossil fuel price:	The business case is strengthened when the price of electricity is relatively low compared to the fossil fuel alternative used in a boiler (natural gas). CGD is in the process of adopting a Power Purchase Agreement (PPA) for bulk and bulk renewable electricity supply.

Building Applications

Utilisation of waste heat	Capturing waste heat from other parts of the building increases system efficiency
Cooling and heating demand	Business case is strong, as the heat pump can meet both heating and cooling needs
Highly energy efficient buildings	Near zero energy, passive or positive energy buildings are most suitable for heat pumps

6. Sustainability

- Doing more with less, very high Coefficient of Performance
- Minimum maintenance
- Longer service life
- No waste – energy, emissions, pollutants
- Zero emissions

7. Risks and Opportunities

The risk assessment summarises the significant project risks and opportunities and how they will be managed.

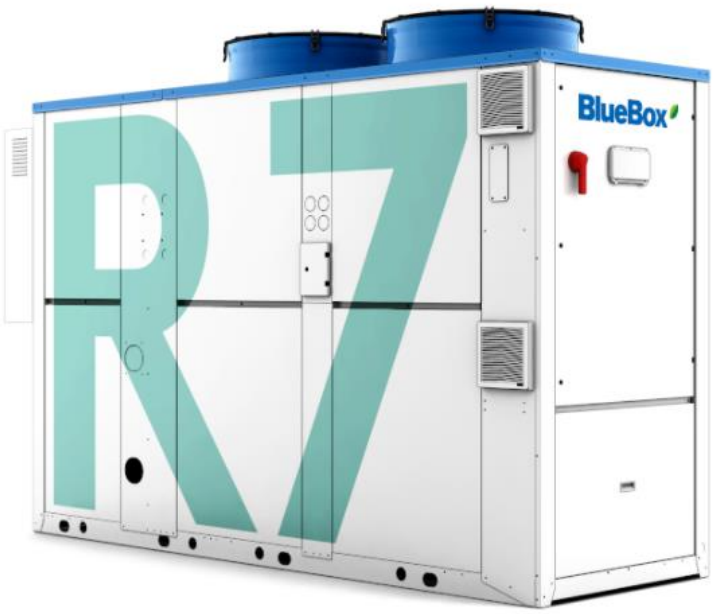
Category	Risk	Mitigation
Product risk	Selected HP is under size or unsuitable	The HP provides a very good balance between performance (COP 5) and cost.
Health & Safety	HP refrigerant is toxic or flammable	R32 is mildly flammable. The HP will be located outdoors and worked on by specialist technicians.
Environmental	HP has high Global Warming Potential	R32 is a new refrigerant with the lowest GWP (675) of all HFC refrigerants and an ozone depletion potential of zero.
Commercial	The HP has a high capital cost	The cost of the HP is $62K; $299/kW delivered The total cost is $124K; $600/kW delivered, with a full payback period of <3 years.
Commercial	The price of gas increases	In the likely event that the price of gas increases or that of electricity decreases the payback period of the HP will be shorter.
Multi-Faceted	Not doing anything	Increased running costs; loss of credibility re climate change and environmental sustainability policies.

Category	Opportunity	Analysis
Environmental	Reducing the use of fossil fuel	In-line with CGD Corporate Sustainability Building Policy (2020)
Political	Showing leadership	Demonstrating and validates sustainability commitments such as Council's declaration of a Climate and Ecological Emergency.
Commercial	Reduction of operational costs	The model in this business case demonstrates a real savings of $62K p.a. even when the price of gas is circa 350% cheaper than electricity. Maintenance costs are reduced. Long useful life – 30 to 35 years
Commercial	Using the HP waste – cold air	The discarded air can be directed to cool the building during the warmer months, thereby increasing the machine's COP.
Commercial	Integrating the HP with solar PV panels	Should a solar panel system be made to feed the HP, most of the energy will be free, thereby the savings multiplied.

8. Glossary

Auxiliary heating	Resistance heating used in conjunction with a heat pump, to boost heat output
Ambient temperature	Effective temperature outdoors
COP	Coefficient of Performance; measure of heat pump efficiency
Condenser	Section of heat pump that gives out heat
Design temperature	Outdoor temperature used for selection of required heating capacity
Evaporator	Section of heat pump that absorbs heat
GJ (Gigajoule)	Unit of gas energy; 10^9 Joules
Initial cost	Combined cost of purchase, installation and accessories
kW	Kilowatt; 10^3 watts
kWh	Kilowatt hour; equivalent to 3.6 MJ
MJ	Megajoule; 10^6 joules
Mechanical heat pump	Heat pump operating on the vapour compression cycle
Watt	1 joule per second

9. The Heat Pump is Zeta Sky Hi R7 – Air Cooled Water Chiller



Specifications:

Refrigerant	R32
GWP	675
Heating Capacity @ 5 Deg C	137.3kW
COP Heating @ 5 Deg. C.	3.13
Maximum Absorbed Power	66.2kW
Exchanger	Plate
Hydraulic	1 pump and 1 tank
Cost	$62,000 ex GST

Capital Cost:

Supply & install 137.3kW Zeta Sky HP R7 LN 13.2, includes	$124,390 ex GST
Heat Pump	
Primary Pump (centrifugal)	
Primary Storage Tank	
Titanium Pool Heat Exchanger	
Secondary Heating Pump (centrifugal)	
Labour & Materials (cabling, wiring, switchgear, piping and insulation)	

10. Quantitative Analysis of Costs

The Business Case uses actual billing data of the gas consumed by the boilers to heat the water at the Noble Park Aquatic Centre, over a period of months. Based on available data from May 2019 to January 2021.

Table 1 below shows the actual price difference of gas and electricity, during a 12-month period, founded on corresponding utility bills. All costs exclude GST.

The comparison is made by converting the giga joules units into kilo watts

The Heat Pump (green) matrix demonstrates the energy that would have been generated during the period.

	Gas Usage (GJ)	Converted Gas Usage (kW)	Cost ex GST $	Gas Unit Cost $/kW	Heat Pump Production (kWh)	HP Production Cost $	Electricity Unit Cost $/kWh
Jun-19	1,497.35	415,932	$21,707.38	$0.052	85,024.34	$12,111.67	$0.142
Jul-19	1,881.50	522,640	$22,552.84	$0.043	84,912.21	$12,157.22	$0.143
Aug-19	1,481.68	411,577	$17,890.24	$0.043	85,595.89	$12,156.24	$0.142
Sep-19	1,374.90	381,917	$16,647.09	$0.044	78,586.99	$11,195.00	$0.142
Oct-19	1,278.75	355,207	$15,626.10	$0.044	83,676.36	$11,953.56	$0.143
Nov-19	1,110.26	308,407	$13,601.38	$0.044	85,646.16	$13,760.68	$0.161
Dec-19	867.43	240,954	$10,887.57	$0.045	93,948.45	$15,250.32	$0.162
Jan-20	746.59	207,385	$9,674.07	$0.047	94,991.42	$16,070.09	$0.169
Feb-20	835.78	232,160	$10,689.50	$0.046	90,788.68	$15,057.25	$0.166
Mar-20	784.99	218,052	$10,124.14	$0.046	82,193.49	$14,287.13	$0.174
Apr-20	558.75	155,208	$7,424.41	$0.048	89,654.49	$14,266.01	$0.159
May-20	746.26	207,295	$9,640.98	$0.047	85,024.33	$13,322.84	$0.157
Jun-20	955.73	265,480	$12,098.09	$0.046	75,205.57	$12,704.51	$0.169
Jul-20	1,077.72	299,367	$11,709.38	$0.039	77,136.30	$13,131.78	$0.170
Aug-20	890.35	247,320	$9,701.56	$0.039	75,205.56	$12,599.66	$0.168
Sep-20	735.45	204,292	$8,693.63	$0.043	63,833.02	$11,013.93	$0.173
Oct-20	1,150.97	319,714	$13,887.15	$0.043	68,257.54	$11,416.79	$0.167

Table 1 Price Comparison; Gas v Electricity

The table outlines the disparity in the prices for the same unit of energy. Electricity prices are averaging 330% of the gas prices per kWh. This is largely due to the transportation and transformation of electricity.

This incongruence is expected to narrow as the gas price increases while that of electricity decreases.

The following matrix clearly demonstrates the effectiveness of the selected heat pump when compared with gas-fired boilers to heat water. It shows how a machine that operationally absorbs 30,802kW of energy delivers 154,070kW, equating to a COP of 5.

A further note about the operational aspect of the machine, affecting the bottom line positively. The heat pump requires far less maintenance than boilers and has an operational lifespan of 35 to 40 years with proper maintenance.

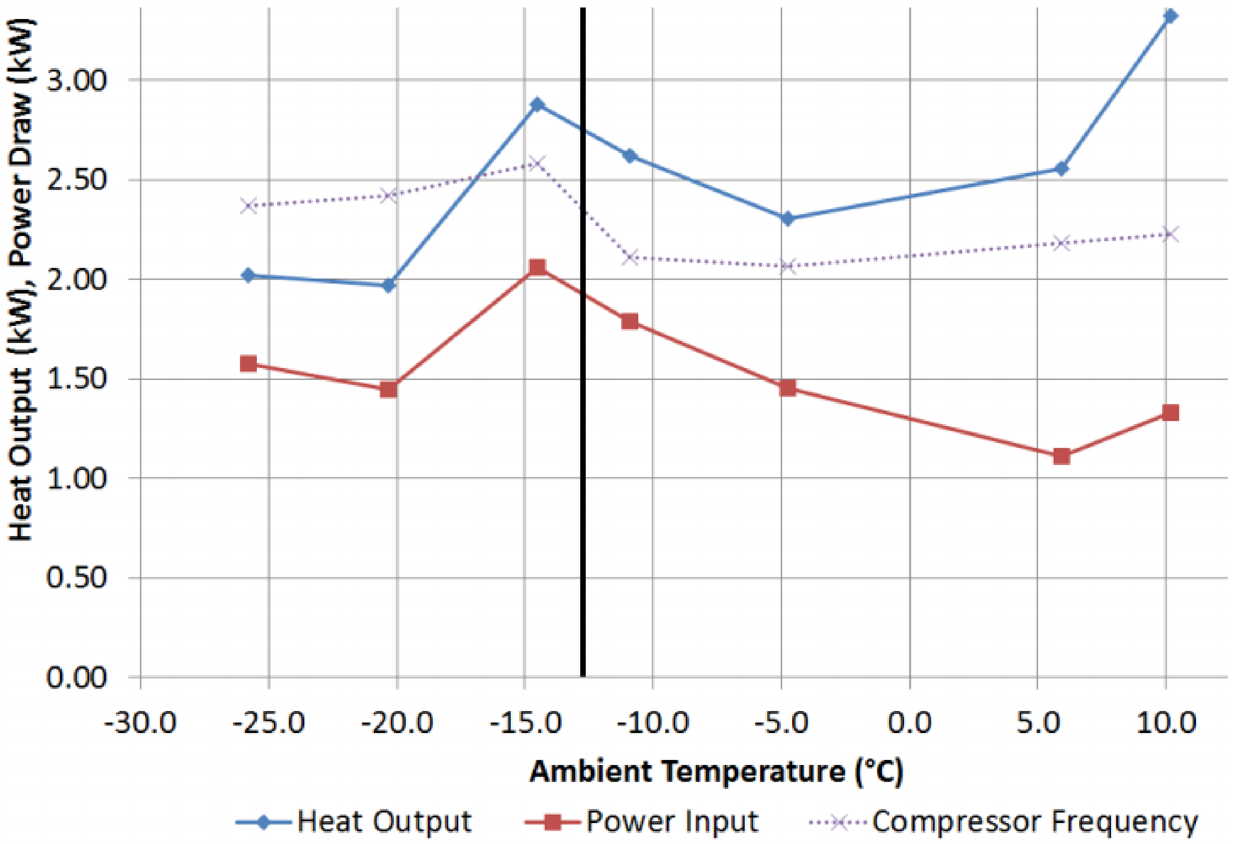


Diagram 1 *Correlation of the power drawn at different ambient temperatures.*

10.1 Understanding the Technical Jargon

In a way of understanding the technical jargon, I offer the following explanations:

<u>Conversion (units):</u>

Gas usage figures are all in kWh. These are obtained from actual energy used figures by dividing the giga joules (GJ) by a factor of 277.77 to change to kilo Watt hours (kWh).

Efficiency:

The heat output of the gas (efficiency) is only 84.7%. Therefore, to achieve the same monthly heat output the boilers burn more energy than they generate. This has been factored in the calculations.

Input Energy:

The expected heating capacity of the machine fluctuates with various ambient temperature conditions, so as the ambient temperature rises the work energy required to drive the machine is reduced while the output energy delivered increases. The heat pump has a maximum absorbed power of 66.2 kW when the ambient temperature is 5°C (given). For the purpose of this business case the mean average of 41.4kWh has been used. Therefore, 41.4kWh x 744 hours (31 days) = 30,801.6 kWh

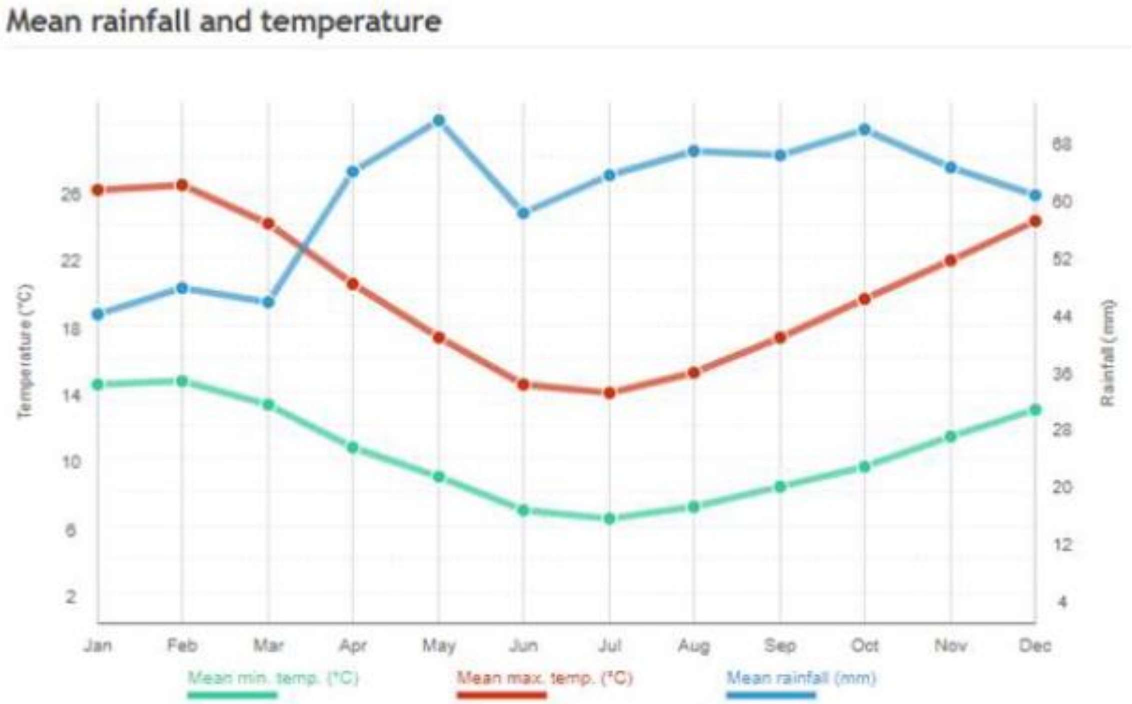
Output Energy:

The heat pump's heating capacity is 137.3kWh at an ambient temperature of 5°C (given). With a warmer ambient the generation capacity increases. The meteorology temperature chart below demonstrates the low and high temperatures that occurred in Noble Park over the period of last year.

For this exercise the mean average of 175.4kW is used. Finally, this business case allows for the machine to be operational 24/7, thus generating: 175.4kW x 744 days = 130,497.6 kW. Taking the efficiency factor into consideration = 130,497.6 / 0.847 = 154,070.4kW.   COP = 1:5

Note: the word "generation" is used loosely, as the heat pump only transfers the energy.

http://www.meteorology.com.au/local-climate-history/vic/noble-park



Bureau of Meteorology (BOM) minimum and maximum temperature chart for the months of study.

ZETA SKY HP R7 13.2			
Ambient (°C)	Heating Capacity (kWh)	Power Input (kW)	COP
5	137	41.51515152	3.3
10	148.6	41.39275766	3.59
15	165	42.74611399	3.86
20	182	43.85542169	4.15
25	196	45.26558891	4.33
30	212	45.59139785	4.65

Table 2 Net energy gains at various ambient temperatures

10.2 Cost comparison of Heat Pump v Gas Boilers

How to read the matrix:

1	Gas (GJ)	Actual amount of gas used, measured in Giga Joules – taken from utility bill
2	Convert to kWh	Conversion of energy units, from Giga Joules to Kilo Watt Hours (x 277.78)
3	Actual kWh	The result of the conversion
4	$/kWh	Cost of gas per kW hour ($0.052 – taken from utility bill)
5	$ ex GST	Total cost of gas for the month – taken from utility bill)
6	kW @ 5°C	Heat Pump energy absorption, @ ambient temperature of 5 degrees C
7	kW @mean average	Heat Pump energy absorption, @ yearly mean average ambient temp in NP (BOM)
8	$ / unit cost	Cost of energy per kW hour ($0.159 – averaged over whole year)
9	Mth (Days * Hrs)	Number of hours in the month
10	Mth kWh	Amount of energy used by heat pump in the month
11	$ / Mth	Cost of energy used by heat pump in the month
12	kW @ 5°C	Energy that heat pump produces per hour at ambient 5°C
13	kW @ mean average	Energy that heat pump produces per hour at mean average temperature (BOM)
14	Mth (Days*Hrs)	Number of hours in the month
15	Sub Total	Energy production in the month
16	Gas Inefficiency	Gas energy efficiency versus electricity
17	Production kWh	Dividing the energy production by the gas inefficiency = total production
18	Ratio to Actual	Actual gas energy used divided by the total production of the heat pump
19	Compare Cost $	Total cost of heat pump absorption to produce same amount of energy
20	Savings $	Cost difference between gas and heat pump energy usage

	Actual Gas Consumption by Boilers					Heat Pump Consumption per Month						Heat Pump Production per Month								
	Gas (GJ)	Convert to kWh	Actual kWh	$/kWh	$ ex. GST	kW @ 5°C	kW @ mean average	$ / Unit Cost	Mth (Days*Hrs)	Mth kWh	$ / Mth	kW @ 5°C	kW @ mean average	Mth (Days* Hrs)	Sub Total kWh	Gas In-efficiency	Production kWh	Ratio to Actual	Compare Cost $	Savings $
May-19	1,425.12	277.78	395,870	0.052	20,763.358	66.20	41.40	0.142	744.00	30,801.60	4,387.67	137.3	175.4	744	130,497.6	0.847	154,070.4	2.57	11,273.72	$9,489.64
Jun-19	1,497.35	277.78	415,935	0.052	21,815.790	66.20	41.40	0.142	720.00	29,808.00	4,246.13	137.3	175.4	720	126,288.0	0.847	149,100.4	2.79	11,845.15	$9,970.64
Jul-19	1,881.50	277.78	522,644	0.043	22556.54	66.20	41.40	0.143	744.00	30,801.60	4,409.99	137.3	175.4	744	130,497.6	0.847	154,070.4	3.39	14,959.73	$7,596.81
Aug-19	1,481.68	277.78	411,580	0.043	17,890.23	66.20	41.40	0.142	744.00	30,801.60	4,374.41	137.3	175.4	744	130,497.6	0.847	154,070.4	2.67	11,685.69	$6,204.54
Sep-19	1,374.90	277.78	381,920	0.044	16,647.08	66.20	41.40	0.142	720.00	29,808.00	4,246.26	137.3	175.4	720	126,288.0	0.847	149,100.4	2.56	10,876.77	$5,770.31
Oct-19	1,278.75	277.78	355,210	0.044	15,634.07	66.20	41.40	0.143	744.00	30,801.60	4,400.15	137.3	175.4	744	130,497.6	0.847	154,070.4	2.31	10,144.57	$5,489.50
Nov-19	1,110.26	277.78	308,409	0.044	13,601.37	66.20	41.40	0.161	720.00	29,808.00	4,789.22	137.3	175.4	720	126,288.0	0.847	149,100.4	2.07	9,906.35	$3,695.02
Dec-19	867.43	277.78	240,955	0.045	10,891.48	66.20	41.40	0.162	744.00	30,801.60	4,999.91	137.3	175.4	744	130,497.6	0.847	154,070.4	1.56	7,819.52	$3,071.96
Jan-20	746.59	277.78	207,386	0.047	9,674.07	66.20	41.40	0.169	744.00	30,801.60	5,210.83	137.3	175.4	744	130,497.6	0.847	154,070.4	1.35	7,014.04	$2,660.03
Feb-20	835.78	277.78	232,162	0.046	10,689.50	66.20	41.40	0.166	672.00	27,820.80	4,614.06	137.3	175.4	672	117,868.8	0.847	139,160.3	1.67	7,697.67	$2,991.83
Mar-20	784.99	277.78	218,054	0.046	10,124.14	66.20	41.40	0.174	744.00	30,801.60	5,354.03	137.3	175.4	744	130,497.6	0.847	154,070.4	1.42	7,577.49	$2,546.65
Apr-20	558.75	277.78	155,209	0.048	7,424.40	66.20	41.40	0.159	720.00	29,808.00	4,743.11	137.3	175.4	720	126,288.0	0.847	149,100.4	1.04	4,937.44	$2,486.96
May-20	746.26	277.78	207,296	0.047	9,640.99	66.20	41.40	0.157	744.00	30,801.60	4,826.44	137.3	175.4	744	130,497.6	0.847	154,070.4	1.35	6,493.80	$3,147.19
Jun-20	955.73	277.78	265,482	0.046	12,098.08	66.20	41.40	0.169	720.00	29,808.00	5,035.48	137.3	175.4	720	126,288.0	0.847	149,100.4	1.78	8,965.97	$3,132.11
Jul-20	1,077.72	277.78	299,369	0.039	11,709.38	66.20	41.40	0.170	744.00	30,801.60	5,243.70	137.3	175.4	744	130,497.6	0.847	154,070.4	1.94	10,188.87	$1,520.51
Aug-20	890.35	277.78	247,321	0.039	9,701.56	66.20	41.40	0.168	744.00	30,801.60	5,160.39	137.3	175.4	744	130,497.6	0.847	154,070.4	1.61	8,283.71	$1,417.85
Sep-20	735.45	277.78	204,293	0.043	8,693.63	66.20	41.40	0.173	720.00	29,808.00	5,143.16	137.3	175.4	720	126,288.0	0.847	149,100.4	1.37	7,047.01	$1,646.62
Oct-20	1,144.66	277.78	317,964	0.044	13,887.72	66.20	41.40	0.167	744.00	30,801.60	5,151.89	137.3	175.4	744	130,497.6	0.847	154,070.4	2.06	10,632.25	$3,255.47
Nov-20	866.17	277.78	240,605	0.039	9,462.85	66.20	41.40	0.159	720.00	29,808.00	4,739.47	137.3	175.4	720	126,288.0	0.847	149,100.4	1.61	7,648.13	$1,814.72
Dec-20						66.20	41.40	0.159	744.00	30,801.60	4,897.45	137.3	175.4	744	130,497.6	0.847	154,070.4			
Jan-21	786.61	277.78	218,505	0.046	10,065.80	66.20	41.40	0.159	744.00	30,801.60	4,897.45	137.3	175.4	744	130,497.6	0.847	154,070.4	1.42	6,945.63	$3,120.17
																				$81,028.53

Table 3 Cost comparison of Heat Pump to generate same heating energy as consumed by Gas Boilers

Note:

NPAC was closed to the public on 18 March 2020; opened on 22 June 2020

Closed again on 9 July 2020; opened on 5 October 2020.

It has been open since, except for the lockdown week in February 2021.

Throughout this period gas energy was saved by the reduction of the pool temperatures. A clear example is comparing the consumption during the month of May 2019 against the same month the following year, 395,870 kWh vs 207,296 kWh, a 48% reduction. This gives strength to the business case, using conservative data.

11.0 Summary

Over the study period of 20 months

Gas energy expended	Cost of gas energy
5,846,168 kWh	$262,972 (@$0.045)

Energy expended by HP	Cost of HP energy (@$0.158)	Energy produced by HP	Energy Ratio to Gas
606,096	$95,974	3,031,707 kWh	1.9283
1,168,735 kWh	$185,066	5,846,168 kWh	

Capital Sum	Savings over 20 mth period	Amortisation	Payback Period
$124,390	$77,906	=1.5967 * 20 Mth	31.9 mths (2 yr 8 mth)

<u>Tangible Gains</u>

The above matrix demonstrates that the heat pump can generate the same amount of heat as the gas boilers in a year, for a cost of $107,552 while the gas consumed by the boilers for the same amount of energy cost $177,712, The difference of $70,159 is the potential savings.

However, if the Heat Pump was to be linked with a solar PV system, the cost would be likely reduced by 40%, thus the potential savings will increase to $113K circa.

<u>Intangible Gains</u>

- Environmental,
- Political,
- Long operational life,
- Reduced maintenance,
- Using waste heat to increase efficiency.