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Renewable Energy Options
for Hot Water Systems in Remote Areas

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Paper for the World Renewable Energy Congress, Murdoch University, Perth, WA, February 1999
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Abstract

Providing hot water for remote Indigenous communities in Australia has become a priority as part of the effort to improve Indigenous health. Earlier work by *Healthabitat* among others has identified washing people to be important in overall health outcomes. In the remote central and northern regions of Australia the solar regime is very good and the potential for the use of solar hot water systems has been thought to be among the best in the world. Reports from communities in these areas, however, have been pointing to severe problems with the operation of solar hot water systems. The present paper gives the results of a trial of 29 hot water systems in remote locations with the view to identifying the best systems. Of the 29 systems 14 were solar systems, 6 were heat exchange systems and the remainder gas and electric. In addition four biomass heaters (CAT chip heaters) were trialed alongside solar systems. The hot water systems were located at Napranum (northern Queensland) Kintore (NT), Kalka (SA), Wataru (SA) and Alice Springs (NT). The trial started in June 1997 and finished in October 1998. Data loggers were placed on the systems to monitor water temperature, electricity consumption and water flow. Solar radiation and ambient temperature was also monitored at each site. The project was funded by ATSC.

Acknowledgements

The hot water project was funded by the Aboriginal and Torres Strait Islander Commission as a special CAT research project. First and foremost would like to acknowledge the householders in Napranum, Kintore, Wataru, Kalka and the Alice Springs town camps for their assistance and tolerance in letting us trial hot water systems in their households. We would also like to acknowledge the co-operation received from the suppliers of the hot water systems used in the trials. In particular the technical and sales people at Solarhart Australia, Edwards Energy Systems, Quantum Energy Systems, and Rheem were very helpful. The aim of the project is to deliver a better hot water system to remote Indigenous people and it is thought that this aim will be best achieved by working with the existing manufacturing sector. The original idea for looking at hot water systems in Indigenous communities rests with the people responsible for the original UPK work and in particular Paul Pholeros of Healthabitat and Stephan Rainow from the Nganampa Health Council. They provided not only advise on the project direction but on the ground support when it was most needed – in the field when vital bits were missing and things were going wrong. Mike Travers built the original data loggers and was the main support for installing the systems. David Lowe helped in the final stages on field visits removing the loggers.

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Introduction

The origins of this investigation lie not in the field of renewable energy but in environmental health; in particular looking at ways and means of improving Indigenous health through the provision of adequate health hardware. One of the earliest investigations along these lines was the 1987 report of "Uwankara Palyanyku Kanyintjaku" known as the UPK report (1). The UPK study looked at environmental health in the Anangu Pitjantjatjara (AP) lands in north-western South Australia. The authors suggested a nine-point strategy for improving the health status of Indigenous people in Australia. The highest priority was accorded to ensuring people had access to facilities that would enable the adequate washing of their own bodies. Other strategies looked at washing clothes, improving nutrition, controlling dust, reducing crowding, temperature control and reducing trauma. A follow up study, undertaken by Healthabitat (2), which looked in detail at a single community in the AP lands, Pipalyatjara, found that the provision of hot water systems was often the weak link in the chain of events that would lead to the provision of adequate hardware to wash people. To try to find out why hot water systems were not working in remote Indigenous communities a project was first sketched out around 1995, by the people involved in the original UPK study. The Centre for Appropriate Technology (CAT) eventually, in 1996, obtained funding from the Aboriginal and Torres Strait Islander Commission (ATSIC) to progress this work. A steering group met in November 1996 to consider in detail the types of system to be trialled and the locations of the communities. A central consideration in designing the project was to encompass the ethic espoused by Dr. Fred Hollows "no survey without service". That is, the survey must be formulated to have direct benefits to the study sites, in this case where faulty hot water systems were found they must be fixed. Steps were then taken to obtain the test systems.

After consulting a wide selection of Australian manufacturers of hot water systems a final selection was made of two brands of solar systems, one brand of heat pump system, one brand of gas, system, two brands of electric systems and the biomass fuelled CAT chip heater. Good co-operation was received from most of the manufacturers with discounts being received for the purchase of the test units. The number of systems in each category was decided to be around 6 giving a total of 30 separate systems. The study sites selected were Napranum (near Weipa on Cape York), Wataru and Kalka in the AP lands, Kintore north-west of Alice Springs and the town camps in Alice Springs. The parameters to be monitored were the temperature of the water, the flow rate and the consumption of electricity (for electric and electrically boosted solar systems). In addition solar radiation and ambient temperature was to be monitored on a site by site basis and the physical condition of the systems was to be recorded.

Survey of existing systems

A preliminary survey was carried out in April 1997 of hot water systems that were currently in use at Kintore. There were about 50 separate Indigenous households in the main Kintore community all having a single brand solar hot water system. The age of the systems in place ranged between two and ten years. Because Kintore is located in a frost prone area (600 km north-west of Alice Springs) all the systems used a heat exchange system to heat the main water tank. In addition all systems had an electrical boost element installed and permanently switched on through the main supply switchboard. The water used by the community came from an underground bore and was typical of remote desert locations with around 700 ppm of dissolved solids (mainly carbonates and bicarbonates).

The results of the Kintore survey reinforced the conclusions of the earlier Healthabitat (2) study by showing that only 38% of the 50 hot water systems looked at were capable of safely supplying hot water to the household. The main reasons for failure were attributed to faults related to the booster element (62%) and the depletion of the heat exchange fluid (42%). Other problems found were failed safety valves and corroded main tanks. Lack of maintenance and poor maintenance were the probable ultimate contributing factors together with poor water quality. Faulty systems were fixed wherever possible. Where this was not possible the more damaged systems were earmarked to receive the new test systems to be provided under the main hot water project.

A similar survey of existing solar systems was carried out at Napranum in conjunction with the installation of the HW trial systems there in July 1997. Napranum is a much larger community than Kintore with its own works department and much closer to the infrastructure and support provide by the mining town of Weipa (only 20 km away). The community has around 200 Indigenous households served by a variety of mainly electric and solar hot water systems. At the start of the main hot water trial the households were billed monthly by the local electricity supply company. As the earlier Kintore study had shown a poor operational status of solar systems it was decided to survey only the solar systems at Napranum. Some

30 households were identified as having solar systems originating from two manufacturers. Of the 30 systems the survey found only 7 working satisfactorily. Installation was found to be very poor in almost all cases, with poor panel orientation, no systems having overflow pipes plumbed to ground and many systems having no heat transfer fluid in place; even though nearly all systems were of the heat transfer type. One of the reasons given for the latter omission was related by one of the plumbers. The plumber suggested that because the proprietary brand fluid had "must be used in frost prone areas" on the label and as Napranum was certainly not in a frost prone area no fluid was used in the system at all. When the mistake was realised the full strength fluid was added to some of the systems leaving a shortfall (a ratio of around 4:1 is assumed by the manufacturer). The very aggressive (pH 5) water in the area contributed to a large number of cases of corroded main tanks and the prevalence of bauxite dust sticking to the panels would certainly degrade performance. Systems were fixed wherever possible but the large number of systems that needed replacing was documented and given to the works department.

Installation of systems for the main survey

Because of the fixed budget and the relatively large number of systems involved (30) it was decided to build up the data logging systems at CAT using three cheap single channel "Easylog" 8 bit data recorders. The loggers were capable of storing 8000 readings, which was enough for three months of data, taking one record every 20 minutes. One logger was earmarked to record the water temperature from a K type thermocouple, the second to record the flow rate by counting pulses from a liquid flow sensor (supplied by Radio Spares) and the third to measure the electricity used by counting pulses from a conventional pulse output electricity meter (supplied courtesy of the Power and Water Authority NT). Considerable problems resulted from this choice of logger. The first was that operation in the pulse counting mode resulted in an internal battery life of only three weeks; instead of the three years cited in the manufacturer's documentation for other modes. This problem was not realised until the first three-month of data was ready for collection. It was remedied by connecting the data logger supply to the separate backup (sealed lead acid) battery used to power the flow meter. The backup battery was charged from the mains in most instances (see later). The second problem encountered was that the version of the software supplied with the logger was faulty and caused the time record to get out of synchronisation with the data record. This fault became apparent when the solarimeter record for Kintore suggested that the time that the sun rose changed from around 6am, early in the record, to a little after 1 am towards the end of the three-month record. This problem was solved by sending all the faulty data to the supplier, who lived by the way in the UK, by email. The supplier would not let on the method of data recovery but it fixed the data and the new version of the software supplied did not have the same disastrous effect. Later problems included a fairly high electrical failure rate (around 15%) of the loggers under field conditions.

The installation of the test systems proceeded between June and September 1997. It was originally hoped that the system manufacturers would take responsibility for the installation of their own systems to ensure that they were installed correctly and to their own specifications. Because of the very high installation costs in the remote locations (over \$2,000 per unit in the case of Wataru), a compromise had to be reached. The compromise was that one set of plumbers and electricians would work on all the different systems under the technical guidance of the separate manufacturers. In one case for the systems in Wataru a manufacturer's technical representative from Perth was present during the installations. The difficulties encountered installing the hot water systems remote from infrastructure support cannot be overstated. Parts from one manufacturer, in particular, were missing from installation kits, and the incorrect batch of heat exchange fluid was supplied. All systems had to be manhandled into position. Nevertheless these difficulties were eventually overcome and all systems were in place by the end of September 1997. The final count was: Brand A solar, 8 systems of two different types; Brand B solar, 6 systems of one type; 6 heat pump systems of one type and brand, 4 electric systems (two brands), 2 gas systems (one brand) and 4 CAT chip heaters. Of the solar systems 10 had electric boost permanently connected and 4 were standalone solar. The low number of gas systems was due to the fact that for various reasons it proved very difficult to convince people in the central desert areas to accept gas systems. In addition to the new systems purchased under the hot water project, one existing gravity-fed solar system and one existing brand B heat exchange system were monitored. During the survey some changes were made; one of the gas systems had to be replaced with a new type Brand B solar system and the gravity fed solar system was replaced with a recently marketed forced flow Brand B system.

The data logging systems were installed at the same time as the hot water systems. The systems at Wataru and Kintore had separate PV panels installed to supply the backup batteries. The reason for these additions was that Wataru had a renewable energy main electricity supply system which was not sufficient for supplying hot water; and was also prone to outages. Kintore had just had "pay as you use" power cards installed and it had been ascertained from the preliminary study that this change would mean that the household supply could not be relied on to be continuous for long (three month) periods. Note that it turned out that the households in the Alice Springs town camps also had the same meter cards installed towards the end of the survey period meaning several of these sites gave failed data

records for the last monitoring period. Luckily the card systems were being installed at Napranum during the very same days that the HW monitoring equipment was removed at the end of the project.

During the installation of the equipment the flow meters were individually calibrated by counting the number of pulses emitted for a fixed 10-litre volume of water. The working thermocouples were checked in the field against a precision electronic thermometer (also a K type thermocouple) which was in turn checked in the laboratory against a calibrated mercury thermometer. The power meters were calibrated and zeroed by PAWA before installation.

As mentioned, the available data storage meant that the data had to be downloaded every three months. Visits were made for this purpose around October 1997, January 1998, May 1998 and August 1998. During the final visit the logging equipment was removed and any faulty systems replaced. The intermediate downloading visits at Wataru, Kalka and Kintore were made by charter flight, Napranum via commercial flight to Weipa and the town camps accessed locally. During these visits non-operational loggers were repaired, failed batteries replaced and the hot water systems were assessed for physical failures. The final visit had to be made by road from Alice Springs in all cases except Napranum.

Main survey results

Data recovery: The amount of data collected during the monitoring period was prodigious, with 3 loggers at each site collecting around 8000 data points every three months for a span of 10 months; this amounted to some 2 million points in total. From the total data files collected, around 63% gave valid data, 17% partial information and the remaining 20% failed to give any information at all. Reasons for failure included failed loggers, failed backup power supplies due to the mains power being disconnected, householders abandoning the house, and in one case the house burning down. Some of the flow records had patches of missing data or data where the pulse rate was over the limit (255 pulses) per 20-minute period. The flow data had to be sifted by hand to correct for these situations and to look for leaks and taps left on. Leaks were distinguished by a constant background pulse rate. Taps left on were usually more erratic with recursions to zero pulses. Data, which could not be corrected for, was deleted from the analysis. The energy data was generally reliable with the total energy recorded, from totalling the pulses, matched with that obtained on the conventional kWh meter.

Temperature records were sometimes misleading because the actual hot water temperature was only available when the hot water was flowing past the sensor. Sometimes this was not the case at the precise time the logger recorded the temperature. In these cases the maximum temperature measured at a nearby time was substituted. Errors in actual temperature contributed to the spread in values when looking at electrical inputs compared with thermal outputs. If no temperature values were available at all the thermostat value was substituted. The ambient water temperatures recorded were found to be almost identical to the ambient air temperatures.

Data analysis: Data analysis has only been completed in detail on the first three months of data covering the period Oct 97 to Jan 98. Total flow and electricity consumption has been analysed for all the three monitoring periods until Oct 98. Details of the first three months are given in a separate report (3).

Hot water consumption: Flow information was recoverable from 54 of the 94 flow files. From this data the average hot water consumption was found to be 240 litres per household per day. This average is consistent with non-Indigenous Australian averages, which typically show hot water consumption to be around 50 litre per person per day. Because of the highly variable number of occupants in Indigenous households at any one time it was not possible to record the consumption per person. Consumption data for individual households showed considerable variation with large "right hand tails". That is, while the average consumption might be around 200 l/d the highest consumption might be as much as 1400l/d. In some cases the high daily consumption was traced to leaking pipes or taps or to taps left on. In other cases the high levels appeared to be attributed to real consumption of hot water.

Electricity consumption: For households connected to a grid the electricity consumption varied from a low of 0.8kWh/day to a high of 31.3 kWh per day with an average of around 8.0 kWh per day. Two very high points around 30 kWh were found for solar systems at Napranum both that had severely leaking hot water systems.

Physical condition: As might be expected for hot water systems after only 12 months of use, the physical condition of the systems was generally good. Two major failures were found: both Brand A solar systems. One of the units at Wataru showed indications of a failure in the main storage tank with calcification around the top seam and around holes in the insulating jacket. The unit was replaced during the final monitoring visit and brought back to CAT for detailed examination. The other failure was in a system at Kintore where severe calcification around a leak in the element seal was identified. Two electrical elements failed one in a solar system and the other in an electric system. Minor problems included a number of leaking relief valves.

Overall system performance:

Electric systems: Only four electric systems (two brands) were part of the program. Of these one site was abandoned due to no occupants and the electricity supply having never been connected. The remaining units showed an efficiency of around 80% with no use losses of between 2 and 3 kWh/day. The combined average for the two brands suggested around 22 litres of hot water @ 60 °C could be produced per 1 kWh of electricity. The main advantage of the electric systems was their easy installation.

Heat pump system: Data for the single brand heat pump system was the most consistent, giving good correlation between electricity consumption and hot water use. An analysis of the data showed an operating coefficient of performance (COP) from between 2.0 and 2.3. This value should be compared with the manufacturer's literature, which gave a COP of 4.0. Daily standing losses were between 0.6 and 1.3 kWh/d (electrical). The systems on average gave 52 litres of hot water @ 60 °C for every 1 kWh of electricity consumed. No failures were recorded but one unit needed a reset on the compressor motor.

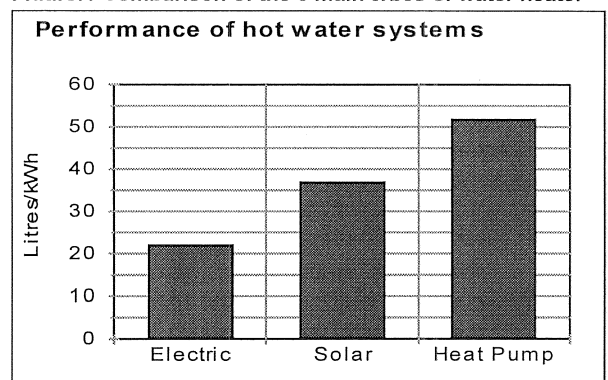
Solar systems: For the 10 solar hot water systems, where reliable data was available and the boost was connected, on average 1 kWh of electricity produced 37 litres/day of hot water @ 60 °C. That is some 30% lower than the heat pump systems. Two physical failures were recorded and several minor faults were found with the water supply and delivery part of the systems. Installation in remote areas was difficult and it was apparent that community plumbers were not familiar with this type of system. In addition householders were not versed in the operation of the electric boost.

Gas System: Due to the reluctance of householders to accept gas systems, data here was from two systems only. The efficiency was found to be around 90% and no physical problems were found with the units. However the unit at one site in a town camp had to be replaced as the householder complained that the 135 litres capacity unit could not produce sufficient hot water to satisfy the daily demand.

Conclusions and Discussion:

The first conclusion from the study was that the anecdotal evidence from communities and the actual evidence from the small number of household studies suggesting that existing solar systems have not been performing well in remote Indigenous communities were validated. Problems included poor installation of systems, lack of maintenance and failures due to adverse water quality. For the new systems installed under the present project, that were permanently connected to an electric boost, the performance was also not found to be good (see figure 1). Some of this poor performance might be attributed to the high

Figure:1 Comparison of the 3 main types of water heater



variation in daily household usage with many occasions of daily usage exceeding the tank capacity. Detailed analysis of the data may reveal further causes. In at least one system a complete failure of the thermosiphon was suspected. Because of the high turnover in household occupancy, training in the use of a manual switch to override the boost element was not thought to be a viable option. Some form of intelligent switching may be the way to go. It is hoped to work with the manufacturers on some of these issues. The heat pump units performed well and gave consistent energy gain throughout the seasons. The electric systems performed well except that the short life of elements in areas having high dissolved solid content would tend to cause long term maintenance problems. Finally it is thought that research needs to be done on ways to solve the dislike of gas systems in central desert areas as these seem inherently more reliable than either electric or solar systems.

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