Solar water heating at Ipswich hospital

By Harry Barron, Queensland Health

Introduction

The word "sustainability" has become the catch-cry of the early 21st century. As mankind ruthlessly exploits the fossil fuels inherited from ages past, ever-increasing demand is driving prices to record high amounts. However, concern is mounting amongst thinking people that the sudden (relative to the eons of history) release of huge quantities of carbon dioxide (CO2) may be producing adverse effects on our planet's climate.

Enlightened individuals, corporations, and governments are seeking to limit the discharge of greenhouse gases (GHG's) by implementing various initiatives to reduce the usage of fossil fuels. The added advantage is of course that energy costs also reduce with decreasing usage. Even relatively conservative entities such as the Building Code of Australia are introducing sustainability provisions with new energy efficiency provisions for Class 9a buildings scheduled for introduction in May 2006. The mood of the time can probably be summed up by the following statement:

> *"While this* [the doubling of the price of oil] *may sound gloomy, the planet may well benefit from an oil crisis, enabling more environmentally sympathetic alternatives, such as solar, to be developed and embraced."*
>
> Terence Jeyaretnam, Engineers Australia, April 2005.

Of course, hospital engineers and managers have always promoted efficient energy use and lowest possible energy costs in their facilities, which are acknowledged as large users of energy. They have succeeded when given the opportunity, the finance, and the political/corporate will to do so.

PART ONE: Solar heated domestic hot water description of original hot water service

This part of the paper is concerned with the production of domestic hot water for the main In-patient accommodation at Ipswich Hospital, colloquially known as the Ward Block.

The domestic hot water is produced by a bank of six electric cylinders and a bank of six natural gas fired cylinders installed in a parallel arrangement. This unusual configuration was chosen to allow for flexibility according to the changing relative price of different energy sources and to allow repairs on one bank to be completed without affecting the production through the other bank.The down-side of this arrangement is that control to produce a constant discharge temperature is difficult to achieve.

Existing gas hot water cylinders

Modified electric hot water cylinders

The total storage capacity is 3540 litres with a maximum power input of 129.6 kW of electricity and 258 kW of natural gas. The estimated daily usage of hot water from this source is 16 kilolitres and the daily energy consumption has been measured at 3200 megajoules. The energy cost is around $2,000 per month and town water costs around $620 per month.

Description of new solar water heating installation

In mid 2003, approval was given for the purchase of 12 flat panel (1900 x 990) solar water heaters. These were installed on the roof of the Ward Block, immediately above the existing hot water service plant room. This plant room was on the eighth (top) level of the Ward Block.

The pitch of the roof and the solar heater installation was 6.5 to the horizontal. This is well below the 25 recommended in AS 4234 for the hospital's latitude. This was not considered a major concern as the solar heat energy was always going to be fully used. In reality, this orientation meant that the solar input in winter would be less than its possible potential for that time of the year. However, the summer solar heat input would be increased, as the electricity and gas tariffs as well as the usage of hot water are reasonably constant throughout the year. The added expense of the manufacture and installation of suitable supporting frames was not considered to benefit overall annual performance to any substantial amount.

The solar panels were installed as a pre-heater to the electric cylinders, adding heat to the make-up water to these heaters. The solar-heated water flowed back into the electric cylinders via a pipe work connection at the top row of elements, which were removed. All six cylinders were connected.

The initial installation and commissioning was completed under the instruction of the original equipment manufacturer

Solar heaters as installed

Insulation

Initially the installation used pre-lagged hot water pipe insulated by a 3mm thick PVC coating. This piping is commonly used on internal domestic and commercial hot water applications. This lagging could be expected to handle temperatures of up to 80 C. During installation this lagging was found melted and dripping from the return pipe work. Unfortunately this occurred in unusual circumstances. The newly installed solar collectors had been left pressurized by town water but the return valve had been left closed. The water temperature reached an estimated 120 C in mid-Autumn. At the time this gave an overly-optimistic expectation of the heaters performance.

The original insulation was replaced with foiled-covered pre-formed fibreglass insulation that has a much higher melting point.

The effect of insulation can be seen from TABLE ONE below.

TABLE ONE: Effect of insulation on water temperature

Insulation	Litres	Average Flow Temp	Average Return Temp	Temp Difference
None	5180	53.2	62.6	9.4
Fibreglass 25 mm	5010	53.3	67.3	14

Commissioning

Eventually the system was put into service, still under direction of the manufacturer's representative.

The original installation did not include monitoring equipment. Thus the actual performance of the system could not be determined. After a short time of operation, monitoring equipment was approved and installed to measure the flow and return temperatures and the exact flow quantity. These were connected to the site Building Management System (BMS) for ease of recording and reporting results.

This monitoring showed that the original control system was indeed switching the circulating pump on and off at suitable times and day-time performance was acceptable. However, the monitoring also showed that at night a thermo-siphon was occurring, cooling the hot water from the make-up line in the low usage night time and cooling it through the solar water "heaters". In fact, the night flow losses were exceeding the day flow gains (as shown in TABLE TWO below). The new solar hot water heater arrangement was costing more than the original system.

TABLE TWO: Solar hot water heater performance pre-modification

June 2004	Daytime Operation	Night time Operation	Nett Gain / Loss
Average time of operation (Hours)	5.1	18.8	
Average Boost/Loss (degrees C)	7.2	-22.4	
Average Flow (litres)	1991	1034	
Average Energy Gain (MJ)	62.4 (Day)	-97.0 (Night)	**-34.6 (loss)**

A solenoid valve fitted with a variable flow by-pass was installed in the pipe work. This valve is opened by the same control signal that starts the pump. This solenoid valve reduced the night flow to practically zero, considerably increasing the overall efficiency of the solar heating.

The only other problem encountered was the standard connector clips between the twelve panels cracked after becoming brittle after 9 months service. These were replaced by the manufacturer under warranty.

Flow rate through solar heaters

In an experiment, the flow rate was doubled by increasing the speed of the solar heater's circulating pump. The result was half the temperature rise through the solar heaters. This indicated that the heating effect was at the maximum achievable with this installation.

Heater performance

Several different performance measures were monitored over a period of twelve months to determine the worth of the new solar energy source. Of these three are presented here:

Average daily heat gain (MJ)

AUG 04	SEPT 04	OCT 04	NOV 04	DEC 04	JAN 05
120	207	155	183	208	247

Average hours of operation per day

AUG 04	SEPT 04	OCT 04	NOV 04	DEC 04	JAN 05
6.4	7.8	6.8	7.5	8.6	9.3

Average solar heater temperature boost (°C)

AUG 04	SEPT 04	OCT 04	NOV 04	DEC 04	JAN 05
10.4	13.2	10	11.7	12.5	12.9

On 7 July 2005, the quantity of solar heated water passed 1.5 million litres.

Summary of heater's performance

After the first 12 months monitoring, several aspects of the performance of the solar heaters became apparent. These were:

- Effectiveness was very dependent on the weather and the season. While obvious, the extent and randomness can be seen in the collected results. The actual temperature rise across the heaters varied between 10° C and 13.2°C. However, the highest was in September and the lowest in October.
- The payback period achieved by this installation was 14.4 years at 2004 energy prices. However electricity prices have recently risen considerably (up to 40% for peak times of usage) and the Queensland Government has introduced a "Green" levy on electricity produced from coal for large users. These increases are seen as a portent of the future, but have impacted positively on the IRR for the project.
- Performance monitoring is desirable when installing new equipment, especially when the depth of knowledge evident in the supervising personnel is limited.
- Increasing the number of collectors would result in increased savings. For no electric input to be required during the operating hours of the solar heater, a total of 218 solar heating panels would be required at Ipswich Hospital. Additional panels will have a payback period of 9.6 years at 2004 pricing), because the supporting infrastructure is already in place.

Conclusions from part one

Installation of the latest generation of flat solar heaters does not become an economic source of commercial hot water until energy charges exceed 11.3 cents per kilowatt-hour. However, in those facilities where this unit-price is charged, this form of heating does become an economical proposition. The WMHSD is using the results of the Ipswich Hospital installation to determine in which locations solar hot water is appropriate. It appears that small rural hospitals and off-site residences offer good opportunities.

PART TWO: The future for solar hot water at ipswich hospital

Energy performance contracting

Queensland Health (QH) has chosen to use Energy Performance Contracting (EPC) as a means to implement Queensland Government policies to:-

- Increase the energy and water efficiency of its facilities
- Reduce energy and water costs
- Contribute to a reduction in the generation of greenhouse gases

The stages of implementation of an EPC are:

1. Calling of expressions of interest
2. Request for tenders
3. Detailed facility study (DFS)
4. Signing of energy performance contract
5. Preparation of detailed plans and monitoring and verification proposal
6. Equipment installations
7. Period of monitoring and verification (as agreed at Stage 4)

Details of the EPC process were presented at last year's IHEA conference by Mr. Fred Nicolosi. Mr. Nicolosi has been retained by QH to act as expert advisor on the sensitive area of Measurement and Verification (M &V). I will not attempt to further detail this process, rather to detail the experience to date of the QH approach to the EPC process.

The EPC's major attraction is that the results are nominated and guaranteed before signing the contract i.e. before any funds are committed to the project by the Principal. This guarantee provides the Principal with an entirely low risk financial strategy, thereby making the funding for the project much easier than other arrangements.

> *"The (EPC process) methodology is highly focused on ensuring that it is acceptable to Governments . . . the process is recommended where highest levels of probity are required."*
>
> Best Practice Guide to Energy Performance Contracting, page 16.

TABLE THREE: Value of energy performance contracts proposed for the Queensland Health Sites

Cairns	$1,192,600	**Logan**	$1,225,000	**Royal Women**	$1,700,000
Nambour	$2,061,000	**PAH**	$5,848,000	**The Prince Charles**	$2,999,000
Ipswich	$2,270,000	**Bundaberg**	$ 503,000	**Gladstone**	$584,000
Mackay	$1,074,000	**Rockhampton**	$ 763,000	**Roma**	$487,000
QE11	$ 839,000	**Royal Children's**	$1,650,000	**Fraser Coast**	$1,561,000
		Total	**$24,825,000**		

Energy conservation measures

The comparison of the costs of the Energy Conservation Measures (ECM's) in the EPC's of the current participants in QH. (TABLE THREE) shows that the cost of the EPC's at Ipswich Hospital is high for the size of the hospital. This has resulted from an enlightened approach from local management to go beyond the tried and proven (safe) measures and, while still remaining within the economic restraints imposed by our capital provider, adopt some innovative measures. The intention being that the savings, although right on the margin at the present time, will in future produce increasing savings as energy and water costs rise.

Only one contractor out of the five Expressions of Interest provided such a proposal with any innovation. Such measures included the harvesting of rainwater for potable and/or non potable purposes and the installation of a small absorption chiller which would be powered by solar energy exclusively.

One of the major considerations at Ipswich was the maximisation of the reduction in greenhouse gases. Some 'safe' ECM's quoted for some sites have paybacks in six months. However, these would only save hundreds of tons of GHG's over a fifteen year period. The Ipswich ECM's have a payback in around seven years but will save thousands of tonnes of GHG's over this period.

Proposed energy conservation measures at Ipswich hospital

Nine ECM's identified to achieve the guaranteed performance for Ipswich Hospital are summarised as follows:

1. Installation of a thermal energy solar collector field
2. Installation of an absorption chiller and associated equipment
3. Upgrade and modify HVAC systems for optimum efficiency
4. Installation of electric heat pumps for water heating
5. Upgrade selected light fixtures to new efficient luminaires
6. Installation of lighting controls for improved management of lighting
7. Water use reduction systems
8. Rainwater harvesting and re-use systems
9. Installation of energy use monitoring system

It should be stressed that these measures have been determined for the existing circumstances at Ipswich Hospital and should not be expected to perform successfully at any other location.

The EPC process used the same documents for the three trial hospitals to produce many similar Energy Conservation Measures but with differing innovative centre pieces. In all facilities the ECM's concentrated on sophisticated controls on lighting and air-conditioning for energy conservation. Water reduction concentrated on the fitment of flow limiting devices on water supply fittings. The variances are in different numbers and equipment type and set-up to suit the particular requirements of the individual locations.

Innovation one — solar-powered absorption chiller

At Ipswich it was concluded that an innovative approach could be taken with the supply of chilled water to the chilled water circuit. The installation of a 300 kWr solar powered absorption chiller is proposed.

The HVAC system of the site represents a large proportion of the peak electrical energy necessary to condition air. The most innovative ECM proposes to use a double effect absorption chiller and a field of solar water heaters.

The economic feasibility of absorption chillers depends on the source energy to deliver high temperature water at low cost. The inherent advantage of the solar assisted cooling is the correlation between the availability of solar energy and the cooling load within the building. This proposal is to use parabolic trough collectors which have a high efficiency over a large temperature range that track the sun to ensure maximum heating throughout the day. The solar water heaters will be controlled by a PLC which will monitor the radiation levels to track the sun.

The chilled water produced by the absorption process will be connected to the existing chilled water circuit in a side stream arrangement that enables the new chiller to operate in both parallel and series with the existing chillers. The staging of the four chillers will be controlled through the Building Management System.

Innovation two: — water conservation measures

Water conservation measures were found to be particularly difficult to justify economically, due to the current price of water at $1.30 per kilolitre (excess usage rate above the first 150 kilolitre every quarter). Compare this price to petrol, milk or other useful liquid. Astute observers may have noticed that governments have recognised this situation and are rectifying this as quickly as they can politically. Currently such efforts are being ably assisted by the long term drought in our part of Australia.

A token water innovation offered involved the use of harvested rain water for potable and/or non-potable purposes. However, the majority of water savings will come from standard conservation measures and the cost of innovation cross-subsidised from energy savings.

Sources of delays at the trial sites

> *"Past experience with performance contract, particularly in the public sector, shows that obtaining the approval from decision-makers can be a long and slow process."*
>
> Best Practice Guide to Energy Performance Contracting, page 14.

The process in the Queensland Public Sector environment has taken much longer than suggested in the Best Practice Guide despite this methodology's financial advantages. Because of the slow rate of progress in the EPC process, later starters have been able to reach the same position as the "trial" sites at Cairns, Nambour, and Ipswich.

One delay revolved about legal issues, and agreement on the document wording to suit both parties. For example, one of the stumbling blocks to reaching agreement at the Detailed Facility Study stage was Intellectual Property Ownership and Rights.

Another source of delay was the resistance of budget-weary managers at all levels to this process that, in fact, is very low risk technically and financially. The size of the outlay (in West Moreton's case around $2.2 million) seems to cause some nervousness. This has led to recognition that decisions made regarding an EPC should involve senior management, finance and engineering so that all these interests can gain a full appreciation of the process and participate in decision-making.

Other unavoidable causes of commercial concern were chiefly related to the retrofitting nature of this project. These were:-

1. Latent conditions relating to the existing site
2. Measuring and verification of the guaranteed quantities, especially in an environment of organisational change
3. Maintenance of EPC plant during the Warranty period (one year) and during the guarantee period (fifteen years); especially in those areas where the new works are an expansion of existing systems.
4. Quantifying savings based on maintenance reductions
5. Length of the M&V period.

Technical issues that required clarification included:-

1. Minimising the fresh air make-up to in-patient accommodation areas
2. Philosophy of temperature set-backs
3. The installation of a large number of electrical meters into existing switchboards
4. Maintenance providers during the periods of warranty and performance guarantee.

Conclusions from part two

1. The amount of common ECM's in the three 'trial' hospitals indicates that the future construction of hospital buildings should include these common items from new. That is, the standards of building services should be raised to include these energy-efficiency raisers at construction for two major benefits. Firstly, the installation and integration of these items would be far more economical, and secondly, the benefits in energy costs, water costs, and GHG reductions would accrue throughout the entire life-time of the building.
2. Water conservation measures were found to be particularly difficult to justify economically, due to the current price of water.
3. Decisions made regarding an EPC should have the facility's senior management, finance and engineering at the one meeting so that all these interests can participate in decision-making. This participation would increase the speed of implementation and maximise the acceptance of the decisions.

Bibliography

New energy provisions for multi-residential buildings, *Australian Building Regulation Bulletin*, Winter 2005, p4.

Sustainability, *Engineers Australia*, April 2005

Best Practice Guide to Energy Performance Contracts, Australasian Energy Performance Contracting Association, 2000.

Best Practice Guide to Measurement and Verification of Energy Savings, Australasian Energy Performance Contracting Association, 2004.