Centre for Appropriate Technology

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CAT Report 00/10

Hot Water Use and Water Heating Systems in Remote Indigenous Communities.

December 2000

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Contents

List of Tables

List of Figures

ACKNOWLEDGEMENTS

The study involved organisations and numerous individuals in the communities of Kintore, Kalka, Wataru, Napranum and the town camps of Alice Springs. The assistance and cooperation of these communities is gratefully acknowledged. The Aboriginal and Torres Strait Islander Commission (ATSIC) funded the project work. Nganampa Health Council also supported the project. We would like to thank hot water system manufacturers; Edwards, Hardie Dux, Quantum, Rheem, Solahart and Sunsaver for providing systems for the trials at a discount. Input from members of the project steering group was highly valued throughout the life of the project. Bob Lloyd took all photographs.

EXECUTIVE SUMMARY and RECOMMENDATIONS

This investigation of hot water supplies in remote Aboriginal communities was undertaken as a collaborative effort by Nganampa Health Council and the Centre for Appropriate Technology (CAT) between January 1997 and December 1998.

The project involved the funding, installation, monitoring and maintenance of a range of commercially available hot water systems in the selected Aboriginal communities. The technologies trialled included: electric, heat pump, gas, solar (with electric boost), solar (no boost) and biomass. The selected communities were Napranum (Queensland), Wataru & Kalka (South Australia), Kintore (Northern Territory) and several town camps in Alice Springs (Northern Territory).

A total of 33 hot water systems were monitored during the trials. These were monitored using electronic datalogging equipment. This data was downloaded during quarterly visits to each site. A large amount of data was collected during the trial, although due to several problems a proportion of this data was lost or corrupted.

The study looked at consumption rates of hot water for the households involved in the trial. The average daily hot water consumption was around 240 L/household/day. However there was significant variability in consumption rates of hot water in these communities. This was linked to the highly variable population in many Indigenous households. The average per capita consumption of hot water in these communities (~40 L/person/day) was similar to that of the wider Australian population (~50 L/person/day).

Technology	Fuel Price ($/kWh)	Estimated Average Fuel Cost ($/100L)
Electric	0.16 (subsidised)	0.80
	1.00 (real)	5.00
Heat Pump	0.16 (subsidised)	0.30
	1.00 (real)	1.96
Solar (boosted)	0.16 (subsidised)	0.40
	1.00 (real)	2.30
Solar (no boost)	-	-
Gas	0.16	0.85
Biomass	0.02	0.47

Table 1 summarises estimates of the average fuel cost for each type of system.

Fuel efficiency and running cost was investigated for each system. **Table 1** summarises the analysis of running cost based on data acquired through the trials.

Of those systems using electricity, heat pump systems consistently had very good fuel efficiency and a relatively low running cost.

The performance of solar systems (with electric boost) was highly variable, being dependent on local operating conditions and household demand patterns. The data indicated that heat pump systems performed marginally better than boosted solar units. However, when the statistical significance of the small sample is taken into account, the relative performance of the two technologies cannot be separated with any certainty.

Of those systems using electricity, electric units were the most expensive to run.

Subsidised energy costs (especially for electricity) were identified as a key factor in determining the most "cost effective" energy option for Indigenous householders. The feasibility of using energy sources other than electricity, particularly gas, depends on the respective prices paid by end users for these energy sources.

While the unboosted solar units appear to incur no fuel cost to householders, the efficacy of these units also depends on their ability to provide the desired levels of hot water. The results of the trial indicate that the unboosted solar units often failed to provide sufficient hot water for the household, particularly at times where demand for hot water was higher than normal.

The use of cost effective alternatives to electricity reduces the electrical load on the community generators and creates an opportunity to use alternative sources for community electricity such as renewable energy. This is a desirable goal for both communities and funding agencies, faced with ever growing diesel fuel bills for electricity generation. Generally speaking, hot water systems using electricity were found to be incompatible with the use of stand-alone renewable energy systems.

The level of data available and the short duration of the trial (relative to the lifetime of a hot water system) made it difficult to draw any firm conclusions concerning the long-term reliability of systems. Some insight into the long-term reliability of solar hot water systems was provided by preliminary surveys of existing hot water systems, carried out in two communities (Kintore and Napranum) prior to the trials.

The preliminary survey of 54 solar hot water systems at Kintore, carried out in 1997, included examination of solar hot water systems ranging in age from 2 to 13 years. The survey showed that only 38% of systems were capable of supplying hot water to the household. The main reasons for failure were attributed to faults related to the booster element and the depletion of heat exchange fluid. A similar survey of existing solar hot water systems was carried out at Napranum. Some 30 systems were surveyed. The survey found only 7 (23%) of these units were working satisfactorily.

The study identified a variety of factors that influence the performance and lifespan of hot water systems. These include:

Quality of manufacture and packaging – poor manufacture led to premature degradation of systems. Poor quality control in packaging led to significant problems when systems were being installed in remote areas.

Transportation and installation – poor quality installation was found to be a major factor leading to premature failure of systems.

Operating environment – the highly mineralised waters found in many remote communities led to scaling and corrosion of elements and tanks, this resulted in system failure and a shortened lifetime.

Repairs and maintenance - the absence of preventative maintenance programs was identified as a major factor contributing to the poor performance and short lifetime of systems.

Study Recommendations

1. That improved **installation standards** be encouraged and supported through:

    - *Manufacturers of hot water systems and training providers developing, or improving existing, training programs suitable for installers of systems in remote Indigenous communities.*

    - *ATSIC investigating the feasibility of setting up regional contractor accreditation schemes for tradespeople working in remote communities.*

    - *Indigenous housing organisations adopting policies requiring suppliers and installers to provide a quality installation service. These should be backed up by inspection procedures to validate the quality of installation.*

2. That cyclical and responsive **maintenance and repair** issues be addressed via:

    - *Manufacturers of hot water systems and training providers developing, or improving training programs and resources on maintenance and repair of hot water systems available for members of remote Indigenous communities.*

    - *CAT establishing or monitoring projects to provide opportunities to evaluate a variety of models for cyclical maintenance, (including plumbing maintenance).*

    - *Indigenous housing organisations and outstation resource agencies adopting regular cyclical maintenance and repair programs for hot water systems.*

3. That the effect of **poor water quality** on water heating systems be addressed through:

    - *CAT disseminating information on actions that can be taken to minimise the impact of water with high levels of dissolved minerals and/or acidity on water heating systems.*

    - *CAT undertake independent laboratory and field testing of the range of devices and innovations claiming to minimise the effects of hard water on water heating devices.*

4. *That the level of **Indigenous consumer knowledge** of issues relating to hot water technology be improved through the dissemination of independent information and advice on the costs and benefits of current hot water technology options in remote areas.*

5. **Further investigation** is required:

- *By industry to ensure energy efficiency improvements through development of an intelligent control system for the operation of the boost element in solar hot water units.*

- *ATSIC and CAT to devise strategies to increase the uptake of gas as a fuel source in remote communities.*

- *CAT to study long term field observations on hot water systems in order to obtain a better picture of the relative reliability of technologies over time.*

1. INTRODUCTION

1.1 Background

This investigation of hot water supplies in remote Aboriginal communities was undertaken as a collaborative effort by Nganampa Health Council and the Centre for Appropriate Technology (CAT) between January 1997 and December 1998. The research project was initiated in response to the 1987 UPK[1] and Housing for Health[2] Reports, and as a result of discussions which took place between a group of interested stakeholders in Alice Springs during November 1996.

The UPK Report showed that for most communities in the Pitjantjatjara Lands there were frequent breakdowns in housing stock and almost a complete lack of formalised maintenance systems for health hardware[3]. In most communities there were ongoing issues and problems to do with washing facilities sewerage and waste-water disposal. The report stressed the importance of enabling people to perform ten healthy living practices and listed these in order of importance for improvement of health in the Pitjantjatjara Lands. At the top of the list was washing – the need for people to be able to wash themselves regularly – particularly babies and children under the age of 5 years.

An understanding of the factors influencing the usefulness and reliability of the health hardware necessary to facilitate these healthy living practices is vital to any strategy for improving environmental health.

The need for hot water was again stressed in the 1993 "Housing for Health" Study which looked carefully at the apparently commonly held view that people in the Pitjantjatjara lands are not very interested in washing themselves or their clothing. The study showed that Aboriginal people consistently made use of washing facilities when they were maintained and working well.

To further this work, the Centre for Appropriate Technology, with the support of Nganampa Health Council, initiated this project to examine hot water systems in remote environments. Funding for an experimental hot water project was obtained from ATSIC in August 1996.

1.2 Project Summary

The project involved the funding, installation, monitoring and maintenance of a range of commercially available hot water systems in selected Aboriginal communities. The project consisted of two distinct phases:

- A preliminary survey of existing systems in two communities (Kintore and Napranum)
- A primary trial of 33 newly installed systems and existing systems in 5 remote locations

[1] Nganampa Health Council, "*Report of Uwankara Palanyku Kanyintjaku: An Environmental & Public Health Review with the Anangu Pitjantjara Lands*" Nganampa Health Council, Alice Springs 1987. – the UPK Report.
[2] Pholeros, P., Rainow, S. and Torzillo., "*Housing for Health*" HealthHabitiat, Newport Beach, NSW, 1993.
[3] Nganampa Health Council, *ibid*

During preliminary surveys the condition of existing solar systems was surveyed in two communities. In the primary hot water trials, carried out over a minimum period of twelve months, the project monitored and evaluated the performance; economy and maintenance of 33 selected commercial hot water systems.

The project was designed and supported by regular meetings of a Steering Group comprised of representatives from Nganampa Health Council, Tangentyere Council, Walungurru Community Council and the Centre for Appropriate Technology.

1.3 Project Goal

To improve the delivery of hot water to remote Indigenous communities

1.4 Research Aims

1. To provide a comparative analysis of the performance of a range of hot water systems in remote settings, across a range of performance areas.

2. To identify:
   - primary and secondary causes of poor performance and failure of systems and,
   - maintenance and installation requirements

3. To provide a provisional cost analysis for installation and maintenance of a variety of systems.

4. To gather data on hot water usage and energy consumption patterns.

1.5 Projected research outcomes

- Identification of the most efficient and reliable hot water service units for community and outstation use.

- Identification of modifications and system adjustments for uptake by manufacturers and communities.

- Facilitation of improved repair and maintenance procedures and strategies.

1.6 The Steering Group

A Steering Group informed the implementation of the project and liaised with community management and householders in trial communities. The first meeting of the Steering Group was held at CAT in Alice Springs on the 4th of November 1996. Members were:

Bob Lloyd	CAT, Manager RD&P
Bruce Walker	CAT, Director
Su Groome	CAT, Cairns Office
Jamie Nyanginu	AP Services
Paul Pholeros	Healthabitat
Newton Langford	Technical Consultant, Melbourne
Stephan Rainow	Nganampa Health, Alice Springs
Dr Alex Hope	Division of General Practice, Alice Springs
Philby Bigg	Tangentyere Design, Alice Springs
Sonja Peter	Tangentyere Design, Alice Springs

The initial meeting decided that:

- A range of new hot water systems should be installed and trialled (Solar, Electric, Gas, Heat Pump and Biomass) in several remote Indigenous communities.
- The systems should be trialled in a selection of locations encompassing central remote regions, tropical areas and the Alice Springs town camps (for semi-urban comparisons).
- Around 6 systems of any given category/situation should be monitored to give reasonable statistical results, which allowed for, and recorded failures (both of the systems and/or the logging units).
- Units should be monitored for at least a full cycle of seasons.
- The research parameters for the project as outlined in **Table 2** below:

Parameters to be investigated	**Type/s of systems**
The volume and temperature of hot water consumed, (as a function of time)	all systems
Inlet water temperature, and ambient temperature	all systems
Water quality (total dissolved solids)	all systems
Water pressure	all systems
Usual household occupancy rate	all systems
Household satisfaction with the supply	all systems
The supply current (logged as a function of time)	For electric systems (including electricity as a backup)
The total global radiation in a horizontal plane (In addition both the azimuth and inclination of the collector panel should be noted).	Solar systems

1.7 Project Justification

Washing children daily and the regular washing of hands and faces is likely to reduce the incidence of the four most prevalent childhood diseases in remote Australia (diarrhoea, pneumonia, skin infections and trachoma) (UPK 1987).

Although hot water is required for effective cleansing and disease prevention there were a range of problems *related to the provision and maintenance of hot water* identified *by the Steering Group* prior to the study. These included:

- Hot water systems currently in use *frequently break down and/or fail to deliver enough hot water.* This was partly attributed to a range of factors such as: poor quality water, problems with the power supply, overcrowding of houses, poor technical design, insufficient repairs and maintenance, usage characteristics of remote communities and in some cases installation factors.

- The *high cost of hot water, and systems replacement.*

- Electrical units and solar units with electrical boosters, *require a reliable supply of power.* (Preliminary work done at Pormpuraaw, Nth Queensland indicated that hot water services are turned off in 40% of cases because people could not afford the power to run them).

- *Little data was available on the characteristics of usage or failure rates* of existing systems in remote areas.

- The *problem appeared to be too small for commercial suppliers* to take an interest; (there was a need for valid scientific data that could support advocacy).

- A systems approach to product design was required since *usage characteristics and affordability were generally not part of commercial product testing* (both of these factors have a high impact in remote areas, and with Indigenous use).

- Clearly, a project that could extend the life of hot water systems and reduce recurrent maintenance costs would have a significant impact on community budgets and environmental health.

1.8 Participating companies

Letters were written to all the major solar hot water manufacturers, to Quantum (the only supplier of heat pump systems in Australia at the time) and to a selection of electric and gas hot water system manufacturers. Manufacturers were asked to participate in the trial and to discount their systems in return for access to test results.

The following companies agreed to provide systems for the tests:

- Solahart (solar)
- Edwards (solar)
- Quantum (heat pump)
- Hardie Dux (electric)
- Rheem (gas and electric)
- CAT (biomass)
- Sunsaver (solar)

2.0 PRELIMINARY SURVEYS OF EXISTING SYSTEMS.

Preliminary surveys of existing hot water systems were carried out in two communities prior to the main survey.

The aims of the surveys were to:
- Assess the % of functioning systems
- Record the reasons for system failure or malfunction
- Identify potential sites for the hot water system trials

2.1 Kintore – Preliminary Survey

The first survey, which was carried out in April 1997, looked at hot water systems that were in use at Kintore, a community 600 km north-west of Alice Springs. There were about 50 separate Indigenous households in the main Kintore community, all having a single brand solar hot water system. The ages of the systems ranged between two and thirteen years.

As Kintore is located in a frost prone area all 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 power supply switchboard. The water used by the community comes from an underground bore and is typical of remote desert locations with around 700 ppm of total dissolved solids (TDS). (These were mainly carbonates and bicarbonates). The results of this survey are discussed in Section 5.2.2

2.2 Napranum - Preliminary Survey

A similar survey of existing solar systems was carried out at Napranum in conjunction with the installation of the hot water trial systems in July 1997. Napranum is larger than Kintore with a population of around 1000. It has its own works department and is close to the infrastructure and support provided 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 time the main hot water trials commenced households were billed monthly by the local electricity supply company.

As the earlier Kintore study had demonstrated a poor operational status of solar systems it was decided to limit the survey at Napranum to solar hot water systems. Approximately 30 households were identified as having solar systems, originating from two manufacturers. The results of this survey are also discussed in Section 5.2.2

3.0 THE PRIMARY HOT WATER SYSTEM TRIALS

3.1 Research sites

By May 1997 the location of the trial units were identified as:

- Alice Springs town camps (NT)
- Napranum (near Weipa on Cape York, QLD)
- Wataru (AP lands, SA)
- Kalka (AP lands, SA)
- Kintore (NT)

3.2 Hot water systems installation per research site

Table 3 shows the original plan for installing new systems and monitoring new and existing systems.

Table 3: Original Plan for HW System Installation

	Napranum	Alice TC	Wataru	Kalka	Kintore	Total
Solahart[1]	1	1	2		2	6
Edwards[2]	2	2	2		2	8
Rheem Gas[3]	1	1				2
Rheem Electric[4]		1		1		2
Quantum[5]	1	2		2	1	6
Hardie Dux[6]		1		1		2
Sunsaver	2					2
Existing[7]	1	1	4		2	8
Total monitored	8	9	8	4	7	36
Total to be purchased	7	7	8	4	5	32

Notes:

1. Solahart Model 300J
2. Two Edward's models were to be trailed the LX model and the HXL model
3. Rheem gas 135 L Model Optima 12/95
4. Rheem Electric 125L Model 101 Series
5. Quantum Pacific HD-EC Compact
6. Hardie Dux 50 L Model HDE50V
7. The existing units at Wataru were the CAT chip heaters all other existing units were to be Solahart Model 300Js

For a range of reasons the actual scheme finally implemented differed from that outlined in the above table. Details of the final scheme are listed in **Table 4** below:

Table 4: Final installation scheme

	Napranum	Alice TC	Wataru	Kalka	Kintore	Total
Solahart	2	2[3]	2		3[4]	9
Edwards	2 (HXL)	2 (HXL)	2 (LX)		2 (LX)	8
Rheem Gas	1	0[1]				1
Rheem Electric		1		1		2
Quantum	1	2		2	1	6
Hardie Dux		1		1		2
Sunsaver	0	1[2]				1
Chip Heater			4			4
Total	**6**	**9**	**8**	**4**	**6**	**33**

Notes:

1. The Rheem gas model was replaced with a Solahart Black Chrome model (The gas system was replaced because the householder complained that the gas ran out too often and that the 135-L hot water storage tank was insufficient for the household).
2. Only one existing Sunsaver was monitored
3. In addition a Solahart Streamline model was added to the monitoring towards the end of the project.
4. This includes two new units and one existing unit.
5. Solahart solar system and the gravity fed solar system was replaced with a recently marketed forced flow Solahart system.
6. Of the 18 solar systems 14 had electric boost permanently connected and the 4 at Wataru were stand-alone solar.

Of the 33 hot water systems in the trial, 28 were purchased especially for the project.

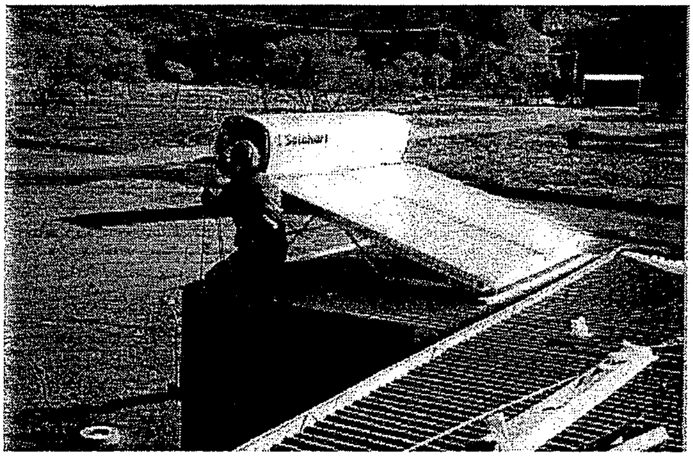

Photo 1: Solahart system being installed at Wataru

In addition to the new systems purchased under the hot water project, one existing gravity-fed solar system (Sunsaver) and one existing Solahart system were monitored.

3.3 Points of note during the installation phase

- The Sunsaver units were not suitable for Napranum due to the difficulties in converting household plumbing for a low-pressure hot water system.

- It proved difficult to identify recipient households for gas systems.

- It is to be noted that there were difficulties encountered with installation in a number of cases. For example, parts from one manufacturer, in particular, were missing from several installation kits, and the incorrect batch of heat exchange fluid was supplied.

- All systems had to be manhandled into position without any lifting devices.

Difficulties were eventually overcome and all systems were in place by the end of September 1997.

3.4 Hot water system descriptions

The following hot water systems were installed as part of the primary trials.
(Specifications of the units are in Appendix A):

Table 5: Summary of hot water unit types

Description	Fuel type	Volume (L)	Cost ($) (1997)
Solahart 302J	Solar/electric	300	2100
Edwards HXL	Solar/electric	300	2000
Edwards LX	Solar/electric	300	2000
Quantum	Electric/environment	340	2050
Rheem	Gas	135	650
Sunsaver	Solar	185	1190
Rheem	Electric	125	425
Hardie	Electric	50	350
CAT Chip-heater	Wood	75	420

3.4.1 Solahart 302 J Solar Hot Water Unit

This is a Solahart 300 J model using a heat exchanger.

This primary circuit of the heat exchanger uses a proprietary heat exchange fluid (*Hartgard*™) which is mixed with the water that runs through the panels.

The collector consists of a multi-flow absorber (35 fluid channels) made from two pressed steel sheets welded together, and finished with black polyester powder coat on both faces of the absorber plate. Heat is transferred to the main hot water tank by thermo-siphon of the primary circuit fluid to a heat exchange jacket in the main tank.

The main tank construction is of mild steel that is lined with vitreous enamel. The outer casing is aluminum with polypropylene casing ends. Insulation is polyurethane foam and the unit is fitted with an electric element, thermostat and sacrificial anode.

3.4.2 Edwards HXL 300 Solar Hot Water Unit

The HXL series was designed specifically to overcome problems in areas where there are heavily mineralised or poor water conditions, and/or very high ambient temperatures.

This system is also a heat exchange type. The working fluid consists of water that has been neutralised with a biodegradable additive. The heat exchange mechanism used by the HXL, however, is quite different to the Solahart. The water- additive mixture flows through copper pipes in the collector plates by natural convection to the main insulated storage tank. The fluid is vented to the atmosphere and can escape to a separate overflow (expansion) tank when heated.

The potable water is heated by passing through a cylindrical coil of copper pipe positioned inside the main tank at the top of the cylinder where the water is hottest. The system also has an electric boost element.

The HXL Edwards systems use a Colorbond™ steel outer casing surrounding a mild steel storage cylinder. The storage cylinder is not lined or treated. The solar collector absorber plate is black painted aluminium, framed by a Colorbond™ steel outer casing.

3.4.3 Edwards LX 300 Solar Hot Water Unit

The Edwards LX solar hot water system is similar to the Solahart system in design philosophy except that it has a stainless steel storage tank. It consists of a primary circuit using food grade glycol as a working fluid. This fluid flows through copper pipes in the flat plate collectors by thermo-siphon to a heat exchange jacket in the main storage tank. The unit has an electric boost element in case of insufficient solar radiation.

3.4.4 Sunsaver Solar Hot Water Unit

The Sunsaver solar hot water system differs from both the Edwards and the Solahart systems in that it is a gravity feed system. Sunsaver is a plastic construction with the main header tank constructed of linear low-density polyethylene containing UV stabilizers. The collector liner is constructed of linear low-density polyethylene containing 1.5% carbon black and the collector cover is made of cast polymethylmethacrylate (Perspex) sheet.

3.4.5 Rheem Gas Optima 12/95

The Rheem gas system was a standard unit with a vitreous enamel lining.

3.4.6 Rheemglas Electric 101.125

The Rheem electric system was a standard unit with a vitreous enamel lining.

3.4.7 Quantum 340 L Pacific HD-EC Compact

The Quantum hot water systems work on the heat pump principle. Essentially they are refrigeration systems where the evaporator is exposed to the outside environment and the condenser to the hot water. An electric compressor drives the vapour cycle, which draws environmental heat into the hot water system. The main storage tank is constructed of glass lined corrosion resistant steel tank and works at mains water pressure. The condenser is constructed of steel bund tube wrapped around the water storage tank. This construction has obvious benefits when the water supply has high dissolved solids content. The unit has a sacrificial anode to prevent corrosion of the cylinder.

3.4.8 Hardie Dux (Electric)

The Hardie Dux models used were conventional electric element hot water systems with 50 litre storage tanks.

3.4.9 The CAT Chip-heater

The CAT Chip-heater is a robust and simple heating device developed by the Centre for Appropriate Technology for use in remote Indigenous communities. It is constructed from unserviceable gas cylinders and a length of steel pipe. The storage volume of the heater is around 75 litres. The fuel source is biomass, generally wood which is placed in a firebox at the bottom of the heater. A separate report was commissioned by CAT to investigate the efficiency of the heater and to suggest improvements.[4] This report and other investigations at CAT suggested the efficiency of the heater varied from 17% to around 30%.

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[4] Todd, John,. "*Test Report: CAT Hot Water Chip Heater*" NTRC Report # cat 97/13, November 1997

3.5 Site descriptions

Table 6: Summary of site information

Community	State	Population	No. of Houses	Distance to nearest major service centre	Total dissolved solids (TDS)
Napranum	QLD	1000	200	13 km	Acid pH 5.2 Low TDS
Alice Springs Town Camps	NT	1400	180	0	500 ppm
Wataru	SA	20- 60	11	800 km	1000 ppm
Kalka	SA	80-120	7	700km	600 ppm
Kintore	NT	300-400	50	520km	700 ppm

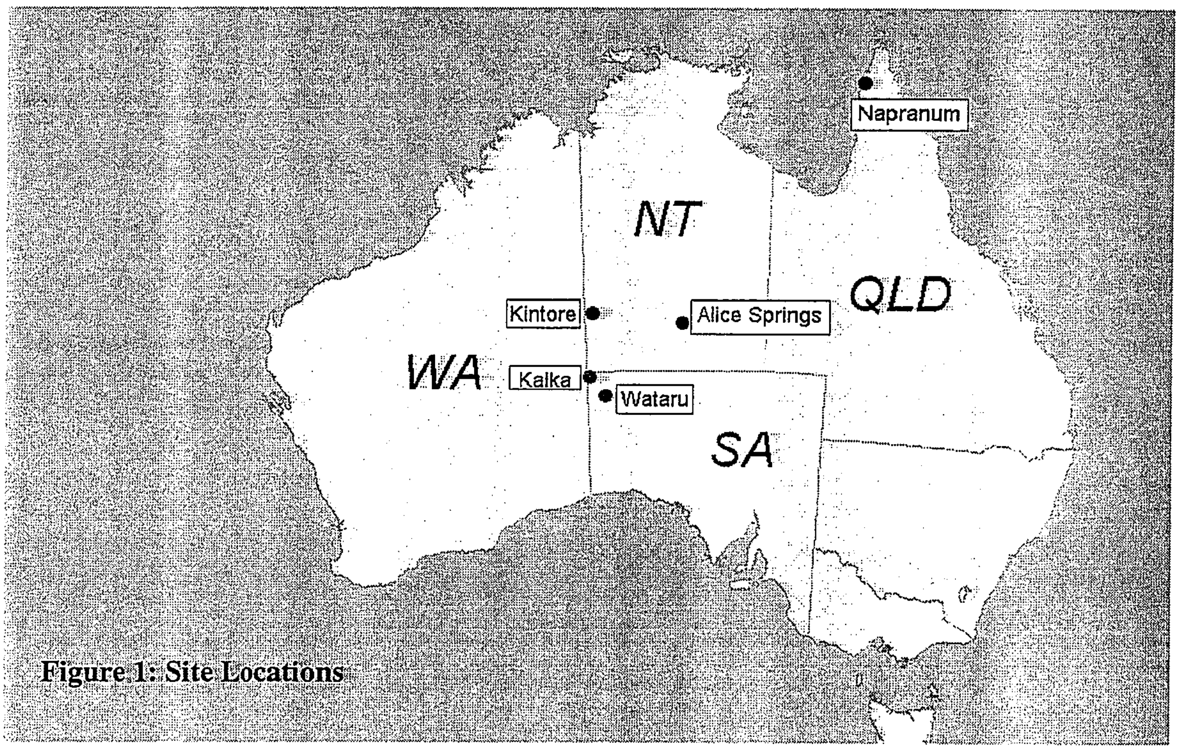


Figure 1: Site Locations

3.5.1 Napranum

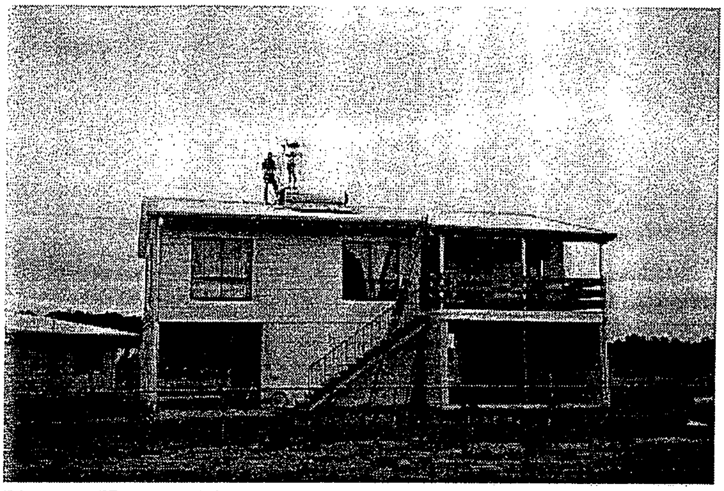


Photo 2: House at Napranum

Napranum is an Indigenous community located approximately 13km south of Weipa on the west coast of Cape York Peninsula. It was the largest single community used as a study site with a population of some 1000 persons. The community includes over 200 residences and also has a range of community facilities including a church, snack bar, store, school, pre-school, tavern and sporting facilities. In addition there is a large community works department that also engages in some production activities. Napranum is connected to the main Weipa electricity grid and is serviced by a deep sewerage system. The water supply is typical for Cape York having low dissolved solids but very high acidity.

3.5.2 Alice Springs Town Camps

There are 18 town "special lease areas" (locally known as town camps) in and around Alice Springs. Hot water systems were installed at 8 of these camps including Ilpeye Ilpeye (Golder's Camp), Akngwertnarre (Morris Soak), Nyewente (Trucking Yards), Ewyenper-Atwatye (Hidden Valley), Anthelk-Ewlpaye (Charles Creek), Karnte, Mpwetyerre (Abbott's Camp) and Ilperle Tyathe (Walpiri Camp).

Electricity is supplied via the main Alice Springs grid. Water and sewerage are also provided by the Alice Springs town services. Alice Spring's water supply has a relatively high dissolved solids content at around 500 ppm. Population and house number details appear in **Appendix B.**

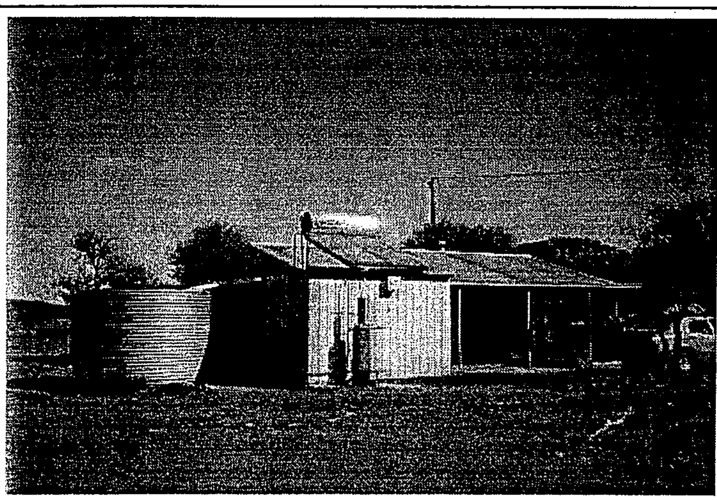


Photo 3: House at Wataru

3.5.3 Wataru

Wataru is located approximately 800 km SW of Alice Springs in the Anangu Pitjantjatjara (AP) Lands. The community is larger than most outstations but smaller than the main communities in the Pitjantjatjara Lands with an average population of around 60 people. Access is either by road from Alice Springs or by light aircraft. Occupation rates however can vary considerably and changes of between 5 to 80 people are not unusual. The community consists of 11 houses along with a school, a store, a workshop and a clinic. The water supply is from local bores and has a high dissolved solid content at around 1000 ppm. In earlier times Wataru had one of the early WA developed "Solarpak" photovoltaic supply systems. The community electricity supply then progressed to a larger photovoltaic- wind- diesel hybrid system that has recently been upgraded. The community was chosen because it was one of the larger communities in the AP lands that did not have a full mini grid electricity supply. The solar hot water heating systems installed in Wataru did not have the electricity boost connected.

3.5.4 Kalka

Kalka is also located in the AP Lands some 700 km SW of Alice Springs near the "corner region" of the three state boundaries (SA, WA and the NT) The community has a population of between 80 to 120 people. Access is by road from Alice Springs or by light aircraft. The community has eleven houses and little in the way of community facilities. There is a community office but no store, school or clinic. The main support infrastructure is located at nearby Pipalyatjara. The electricity supply comes from a mini-grid at Pipalyatjara. The water supply is from local bores and has a high dissolved solids content at around 600 ppm. The water pressure measured at the clinic was 275 kPa.

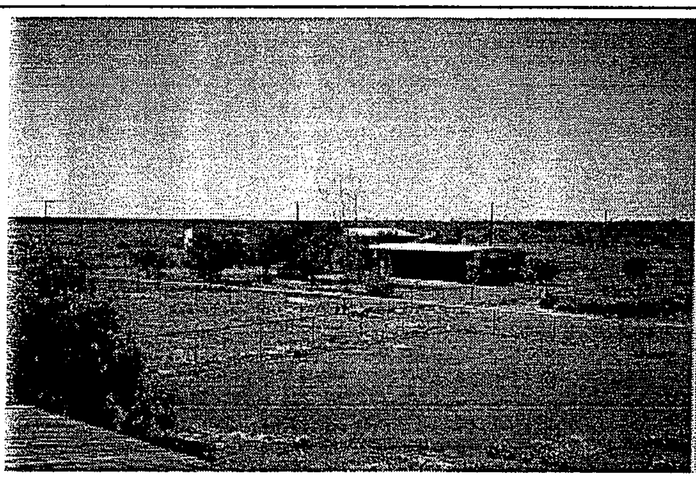


Photo 4: Kintore

3.5.5 Kintore

Kintore is located approximately 520 km W of Alice Springs on the edge of the western desert. The population of the community varies between 300 – 400 people. The community includes approximately 50 houses and has a range of community buildings including a store, school, council office, clinic, women's centre and a workshop. The electricity supply is via a mini-grid. The water supply is from local bores and has a high dissolved solids content of around 700 ppm.

3.6 Systems Installation

Originally it was hoped to secure cooperation from the system manufacturers who would be responsible for the installation of their own systems thereby ensuring compliance with installation specifications. None of the manufacturers were willing to pay for installation however, once the real cost was ascertained. Faulty installation therefore was not the responsibility of the manufacturer.

As outlined in the section on research findings, installation of systems proved difficult due to:

- Cost and logistics of transportation
- Size of the systems leading to difficulties of handling
- High cost of getting plumbers and electricians on site

3.7 The Data Logging process

Because of the fixed budget and the large number of systems involved data logging systems were assembled at CAT using three relatively economical single channel "Easylog" 8 bit data recorders. The loggers were capable of storing 8000 readings, (enough for three months of data) taking one record every 20 minutes.

3.7.1 Data logger installation

For each hot water system there were data loggers measuring:

- *the water temperature* - from a K type thermocouple;
- *the flow rate* - by counting pulses from a liquid flow sensor (supplied by RS Components); and
- if applicable - *the electricity used* - by counting pulses from a conventional pulse output (electromechanical) electricity meter[5].

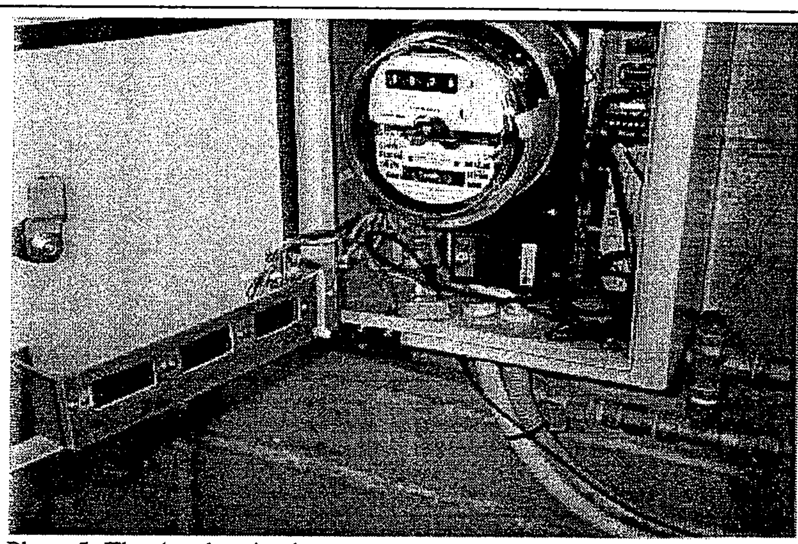


Photo 5: The data logging box

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 because Wataru had a renewable energy main electricity supply system that was not sufficient for supplying hot water; and was also prone to outages. Kintore had recently installed "pay as you use" electricity meters and thus there was no secure connection to individual households.

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 (traceably) calibrated mercury thermometer.

The electromechanical power meters were calibrated and zeroed by PAWA before installation.

[5] Supplied courtesy of the Power and Water Authority of the NT- PAWA.

3.7.2 Data acquisition methods

Due to limited data storage capacity data had to be "downloaded" to a lap-top computer every three months.

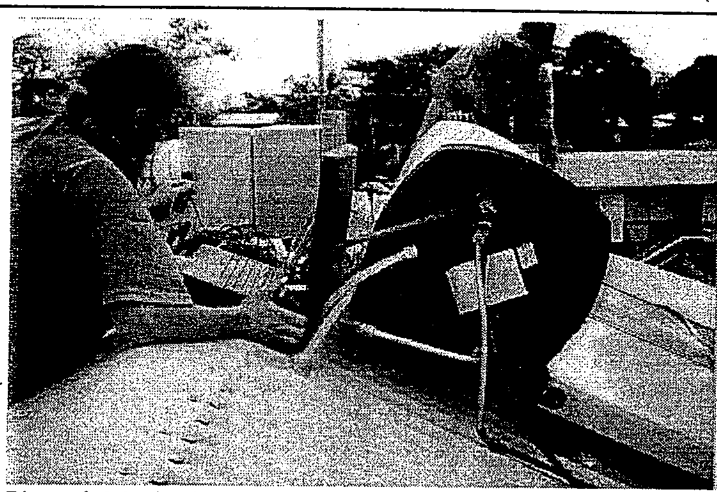


Photo 6: Monitoring equipment being installed at Napranum

Field visits

The first field visit, during October 1997, proved problematic and no data was available for the first three month monitoring period.

The second downloading visits took place during January 1998. Visits to Wataru, Kalka and Kintore were made by charter flight. Napranum was reached by taking a commercial flight to Weipa. Alice Springs Town camps were accessed with ease. During the second visits non-operational loggers were repaired, failed batteries replaced and the hot water systems were assessed for physical failures.

The third and final visit took place between May and August 1998, visits were made by road from Alice Springs in all cases except Napranum. During the final visit the logging equipment was removed and any faulty hot water systems made good.

3.7.3 Volume and reliability of data

The amount of data collected during the monitoring period was very large. The 3 loggers at each hot water monitoring system collected around 8000 data points every three months for a span of 10 months. Therefore some 2 million points were collected altogether.

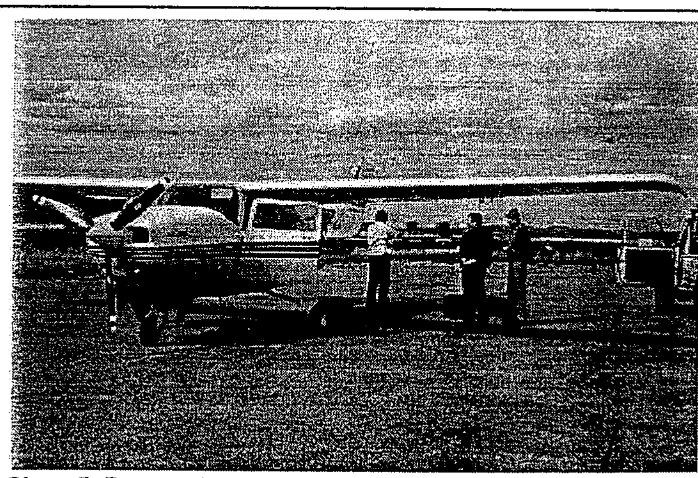


Photo 7: Data retrieval trip to Kalka using a charter flight

The electrical energy consumption data was generally reliable with the total energy recorded by totaling the pulses, matching that obtained on the conventional electromechanical kWh meter. In addition to the individual household monitoring data each site had ambient temperature, water temperature and solar radiation data records.

From the total data files collected:

- approximately 60% gave a complete data record
- 19% partial information and
- 21% failed to give any information at all.

Table 7 below provides a summary of the data collection for each of the three successful data collection periods.

Table 7: Data recovery from Easylog loggers

	F1	F2	F3	%	P1	P2	P3	%	T1	T2	T3	%	All	%
Good data	17	22	15	54	14	14	12	40	25	23	19	67	255	59%
Partial data	7	4	10	21	6	5	6	17	1	2	3	6	82	19%
No data	8	5	6	19	6	7	8	21	3	3	6	12	92	21%
Total	32	31	31	94	26	26	26	78	29	28	28	85	429	100%

Figures refer to the number of data loggers inspected

Periods:
F/ P/ T1 = October 1997
F/ P/ T2 = January 1998
F/ P/ T3 = May 1998 and August 1998

Key:
F1=Flow sensors, P1=Power sensors, T1=Temperature sensors: 1st monitoring period Aug 97-Jan 98
F2=Flow sensors,P2=Power sensors, T2=Temperature sensors: 2nd monitoring period Feb 98-May 98
F3=Flow sensors, P3=Power sensors, T3=Temperature sensors: 3rd monitoring period Jun 98-Sep 98

3.7.4 Problems associated with data logging and data acquisition

The data collection process presented numerous challenges. A number of factors conspired to affect data collection and accuracy to various extents. These are listed below:

- ***Internal battery life***

Considerable problems resulted from the 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-months of data was ready for collection. The short battery life problem 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.

- ***Faulty software***

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 the entire faulty data for the first successful monitoring period to the manufacturer of the Easylog loggers (LASCAR) in the UK, by email. The supplier would not reveal the method of data recovery but it fixed the data and the new version of the software supplied by the company did not have the same disastrous effect.

- *Overly high pulse rates*

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. For example, *plumbing leaks and taps left on* contributed to irregularities. Leaks were distinguished by a constant background pulse rate from the flow meter. Taps left on were usually more erratic with recursion to zero pulses. Data, which did not make sense, or could not be corrected, was deleted from the analysis.

- *"Pay as you use" power cards*

Kintore had "pay as you use" power cards installed immediately before the trials 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.

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. Fortunately the card systems were being installed at Napranum during the very same days that the hot water monitoring equipment was removed at the end of the project.

- *Water temperature records*

Water temperature records were sometimes difficult to interpret 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 at equilibrium with ambient air temperatures. This was because there was no way of ensuring that the cold water flow was on when the logger recorded the water temperature.

Thus the ambient water temperature used to calculate thermal heat gain for a day was taken as the average ambient temperature for that day.

- ***failed loggers***
- ***failed backup power supplies*** due to the mains power being disconnected
- householders ***abandoning the house***
- in one case, the ***house burnt down***.
- Later problems included a ***fairly high electrical failure rate (around 15%)*** of the loggers under field conditions.

4.0 RESEARCH FINDINGS

4.1 Hot Water Consumption Patterns

From the available data, the average hot water consumption was found to be 240 L/household/day. The standard deviation for this data was significant at 160 L/household/day.

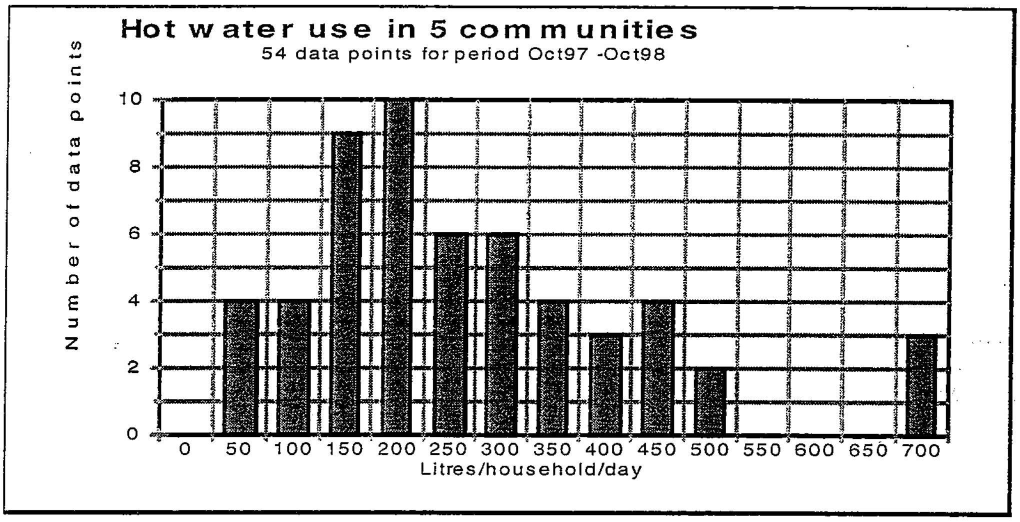


Figure 2

Figure 2 shows the distribution of consumption figures. Each data point represents the daily consumption for a household averaged over a three-month monitoring period.

Due to the highly variable number of occupants in Indigenous households at any one time it was not possible to record the actual consumption per person for individual households. There was no systematic monitoring of household populations during the trials. Householders were simply questioned on the usual population of their house at the commencement of the trial. The average household population taken over the entire sample came out at around 6.5 persons (4 adults and 2.5 children).

Based on this average occupancy, the average hot water usage would be nearly 40 L/person/day. This is consistent with non-Indigenous Australian averages, typically around 50 L/person/day.

Consistent with the variable occupancy rate, household hot water consumption data showed considerable variation, with large "right hand tails". That is, while the average consumption might be around 200 L/d the maximum consumption might be as much as 1400L/d.

In some cases unusually high daily consumption was traced to leaking pipes or taps, or to taps left on. In other cases the high consumption was attributable to actual consumption of hot water (likely coinciding with periods of high household population).

The National Indigenous Housing Design Guide[6] cover the often-occurring instance of higher than normal consumption by specifying that the hot water system should be capable of supplying 400 litres of hot water at 60 °C in any 24-hour period.

Examples of the variation in hot water consumption can be seen by looking at two sites: one at an Alice Springs town camp (Ilpeye Ilpeye) and the other at Kalka.

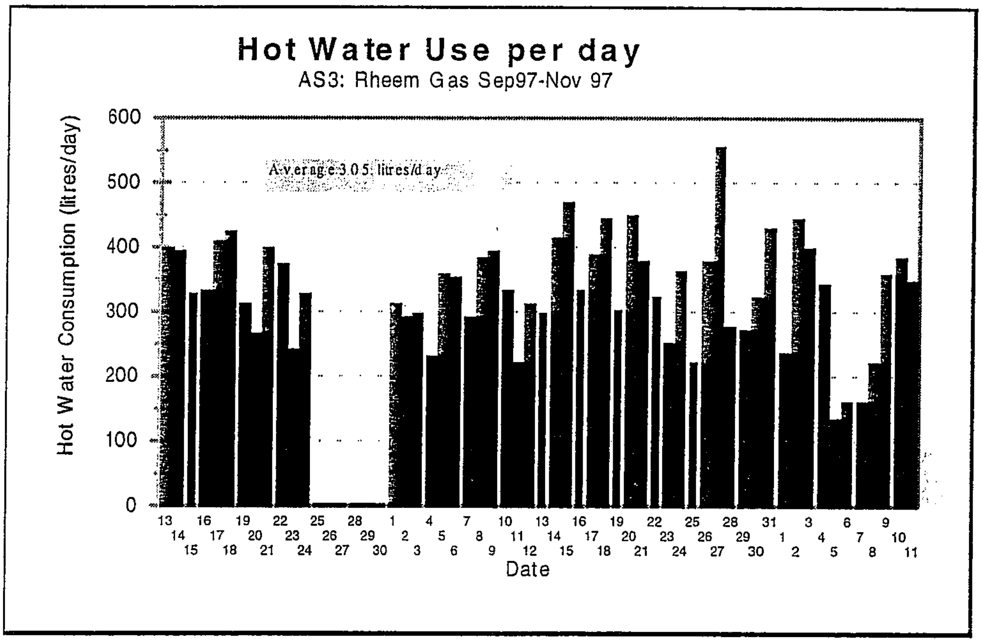


Figure 3

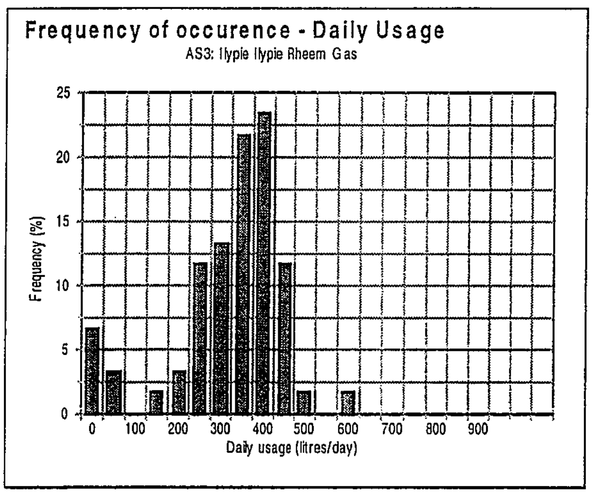


Figure 4

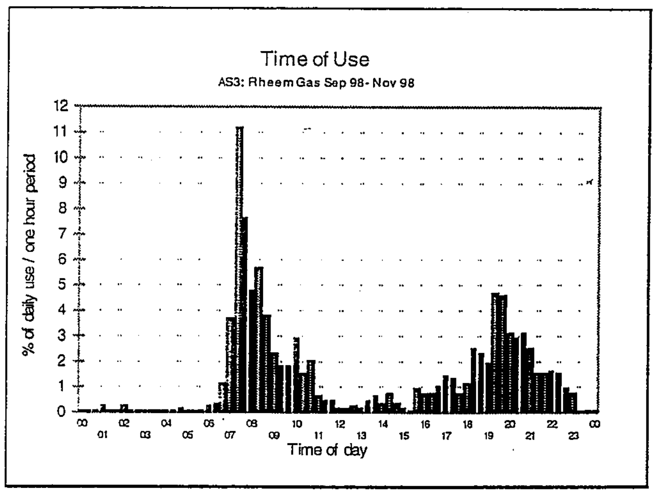


Figure 5

At the Alice Springs site the occupants followed a fairly conventional nuclear family model with both parents working during the day and the children attended school.

[6] HealthHabitat, "*The National Indigenous Housing Design Guide*" September 1999, Pirie Printers. – Prepared for the Commonwealth, State and Territory Minister's Working Group on Indigenous Housing.

The daily use pattern (**Figure 3**) is fairly flat with one period of non-occupancy during school holidays.

The frequency distribution (**Figure 4**) is reasonably symmetrical and peaked around 400 L/d. The time of use distribution (**Figure 5**) shows two peaks at 7:00 a.m. in the morning and 7:30 p.m. in the evening with little usage during the day.

The other (contrasting) site, at Kalka, was more typical of remote community patterns of usage. **Figure 6** and **7** shows large variations of use per day and a high variation of daily consumption peaking at 350L/d but with a maximum as high as 1600L/d. The time of use (**Figure 8**) is much flatter with peaks in the morning and evening along with consistent use throughout the day.

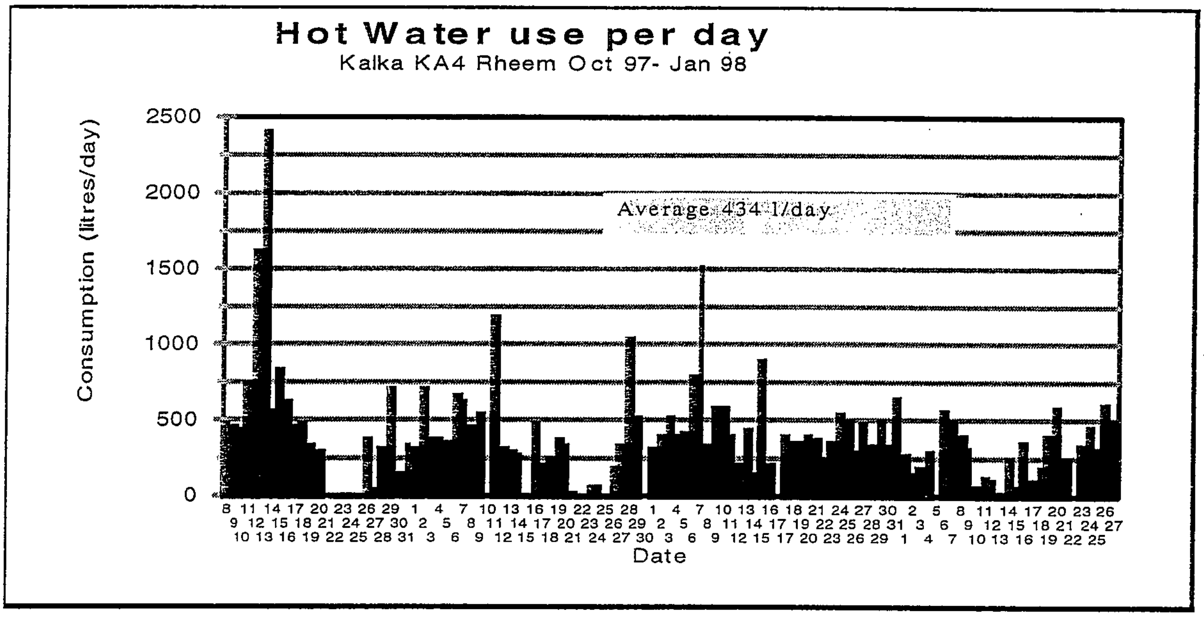
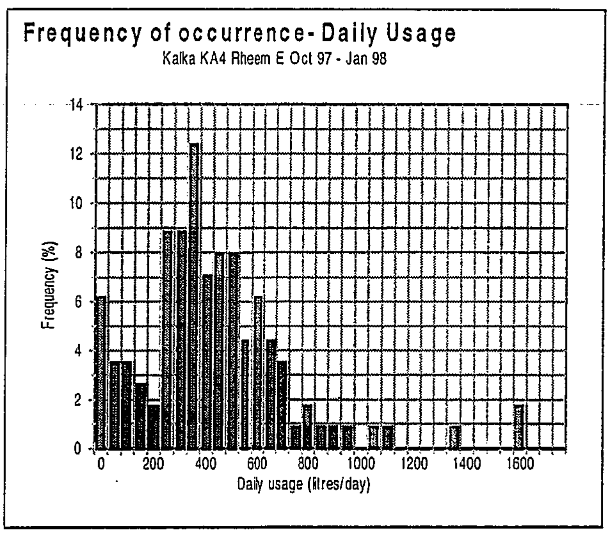


Figure 6



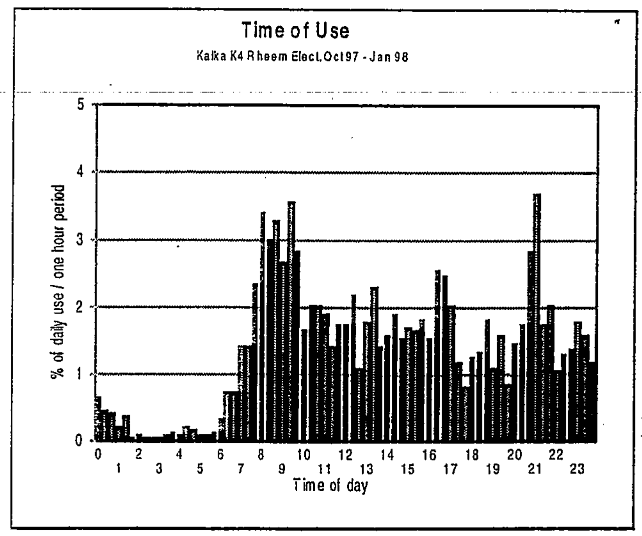


Figure 7 Figure 8

The key point to be drawn from this data is the high variability in consumption of hot water in losses of between 2 and 3kWh.

Efficiency varied with ambient temperature. Energy losses increased as the difference between the temperature of the hot water system and ambient temperature increased. Differing consumption rates within houses saw some of the water delivered at temperatures below the set point of 60 ^{0}C.

The electric-only heaters gave an average fuel efficiency of 20 L/kWh @ 60 ^{0}C. with a standard deviation of 7 L/kWh.

An ideal electric heater (100% efficient) would have a fuel efficiency of 29 L/kWh when heating water through 30 ^{0}C.

When considering the cost of electricity it is important to distinguish between the price householders are paying for their electricity and the real cost of generation. Some householders receive power at a subsidised rate of say 16c/kWh. This will often be the case where houses are connected to the grid or to a community generator managed by a utility. In real terms however this power may cost in the vicinity of $1/kWh to produce, particularly in remote communities.

Using the average fuel efficiency to calculate the fuel cost yields $0.8/100L (@ 16c/kWh) or $5/100L (@$1/kWh).

For an average Indigenous household, consuming 240L/day, the use of an electric hot water unit would cost $1.54 per day (@16c/kWh) or $12 per day (@$1/kWh). Note that higher costs would be incurred where consumption of hot water rises due to increased population or through leakage in systems or plumbing.

4.2.2 Heat Pump systems

Data for the Quantum heat pump systems was consistent giving good correlation between electricity consumption and hot water consumption.

An analysis of the data showed an operating coefficient of performance (COP) of between 2.0 and 2.3. This value should be compared with the manufacturer's literature, which gives a COP of 4.0.

Daily standing losses were between 0.6 and 1.3 kWh/d (electrical). The systems on average gave 51L/kWh of hot water @ 60 ^{0}C. The standard deviation for this distribution was reasonably small at 11 L/kWh.

In terms of the fuel cost this would see a production of around $0.3/100L (@16c/kWh) or $1.96/100 L (@$1/kWh).

For an average Indigenous household, consuming 240L/day, the use of a heat pump unit would cost $0.72 per day (@16c/kWh) or $4.70 per day (@$1/kWh).

4.2.3 Gas systems

Two gas systems were installed and monitored.

No field data was available on gas consumption versus hot water consumption. According to the manufacturers data[7] on the current Optima unit with 135L capacity, the specified fuel efficiency is 3.5 L/MJ (12.6 L/kWh) over a 45 ^{0}C temperature rise. Adjusting this figure for a 30 ^{0}C rise in temperature gives a fuel efficiency of 5.25 L/MJ (18.9 L/kWh)

The cost of LPG varied from location to location. In Napranum, the cost of a 45kg cylinder of LPG varied from $90 to $120 and was around $90 in Alice Springs. Assuming a calorific value of propane based LPG (as used for household needs) of around 50 MJ/kg (or 13.9 kWh/kg), 45kg of LPG would be able to provide around 625 kWh of energy. Taking the cost of a cylinder to be about $100, means a price for LPG of 16c/kWh.

Using this price and the manufacturers claimed fuel efficiency gives a running cost of $0.85/100L of hot water. *For an average Indigenous household using 240 L/day this would equate to around $2 / day.*

By using gas as an energy source the electrical load on the community generators would be lessened considerably and if cooking was also changed to gas it would open up opportunities to use other forms of community energy supply: for example renewable energy sources. There is a growing demand for renewable energy systems as both communities and funding bodies seek to reduce expenditure on diesel fuel for electricity generation.

There was, however, difficulty in getting gas accepted by householders for water heating, even in north Queensland where gas is commonly used for cooking. The issues surrounding the introduction of gas for both cooking and water heating needs attention in regard to most remote Indigenous communities in Australia if the emerging energy issues are to be resolved in these communities.

4.2.4 Solar systems

Data here was the most difficult to analyse due to the dual energy contributions of the sun and the electric boost. There was significant variation in the performance of electrically boosted solar units. Some systems made little use of the boost element while others relied on boost power almost completely (and thereby functioned much like an electric-only unit).

For the 10 solar systems, where reliable data was available and the boost was connected, on average 43 L/kWh of hot water @ 60 ^{0}C was produced. That is some 14% lower than the heat exchange systems. The standard deviation (SD) here, however, was high at 42 L/kWh. The higher SD for the solar systems was due to the large variation in the extent to which systems required the boost element. If the solar systems used very little boost then the fuel efficiency would be very high.

In the case of solar hot water units, solar energy input carries no cost to householders. For this reason, solar energy input is not factored into fuel efficiency in this analysis. The electricity consumed by booster elements is included.

This leads to a fuel cost of around $0.4/100L (@16c/kWh) or $2.3/100L (@$1/kWh).

For an average Indigenous household, consuming 240L/day, the use of an electric boosted solar

[7] Data was taken from the manufacturers website: http://www.rheem.com.au in November 2000.

hot water unit would cost $0.95 per day (@16c/kWh) or $5.50 per day (@$1/kWh).

Solar systems did not perform as well as expected due to difficulties coping with the household population fluctuations. This meant the boost was regularly used to maintain the temperature of the hot water. The system design incorporating temperature stratification in the tank was suspected of not performing as well claimed by the manufacturers.

An important point noted during the trial was that care is needed to ensure the thermostat on solar units is set at a reasonable level. Where the thermostat is set too high, there will be a heavy reliance on boost power. As an example, a solar system trialled in Napranum initially had its thermostat set at 80°C. At this setting the unit was operating like an electric-only unit, that is it was dependent on boost power. When the thermostat setting was later lowered to 60°C it functioned more effectively as a solar unit, using the boost element only occasionally. The thermostat should not be set below 60°C as this creates conditions suitable for microbial growth in the water.

Fuel efficiency improvements could probably be made through better control of the boost element. One modification that has been suggested to the industry is to install an intelligent controller as part of the boost system. Some work is currently underway at the Australian National University as part of a combined heat and power system (CHAPS). The component of this research that would be of most use is an intelligent control system to oversee boost heating of a system that has solar heating as its main power source.

The wide range of hot water consumption levels and the distorting influence of leaking hot water supplies on the data meant it was not possible to easily separate the performance of the two brands studied.

Four solar units, without boost elements connected, were trialled in Wataru. Unfortunately relatively limited data was successfully collected for these installations. Data collected from one system indicated an operating efficiency of around 47%.

Feedback from the Essential Services Officer at Wataru at the time indicated that people were not happy with the performance of the unboosted solar systems. It seems they preferred to use the communal electric hot water units. The big problem with the unboosted solar units was their inability to cope with increases in hot water demand arising from changes in household population.

Some basic modeling using design software created by Solahart[8] illustrates this point. Where a household in Wataru requires 200 L/day @60 °C, over the year the solar system could be expected to provide 85% of needs. During the winter this drops to 60%. If the requirement increases to 300 L/day the unit produces only 65% of the hot water on average and only a little over 40% in winter. This helps to explain why there was dissatisfaction with the solar units compared with an electric unit, which constantly replenishes hot water.

4.2.5 Biomass

The CAT chip heater was trialled via the four units attached to the solar systems at Wataru.

[8] SCF – 24, This design software is downloadable from http://www.solahart.com.au

Unfortunately the data was meager as the households usually left the changeover switch set on the solar system.

Todd (1997)[9] reports on the controlled trials conducted on the CAT chip heater. An efficiency of 17% was measured for the basic chip heater. It was found the unit was capable of heating 75 L through 45 ^{0}C in 100 minutes, consuming about 5.6kg of wood. The wood used had an energy content of 15MJ/kg (4.17kWh/kg). Adjusting this figure for a temperature rise through 30 ^{0}C, gives a notional fuel efficiency of 4.9 L/kWh

In many remote communities wood carries no financial cost, though it does incur an opportunity cost for people. Some householders in the trials saw the physical labour aspect as inconvenient. As an indicator of the financial cost of wood, Tangentyere Council[10] charges $100/tonne for town camps. Commercial operators in Alice Springs may charge higher prices.

Assuming the energy content of wood averages at 15 MJ/kg (4.17kWh/kg) the price of energy from wood works out to about 2.3 c/kWh. The cost of producing 100L of hot water would be $0.47/100L

4.3. Fuel efficiency

Technology	# systems successfully logged.	Mean Fuel Efficiency (L/kWh) (30°C rise)
Electric	2	20 ± 10
Heat Pump	6	51 ± 10
Solar (with electric boost)	10	43± 26
Solar (no boost)	4	-
Gas	0	19
Biomass	0	5

Table 8 above, shows the average fuel efficiency per type of system.

Note: Where possible a 95% confidence interval is also quoted, indicating the uncertainty in the sample data.

- Results indicate that heat pump systems are almost certainly a better option than an electric heater unit, gas unit or chip heater.

- We can be reasonably confident that, given a location with adequate solar insolation, a solar hot water unit is a more effective option than an electric heater unit, gas unit or chip heater

- Lack of data for *gas and biomass systems* meant data on fuel efficiency has been drawn from

[9] Todd, John. "*Test Report: CAT Hot Water Chip Heater*" NTRC Report # cat 97/13, November 1997

[10] Personal Communication with officer at Tangentyere CDEP, 17 November 2000.

other sources and will not necessarily reflect the long-term performance of these systems in the field. No estimate of the error in the estimates for gas and biomass systems was available.

- According to these figures it appears biomass systems have the poorest performance in terms of fuel efficiency.

- The fuel efficiency of standard electric and gas units were similar to each other.

- Comparison of the fuel efficiency of heat pump systems with that of boosted solar units are inconclusive, largely due to the large variation in performance of solar systems.

Figure 9: Hot Water Consumption v's Electricity Consumption

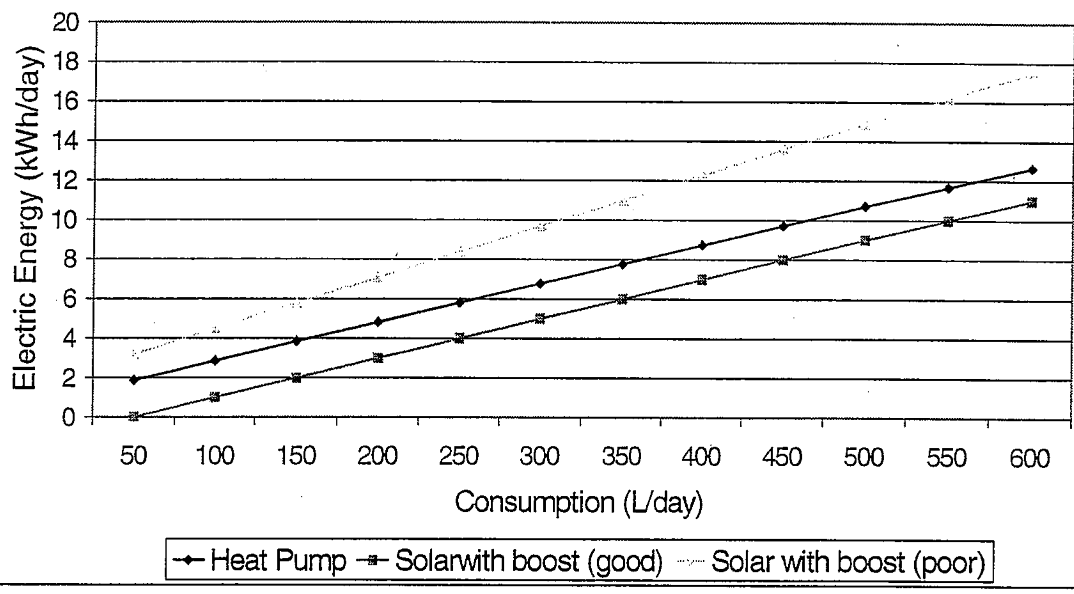


Figure 9 illustrates this last point. The average fuel efficiency for the heat pump systems trialled, is plotted alongside the characteristics for two of the solar systems trialled. Both solar systems used boost power however one system was working well and the other poorly. The figure illustrates a solar with boost that is operating well can outperform heat pump systems.

4.4 Fuel costs

Technology	# systems successfully logged.	Estimated Average Fuel Cost ($/100L)			
		Electricity (subsidised) @16c/kWh	**Electricity (real)** @$1/kWh	**Gas (LPG)** @16c/kWh	**Biomass** @2.3c/kWh
Electric	2	0.80 ± 0.40	5.00 ± 2.50	-	-
Heat Pump	6	0.30 ± 0.06	1.96 ± 0.40	-	-
Solar (boost)	10	0.40 ± 0.24	2.30 ± 1.38	-	-
Solar (no boost)	4	-	-	-	-
Gas	0	-	-	0.85	-
Biomass	0	-	-	-	0.47

Table 9 above estimates of the average fuel cost for each type of system.

Notes:

1. Two prices for electricity are used, a typical subsidised rate (16c/kWh) and an estimate of the real cost of generation ($1/kWh) in remote areas.
2. It is important to note that we have no knowledge of the variability in gas and biomass estimates.

The study found that:

➢ The price of electricity paid by end users directly affects the economic viability of using energy sources other than electricity, particularly gas or biomass.

➢ In real terms, gas may be a more cost effective energy option for heating water than electricity in some communities. However subsidised electricity prices in many of these communities makes gas an unattractive option in terms of running cost. If electricity is charged at or close to the real cost, gas becomes a much more attractive option. Gas prices could be higher in more remote communities when additional transport costs are factored in. The cost of operating a gas system is probably similar to that for running a standard electric unit at the subsidised price for electricity.

➢ While biomass had a low fuel efficiency, according to the price information used it also generally has a low financial cost. Biomass can provide an attractive option as a low cost energy source. Apart from solar without a boost element, biomass may provide the cheapest option when the "real" price of electricity is used. Biomass can be a cost effective option (in pure fuel cost terms) even when electricity is subsidised. The study found that there was a view expressed that collecting firewood was an inconvenience and that the consumer preferred electric options.

➢ Of those technologies that use electricity, electric-only systems were found to be the most expensive to run.

- Heat pump systems are amongst the most cost-effective options in terms of fuel cost. The heat pump units involved in the trial had consistent levels of performance.

- The performance of boosted solar hot water units was inconsistent. Performance depends on matching a range of local factors, such as the local solar resource, demand for hot water and the timing of peak demand periods, to the desirable operating regime of a unit. The variability of performance noted in the trials likely arose through variation in the degree to which household operating conditions were suited to a solar hot water unit. Where the operating conditions in a household are consistent with those required for effective operation of a solar unit, boosted solar hot water systems can be at least as cost effective as heat pump systems.

- Theoretically the solar units that were not connected to boost elements incurred no fuel cost for householders. However, the efficacy of these systems is also contingent on their ability to provide the desired quantities of hot water. There are indications from the trials at Wataru that the unboosted solar units were not providing sufficient hot water at a desirable temperature throughout the year, particularly at times where demand for hot water was higher than normal.

4.5 System Reliability

Where hot water systems are located in remote communities, the reliability of systems is crucial. Failure of systems will often mean a loss or severe reduction in hot water supply for extended periods.

When assistance does arrive it is likely to be at a high price. Skilled trades personnel in remote areas will often charge up to $1/km in travel costs alone. This leads to higher costs for getting hot water systems repaired in remote areas compared with more densely populated areas of Australia. It is desirable that problems with hot water systems be diagnosed and repaired locally. The ability of a community to do this type of work depends upon the skills available and the complexity of hot water systems.

The reliability of systems was monitored during the trials. Systems were inspected during each field visit to assess their overall condition and "failures" were noted. Failures were considered to be a change in the condition of the system, which led to or would inevitably lead to a loss of or severe reduction in hot water provided by the system. These failures could be as simple as an electrical overload temporarily tripping a circuit breaker, failure of an element or the calcification of seals or the tank.

4.5.1 Electric systems

There were four electric-only systems installed for trial. One of these units was never actually used, as the house remained unoccupied throughout the trial. This system has been ignored in the estimation of reliability.

Of the three remaining units, one failure was recorded. One element in an electric system failed (at Kalka). When the element was replaced around two kilograms of calcium salts were extracted from the bottom of the storage unit. Calcification of the element would be the main reason for failure of electric units.

4.5.2 Heat pump systems

Of the six Quantum heat pump systems trialled, two failures occurred during the monitoring period.

One of the Quantum heat exchange units, installed in an Alice Springs Town Camp required re-gassing due to the system being delivered with a broken gas line. A replacement part had to be flown in from Sydney and the systems had to be re-gassed. While this repair was achieved relatively easily in Alice Springs the fault required assistance from the Quantum main office in Sydney. Had the problem occurred in a more remote location repairs would have been very difficult. As this fault occurred prior to installation of the system it has not been included in the assessment of the operational reliability of the units.

A unit at Kintore experienced an electrical overload, which caused an overload relay to disconnect the system. This fault was remedied by resetting the switch.

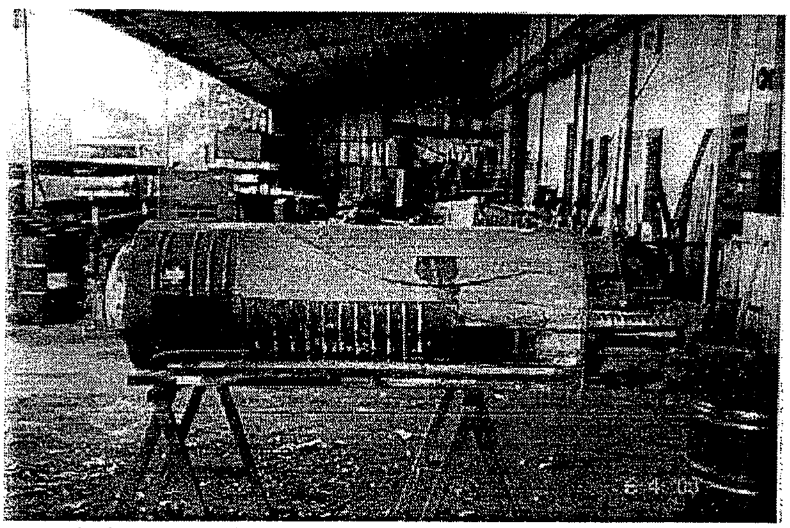


Photo 8: Quantum unit stripped down

One of the Quantum units installed in the Alice town camps was stripped down at the end of the monitoring period and the tank cut open to look for corrosion and/or calcium deposits. The results suggested that neither of these two problems would be of concern.

The heat exchange type of system is relatively new to remote areas and while they performed very well in terms of efficiency their long-term integrity is not known. It is known, however, that if faults do occur in the "refrigeration" section of the unit, repairs will be relatively difficult to secure. The large number of non-operational conventional refrigerators in remote communities testifies to the availability (and cost) of refrigeration repairs in the communities.

4.5.3 The gas system

Two gas systems were monitored but one was replaced at an early stage of the project because the householder complained that the system could not satisfy the household demand. The sole remaining gas heater monitored performed well.

Gas heaters have the advantage that no heating element is involved that can burn out due to deposits being formed owing to the high dissolved solids content of water in the community.

4.5.4 Solar systems

There were two main sources of data gathered on the reliability of solar hot water units. The first source were the preliminary surveys of systems carried out in Kintore and Napranum. The second was the data yielded by the main trials.

Preliminary survey results - Kintore

The preliminary survey of 54 solar hot water systems at Kintore was carried out in 1997 and included examination of solar hot water systems ranging in age from 2 to 13 years. The survey showed that only 38% of systems were capable of supplying hot water to the household.

Table 10: Kintore preliminary survey results

System Component	% functional
Element	38
Glycol	58
Inlet Tap	95
Cold Release Valve	76
Hot Release Valve	87
Relief Drains	43
Element Leaks	48
Overall Pass (Hot water available)	**38**

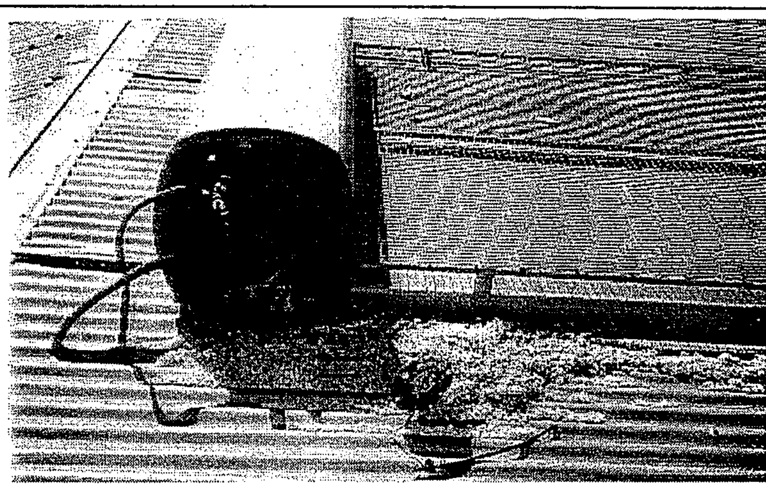


Photo 9: Calcified element at Kintore

The main reasons for failure were attributed to faults related to the booster element (62% failure rate) and the depletion of the heat exchange fluid (42% failure rate). Other problems found were failed safety valves and corroded main tanks. Poor maintenance together with poor water quality were probably the main contributing factors to system failure. Faulty systems identified during the survey were fixed wherever possible. Where this was not possible the more damaged systems were earmarked to be replaced by new test systems to be provided under the main hot water project.

Preliminary Survey Results - Napranum

A similar survey of existing solar systems was carried out at Napranum in conjunction with the installation of the hot water trial systems in July 1997. At the time the main hot water trials commenced, households were billed monthly by the local electricity supply company.

Some 30 households were identified as having solar systems, originating from two manufacturers. Of the 30 systems, the survey found only 7 (23%) working satisfactorily.

Systems were fixed wherever possible but the large number of systems that needed replacing was documented and given to the works department.

Primary trial results

In terms of the 14 solar units involved in the trial there were three failures noted.

In the first case a unit at Wataru showed indications of a failure in the main storage tank with calcification appearing 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. This examination revealed two leaks originating in the stainless steel welds. One of these welds had been patched during manufacture but the patch had obviously not fixed the leak.

The second major failure was in a system at Kintore where severe calcification around a leak in the element seal was identified.

An electric element failed in a third solar system.

4.5.5 Biomass systems

There were no failures identified in the systems monitored. Todd (1997)[1] concurs with this finding concluding that the device is a "simple, robust and effective appliance." Additional evidence gathered from the large number of working CAT chip heaters, widely distributed throughout remote Australia, suggests the physical integrity of this type of system is high.

The use of this system does have a direct impact on the local environment, as wood fuel is necessary. A decrease in the amount of wood fuel in the vicinity of communities is beginning to emerge, particularly in the arid zone. Depletion in the availability of the fuel for these systems could be viewed as an imminent failure.

4.6 Condition of systems at the end of the trial

As might be expected for hot water systems with only 12 months of use, the physical condition of most systems was found to be good. It is difficult to give information regarding the long-term viability of hot water systems that are designed for perhaps 12 years from a one-year trial.

Table 11: Sample failure rates based on systems monitored

Technology	# systems	# system failures	Sample failure rate %
Electric	3	1	33 ± 54
Heat Pump	6	1	17 ± 30
Solar	14	3	21 ± 22
Gas	1	0	0
Biomass	4	0	0

Table 11 summarises the sample failure rates based on systems monitored during the trials (with 95% confidence interval where possible).

The figures show no conclusive difference in reliability between those technologies where failures occurred (i.e. Electric, heat pump, solar). The level of data available and the relatively short duration of the trial (relative to the lifetime of a hot water system) makes it difficult to draw any firm conclusions concerning the relative reliability of systems.

Data for solar hot water systems from the two preliminary surveys demonstrated a high failure rate for these systems in both Napranum and Kintore. However, without similar data for other technologies it is difficult to make a comparison of long-term reliability.

4.7 Factors affecting the performance of hot water systems.

This section discusses the findings of the study in relation to two project outcomes:

1. *Identification of design modifications and system adjustments for uptake by manufacturers and communities.*

2. *Facilitation of improved repair and maintenance procedures and strategies for communities (includes installation)*

The study identified a range of factors that can impact on the performance of hot water systems throughout their lifetime. These have been classified under the following headings:

- Quality of manufacture and packaging
- Transportation and installation
- Operating conditions
- Repair and maintenance

4.7.1 Quality of manufacture and packaging

During the trials several issues arose associated with the quality of manufacture of hot water units.

The cost of installing hot water systems, particularly solar units, in remote locations such as the Wataru site was sometimes almost equal to the initial (retail) cost of the systems themselves. The reasons for this were the expense of transportation and getting qualified people to the site.

Table 12 summarises issues relating to each of the technologies trialled. Electric and biomass units were found to be the simplest to transport and install. Solar units were the most inconvenient.

Table 12: Comparison of System Installation

System	Special installation requirements	Rating : Ease of Installation (1 = easiest)
Electric	• Electrician generally required • Plumber required	1
Heat Pump	• Electrician required • Bulk makes transport an issue	3
Solar	• Panel orientation • Careful adjustment to ensure correct thermo-siphon action. • Units are bulky and can be difficult to mount. • Use of heat transfer fluid where required • Use of manufacturers test kit and pressure testing • Plumber required • Electrician required where electric boost to be used • Bulk makes transport an issue	4
Gas	• Gasfitter required • Plumber	2
Biomass	• Plumber required	1

It is important to stress that hot water failure was generally found to be the result of poor installation or a lack of maintenance. Vandalism was not a significant cause of system failure. As such, bodies responsible for the supervision of system installation should pay special attention that the installation is of a high quality.

4.7.3 Operating Conditions

The two aspects of system operating conditions identified as impacting on the life of hot water systems are:

- Use with poor quality water.
- Installation environment.

4.7.4 The effects of poor quality water

The high mineral salt content of water in many remote communities was found to adversely affect relief valves, taps and most importantly electric elements through corrosion and the accumulation of scale. Hard water also impacts adversely on the storage tank itself.

The failure of electric elements was a significant issue for both electric-only and solar systems with an electric boost. Immersed elements are susceptible to corrosion through the build up of scale on their surface when used in water with a high concentration of mineral salts. The build up of scale on the element acts as an insulating layer. The heating element then has to work harder to heat water to the temperature set by the thermostat. If scale accumulates too thickly elements often burn out. Some elements inspected during the survey had been open circuited through salt build up.

Recent developments by Australian hot water system manufacturers attempt to minimise the impact of scale on heating elements. Solahart now uses a "bobbin" element, which has a sheath surrounding the heating element to isolate it from the water. Edwards is working on the same technology. The sheath is made from mild steel, coated with a double layer of glass that is resistant to corrosion by minerals in hard water. Scale still accumulates on the sheath, but it is said not to impact on the heating element as much. This is a recent development, with the great majority of existing hot water systems still using immersion-heating elements.

Corrosive minerals in scale act to corrode hot water tank walls, the heating element and seals. Sacrificial anodes have been used in hot water systems for some years to reduce this corrosive effect. Corrosive minerals attack the sacrificial anode in preference to other features in the tank. Anodes made from magnesium are said by Solahart to give around five years life before requiring servicing or replacement in areas where hard water has a total-dissolved-solids (TDS) level less than 600 mg/L[11]. For waters with TDS higher than 600 mg/L, magnesium anodes only last around two to three years, and Solahart then recommends using an aluminium anode that will give about five years service.

Tanks are glass-lined (e.g. Solahart) or made from stainless steel (e.g. Edwards) in an attempt to slow corrosion. Solahart have indicated they are now using Teflon-coated cones to seal units, in preference to older rubber ring seals. These new units have a 12-year guarantee on the tank materials (excluding heating element) and are expected to last around 20 years.

Edwards solar hot water systems are trialling the addition of 'Tanamint' crystals to their hot water systems to inhibit the formation of scale. The crystals contain a slow-release chemical that stops scale particles precipitating from hot water[12]. This system is not yet commercially available.

For instantaneous gas hot water systems, scale can accumulate rapidly on the heating element surface in areas of hard water, again reducing heating efficiencies. Scale accumulation inside the pipes of these hot water systems can restrict the flow of water to the point where flow ceases.

During the trials and surveys in Napranum it was found that the very **aggressive (pH 5) water** in that area contributed to a large number of cases of corroded main tanks.

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[11] Marshall, G. *A Review of Scale Prevention Devices for use in hot water systems in remote Aboriginal communities*, CAT Report No. 99/8, Centre for Appropriate Technology, August 1999.
[12] ibid.

4.7.6 Repairs and maintenance considerations

The absence of preventative maintenance programs was identified in the preliminary surveys as a major factor contributing to the poor performance of systems.

Regular preventative maintenance could lead to improved overall operability of systems and system efficiency, allowing a more effective use of fuel. There are definite cost advantages for communities, particularly where maintenance includes repair of associated plumbing, thereby minimising leakage.

A disadvantage of some technologies trialled is the need for specialist knowledge and parts to maintain systems. The heat pump systems are a good example. Repairs to these systems will sometimes require the expertise of a refrigeration mechanic, expertise that is generally unavailable in remote communities. Similarly, extensive work on gas systems will generally require sign off by a gas fitter.

Just as the quality of installation of a system has a bearing on its operational lifetime, so too does the **quality of maintenance and repair work**. The most obvious fault with boost elements in solar systems was leakage around the element seals and the resultant corrosion. Problems with replaced electrical boost elements were apparent during the pre surveys of solar systems. In many cases it was obvious that the elements were replaced without proper pressure testing of the storage tank. Leaking seals quickly caused the boost system to malfunction.

5.0 FINDINGS AND RECOMMENDATIONS

5.1 Hot Water Consumption Patterns

The study found the consumption of hot water in remote Indigenous households was highly variable. This was linked to fluctuations in population experienced by many Indigenous households. The average consumption was 240 L/household/day.

The average consumption of hot water in Indigenous communities on a per capita basis of 40 L/p/d was similar to that of the wider Australian population (50 L/p/d).

5.2 Efficiency of Systems

The study trials investigated the relative energy efficiency of various hot water system types. The analysis used running cost as a measure of the relative efficiency of hot water systems.

Use of running cost as a measure of relative efficiency requires consideration of the price of energy. Subsidised energy costs (especially for electricity) were identified as a key factor in determining the most "cost effective" energy option for Indigenous householders. The feasibility of using energy sources other than electricity, particularly gas, depends on the respective prices paid by end users for these energy sources.

The use of cost effective alternatives to electricity reduces the electrical load on the community generators and creates an opportunity to use alternative sources for community electricity such as renewable energy. This is a desirable goal for both communities and funding agencies, faced with ever growing diesel fuel bills for electricity generation. Generally speaking, hot water systems using electricity were found to be incompatible with the use of stand-alone renewable energy systems.

- **Heat pump systems** had amongst the lowest running cost, particularly of those systems using electricity.

- **Solar systems (with boost)** were observed to have highly variable levels of performance. The performance and cost effectiveness of these systems is highly dependent on local operating conditions and household demand patterns. Under the right circumstances these systems can be at least as cost effective as heat pump systems, however their performance is sensitive to operating conditions. It is thought the energy efficiency of these systems could be improved through intelligent control of boost operation.

- **Solar systems (no boost)** often did not provide adequate hot water to households, particularly where the household population was significantly higher than normal. This is a situation that often arises in Indigenous households.

- **Electric-only systems** were found to have the highest running cost of those systems that use electricity.

- **Gas systems** are unlikely to be an attractive option where householders pay for electricity at a subsidised rate (say 16c/kWh). Where end-users pay close to the "real" cost of electricity (say $1/kWh), gas becomes a more attractive option.

- **Biomass systems** hold some attraction as a low cost energy source. Apart from an unboosted solar unit, chip heater systems are probably the cheapest option particularly where people are paying close to the "real" price for electricity. Even where electricity is subsidised, biomass can be a cost-effective option. It is worth noting that some people involved in the trials found the gathering of fuel wood an inconvenience. Due consideration needs to be given to the long-term sustainability of using biomass as an energy source.

Recommendations

Further investigation is required:

- *By industry to ensure energy efficiency improvements through development of an intelligent control system for the operation of the boost element in solar hot water units.*

- *ATSIC and CAT to devise strategies to increase the uptake of gas as a fuel source in remote communities.*

5.3 Reliability of Systems.

The level of data available and the short duration of the trial (relative to the lifetime of a hot water system) made it difficult to draw any firm conclusions concerning the relative reliability of systems.

Data for solar hot water systems from the two preliminary surveys demonstrated a high failure rate over the long to medium term. However, without similar data for other technologies it is difficult to make a comparison of long-term reliability.

Recommendation

- *CAT to study long term field observations on hot water systems to obtain a better picture of relative reliability of technologies over time.*

5.4 Factors affecting the performance of hot water systems

5.4.1. Quality of manufacture and packaging

The quality of manufacture and packaging of hot water systems was identified as an important factor that could influence long-term effectiveness and reliability. An instance of poor quality manufacturing was found to shorten the lifetime of a trial system. Poor quality packaging led to problems during the installation process.

5.4.2. Transportation and installation

The study revealed significant problems with hot water systems in remote Indigenous communities stemming from poor quality installation work. This work was found to have a detrimental impact on the long-term integrity of systems. Suppliers and installers demonstrated a poor knowledge of systems on several occasions.

The installation of systems in remote communities can pose challenges as the necessary equipment, such as basic lifting devices, are often not available. In addition the cost of installation was found to be high in remote areas owing to the cost of transportation and of getting appropriate expertise to the remote location.

Systems that were lightweight and simple to install were seen as being particularly attractive from a transport and installation perspective. Electric heaters, especially the smaller ones, were easiest to install. The Quantum heat pump systems were relatively easy to install although their bulk made transport an issue.

Gas systems were easy to install if a gas fitter was available. The recipient sites were limited to cases where gas fitters were available and where residents were prepared to use gas..

The CAT chipheaters were found to be easy to transport and install.

The most difficult systems to install were the solar systems because of their bulk and the fact that they required careful adjustment of the tank and panel system to ensure correct thermo-siphon action.

Recommendations

That improved installation standards be encouraged and supported through:

- *Manufacturers of hot water systems and training providers developing, or improving existing, training programs suitable for installers of systems in remote Indigenous communities.*

- *ATSIC investigating the feasibility of setting up regional contractor accreditation schemes for tradespeople working in remote communities.*

- *Indigenous housing organisations and outstation resource agencies adopting policies requiring suppliers and installers to provide a quality installation service. These should be backed up by inspection procedures to validate the quality of installation.*

5.4.3 Operating Conditions

The two aspects of operating conditions identified as impacting on the life of hot water systems are:

- Use with poor quality water.
- Installation environment.

The high mineral salts content of water in many remote communities was found to adversely affect relief valves, taps and most importantly electric elements through corrosion and the accumulation of scale. Hard water also impacts adversely on the storage tank itself.

The correct selection of elements and sacrificial anodes can go some way toward minimising problems due to poor water quality. Regular servicing and cleaning of equipment can also be a reliable method of controlling scale.

Manufacturers have recently developed several innovations in an attempt to minimise the impact of hard water on systems. The success of these measures is yet to be gauged through field experience.

A desktop study on a range of scale prevention devices was skeptical as to their effectiveness in preventing or removing scale from hot water systems.

Protection of hot water systems from physical damage was identified as important. Stone guards fitted to solar collectors were generally found to work well.

<u>Recommendations</u>

That the effect of poor water quality on water heating systems be addressed through:

- *CAT disseminating information on actions that can be taken to minimise the impact of water with high levels of dissolved minerals and/or acidity on water heating systems.*

- *CAT undertake independent laboratory and field testing of the range of devices and innovations claiming to minimise the effects of hard water on water heating devices.*

5.4.4. Repairs and maintenance

The absence of preventative maintenance programs was identified as a major factor contributing to the poor performance of systems.

A disadvantage of some technologies trialled was the need for access to specialist knowledge and parts to maintain systems. The heat pump systems are an example of such a system.

The quality of maintenance and repair work was found to have a definite impact on the long-term integrity of systems. Poor maintenance work often related to a poor knowledge of systems by maintenance personnel

<u>Recommendations</u>

That cyclical and responsive maintenance and repair issues be addressed via:

- *Manufacturers of hot water systems and training providers developing, or improving training programs and resources on maintenance and repair of hot water systems available for members of remote Indigenous communities.*

- *CAT establishing or monitoring projects to provide opportunities to evaluate a variety of* *models for cyclical maintenance, (including plumbing maintenance).*

- *Indigenous housing organisations and outstation resource agencies adopting regular cyclical maintenance and repair programs for hot water systems.*

5.4.5 Consumer Awareness.

The findings of the report suggest a relatively low level of understanding of the costs and limitations associated with the use of hot water technologies in remote areas. It is important that Indigenous organisations and/or individuals procuring hot water units for use in remote areas have an understanding of these issues.

<u>Recommendation</u>

- *That the level of Indigenous consumer knowledge of issues relating to hot water technology be improved through the dissemination of independent information and advice on the costs and benefits of current hot water technology options in remote areas.*

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7. GLOSSARY

Ambient water temperature
The temperature of a body of water in thermal equilibrium with the environment. The base temperature from which water is heated by a system.

Coefficient of Performance (COP)
A performance measure used for heat pump systems. In the case of a heat pump hot water unit it is a measure of the heat delivered to the water per unit of fuel energy input. Heat pump systems also utilise energy from the surrounding environment. The COP can have a value greater than one.

Confidence Interval
A statistical measure used to assess the accuracy of an estimate of the true value of some quantity.

Efficiency
Defined as: Total Heat delivered to water / Energy Input. Will always have a value less than one

L/MJ	Litres of hot water / Megajoule of energy input. Alternatively the unit of kWh can be used in place of MJ. Note that 1 kWh = 3.6 MJ.
LPG	Liquified Petroleum Gas
L	Litres
L/h/d	Litres consumed per household per day
L/p/d	Litres consumed per person per day
c/kWh	Fuel cost in cents per unit of energy
MJ/kg	Megajoules of energy extractable from each kilogram of fuel.
TDS	Total Dissolved Solids. A measure of the mineral content of a sample of water, Measured in units of milligrams / litre (mg/L).

8. APPENDICES

Appendix A:

Hot Water Unit Specifications

Solahart 302 J Solar Hot Water Unit

Specifications:

• Water Storage capacity		300 L
• Tank Weight (Empty)		84kg
• Tank Dimensions:	Length	2310mm
	Width	510 mm
	Height	510mm
• Total Collector Area (two collectors)		4 m^2
• Normal Operating Pressure		850 kPa

Edwards HXL 300 Solar Hot Water Unit

Specifications:

• Water Storage Capacity		300 L
• Minimum Element Rating		3.6kW
• Area of solar collector		4 m^2
• Total Weight of System (Empty)		154 kg
• Storage Tank Dimensions:	Length	1980 mm
	Width	585 mm
	Height	750 mm

Edwards LX 300 Solar Hot Water Unit

Specifications:

• Water Storage Capacity		300 L
• Minimum Element Rating		3.6kW
• Area of solar collector		4 m^2
• Total Weight of System (Empty)		138 kg
• Storage Tank Dimensions:	Length	1200 mm
	Width	560 mm
	Height	620 mm

Sunsaver Solar Hot Water Unit

Specifications:

• Capacity	185 L
• Weight (empty)	65 kg
• Weight (full)	240 kg
• Height (tank section)	450 mm
• Height (collector section)	120 mm
• Length	1690 mm
• Width	1450 mm
• Solar Collector area	1.65 m^2

Rheem Gas Optima 12/95

Specifications:

• Capacity	135 L
• Weight (empty)	68 kg
• Height	1598 mm
• Depth	502mm
• Width	422 mm

Rheemglas Electric 101.125

Specifications:

• Capacity	125 L
• Weight (empty)	42 kg
• Height	1340 mm
• Diameter	435mm

Quantum 340 L Pacific HD-EC Compact

Specifications

• Water Storage Capacity	340L
• Heating Capacity (@30 °C)	5kW
• Water temp.	60 •C
• Power Input	1.1 kW
• Weight (Empty)	148 kg
• Weight (Full)	494 kg
• Refrigerant	R22
• Evaporator box dimensions	600mm * 450mm * 430mm

Hardie Dux (Electric)

Specifications

• Water Storage Capacity	50L
• Weight (Empty)	25 kg
• Overall Height	~ 675 mm
• Overall Diameter	~ 405mm

CAT Chip-heater

Specifications

• Water Storage Capacity	75L
• Heating Capacity	2.4kW
• Water cylinder internal diameter	365mm
• Water cylinder height	~900mm
• Total Height	~1970mm

Appendix B:

System installation details and household descriptions.

Napranum

The identification system used for Napranum was to give each site a code NA followed by a numeral. The system with the solarimeter attached was given by NASOL. In addition the Napranum Council house identification number is documented and wherever possible the name of the original occupants.

Water pressure at Napranum was measured to be 180 kPa, the water was highly acidic with a pH around 5.2 and low dissolved solid content. This water quality was typical for Cape York communities. Due to the bauxite mine solar panels were subject to bauxite dust depositing on the glass collector surfaces. The panels were cleaned during each monitoring visit.

Installation logistics.

The new HW systems to be installed at Napranum included 1x Quantum heat exchange unit, 2x Edwards HXL solar systems, 1 x Solahart 300J solar system, 2 x Sunsaver gravity fed solar systems and 1x Rheem gas system. In addition one existing Solahart system was to be monitored.

All the new systems were freighted to Weipa/Napranum by the freight carrier Tuxworth and Woods arriving at the works depot Napranum Council on Monday morning 14th July. The crew from CAT (Bob Lloyd and Mike Travers) left Alice Springs on Sunday and after overnighting in Cairns arrived in Weipa Monday 1:30 pm. The Solahart plumber (Mike Mayo) traveled with the CAT staff from Cairns. At Napranum some difficulties were experienced in finding out which houses were designated for the installations.

The Napranum council plumber Brian Mc Pherson gave valuable assistance and also learnt about the correct installation and commissioning of the solar units. Council electricians Bill and Darren connected the electrical supplies where appropriate. Wednesday saw the completion of the two Edwards units and the installation of the Rheem gas system at Grant's house. On Thursday the Quantum was installed at house 17 and the monitoring equipment at house 70 was completed. House 70 was a steeply pitched high set house, which provided some safety difficulties. On Friday morning the team tested and surveyed the majority of the existing solar units. After final liaison with Grant Crossley, the Council Clerk, and Steve Topping at the works depot the team left on the 1:30 flight to Cairns that day.

The two Sunsaver units were never installed due to the difficulties of plumbing the houses to accommodate low-pressure units.

House Identification NA1 (House 70) –

System type: existing Solahart 300J system (2/93) with 1.8 kW boost element, Serial # 29405

House Type: High set two-story timber Queenslander with high-pitched roof. Installed: Monitoring system installed 17/7/97
Occupants: 5 Adults and 10 children. The head of the house was the chairperson of the Napranum Council.
Notes: Kitchen taps OK, shower rose OK x2 upstairs and downstairs, laundry machine taps present and OK (Simpson "Riverina" 6.5 kg washing machine), shower taps OK x 2 upstairs and downstairs, laundry tub taps OK, hand basin taps OK.. Although the HW system was checked on installing the monitoring system, later monitoring data showed a severe leak in the hot water side of the plumbing that led to excessive electricity consumption. Despite many requests to have the leak fixed this was not done until towards the end of the project.

House Identification: NA3 (House 17)
System Type: Quantum heat exchange unit 340L, Serial # 92632-TD-EC 7/97. Nominal input power 1300W.
House Type: Concrete block
Installed: HW system installed 17/7/97,monitoring system installed 17/7/97
Occupants: 2 Adults and 7 children. The original occupants of this house vacated the premises shortly after installation and new occupants did not move in until nearly 6 months later. The new household size was approximately 4 adults.
Notes: Kitchen taps OK, shower rose OK, laundry machine taps leaking (small twin tub washing machine), shower taps OK, laundry tub taps OK, hand basin taps leaking (fixed). The lack of occupants for a good proportion of the monitoring period meant that this household did not produce a lot of meaningful data.

House Identification: NA4 (House 192)
System Type: Solahart 300J (5/97) Serial # 69944
House Type: Concrete block house
Installed: HW System installed 15/7/97,monitoring system installed 15/7/97
Occupants: 6Adults and 3 children.
Notes: Kitchen taps OK, shower rose showed some calcification, laundry machine taps present and OK ("Kleenmaid" washing machine), shower taps OK, laundry tub taps OK, hand basin taps
A Torres Strait Islander family occupied this house.

House Identification: NA6 (House 167)
System type: Rheem 135 L Optima, Outdoor Gas system 12/95, Nominal gas consumption 22MJ/hour when heating. Serial # 460846. Originally a single 45 kg LPG cylinder was installed, later this was upgraded to two cylinders to enable easy changeover when one cylinder emptied.
House Type: Concrete block house
Installed: HW system installed 16/7/97, monitoring system installed 17/7/97
Occupants: 2 Adults and 3 children. The head of the house was a non Indigenous employee of the Napranum Council (the Council Clerk).
Notes: Kitchen taps slight leak, shower rose, laundry machine taps OK (small twin tub washing machine – later replaced with a larger automatic model) , shower taps OK, laundry tub taps OK, hand basin taps OK. This site also had the two hobo temperature loggers.

House Identification: NA7 (house 194) –
System type: Edwards HXL (2/93) with 4.8 kW boost element.
House Type: Concrete block house.

Installed: System installed 16/7/97,Monitoring system installed 16/7/97
Occupants: 2 Adults and 2 children. The original occupants were from old Mapoon and spent most of their time there. The house was found to be unoccupied for most of the monitoring period.
Notes: Kitchen taps (leaking), laundry machine taps present and OK (Whirlpool 8100 series commercial quality), shower taps OK, laundry tub taps OK, hand basin taps OK. Not a lot of useful data came from this house due to the fact the occupants were away for most of the time. In addition the HW system had a severe leak, which caused very high electricity consumption. Because of lack of ability to access the interior of the house, the leak could not be fixed. Towards the end of the monitoring period the electricity supply had been disconnected and the house was abandoned.

House Identification: NASOL (House #191)
System type: Edwards HXL Serial number C 4838, 4.8 kW boost element
House Type: Concrete block house
Installed: HW system installed 16/6/97, monitoring system installed 17/7/97
Occupants: 2 Adults and 3 children (holidays only).
Notes: Kitchen taps OK, shower rose corroded, laundry machine taps present and OK, shower taps leaking, laundry tub taps OK, hand basin taps OK. The solar radiation logger was installed was at this site.

Kintore

The identification system used for Kintore was to give each site a code KI followed by a numeral. The system with the solarimeter attached was given by KISOL. In addition the Kintore community house identification number was documented and wherever possible the name of the original occupants.

The water supply pressure at Kintore, was measured at several different locations and did not exceed 370 kPA. The conductivity of the water supply was measured with a Hanna conductivity meter to be 1,200 (S/cm giving a dissolved solids content of around 720 ppm. This is consistent with Hostetler etal (1998)[15] which found bores servicing Kintore fell within the Australian Drinking Water Guidelines limit of 1000 ppm for total dissolved solids.

Installation logistics

The systems to be installed at Kintore included 2 x Solahart solar systems, 2 x Edwards LX solar systems and 1 x Quantum heat exchange system. In addition one existing Solahart system was to be monitored and three additional Solaharts were to be installed (to replace defective units identified in the earlier survey). All original hot water systems at Kintore were Solahart 300 J solar systems as described in the first Hot Water Progress Report (NTRC Report # 97/6).

The hot water systems for Kintore were transported from Alice in the CAT 8 ton truck. The truck left CAT around 2:00 pm on Thursday 24th July with Bob Lloyd and Mike Travers on board. Because of the poor road conditions and the fragile nature of the load the truck did not reach

[15] Hostetler S et al, "*Groundwater Quality in the Papunya – Kintore Region, Northern Territory*" Western Water Study (Wiluraratja Kapi), Australian Geological Survey Organisation, 1998.

Kintore until 10:00 pm that night. The two plumbers from Gould Plumbing arrived by the regular mail flight air on Friday morning. By that time all the systems had been placed on the respective roofs ready for installation. Bob Lloyd flew back on the return flight.

As the Solaharts were simply a "swap over" installation went very quickly with four being installed on the Friday. By Sunday afternoon the Edwards units, the Quantum and the remaining Solahart were all in place. Bob Lloyd arrived that afternoon driving the CAT R&D vehicle with the electrician from ECS (Dieter Henschel). Some work on commissioning the data loggers started that evening but problems developed with two units having flat main batteries. The next morning the R&D vehicle returned with the plumber and Mike Travers, leaving Bob and Dieter to connect the electrical supplies and commission the data loggers. No work could be undertaken in the morning as it was interrupted by a funeral of one of the community women. After lunch more difficulties were found with flat batteries and problematic data logging systems with the result that only three of the six units were able to be set running. Tuesday morning saw the electrical connection of the final hot water system and an unsuccessful attempt to revive the problematic loggers. Bob and Dieter left in the CAT truck about 10:30 am arriving back at CAT just before 5:00 pm.

An additional problem was soon identified with the Kintore systems. At Kintore the electricity is paid by $10 cards that connect the supply as long as the householder is in credit. It was apparent that many householders did not maintain a continuous supply. This supply problem in was fixed by fitting all the monitoring units with their own self-contained 6.0-volt photovoltaic panel supply during a separate trip to Kintore. Ms Michelle Guelden from CAT supervised the installation of the new power supplies along with another CAT employee (Richard Rigney) in September and October 1997. During these visits the flow meters were recalibrated.

Household details:

House Identification: KI1 (House 127)
System Type: Edwards LX
House Type: Concrete block
Installed: HW system installed 28/7/97,monitoring system installed 30/7/97
Occupants: 2 Adults and 4 children.
Notes: Some equipment problems were experienced with the data loggers at this site. Shower rose OK, no hot water laundry machine taps present, shower taps OK, laundry tub taps OK, kitchen taps OK.

House Identification: KI2 (House 144)
System Type: Solahart 300J Serial # 70571
House Type: Concrete block
Installed: HW system installed 28/7/97,monitoring system installed 29/7/97
Occupants: 4 Adults (variable).
Notes: Shower rose OK, laundry machine taps OK, shower taps OK, laundry tub taps OK, kitchen taps OK. Good data eventuated from this site.

House Identification: KI3 (House 143)
System Type: Solahart 300J Serial # 70550
House Type: Concrete block

Installed: HW system installed 26/7/97, monitoring system installed 29/7/97
Occupants: Occupants 4 Adult women plus extras.
Notes: Shower rose OK, laundry machine taps OK, shower taps OK, laundry tub taps OK, kitchen taps OK During the final October visit one of the solar collector glass cover panels was broken, despite the systems having a stone guard in place.

House Identification: KI4 (House 104)
System Type: Edwards LX Serial # T36383 6/97
House Type: Concrete block
Installed: HW system installed 17/7/97,monitoring system installed 17/7/97
Occupants: 4Adults and 3 Children adults.
Notes: Shower rose OK, laundry machine taps OK, shower taps OK, laundry tub taps OK, kitchen taps OK. No washing machine. Good data was produced from this monitoring system

House Identification: KI5 (House 90)
System Type: Quantum heat exchange unit Model 340T D_EC Serial # 9261 9T_EC House Type: Concrete block
Installed: HW system installed 28/7/97,monitoring system installed 30/7/97
Occupants: 4 Adults and 2 children.
Notes: Shower rose OK, No laundry machine taps, shower taps OK, laundry tub taps OK, No kitchen taps (no kitchen)

House Identification: KISOL (House 145)
System Type: Solahart 300J 6/97, Tank Serial # 70574
House Type: Concrete block
Installed: HW system installed 17/7/97,monitoring system installed 17/7/97
Occupants: 5 Adults
Notes: Kitchen taps OK, shower rose OK, laundry machine taps present and OK, shower taps OK, laundry tub taps OK, no washing machine.

House Identification: KISOL (House 145)
System Type: Solahart 300J 6/97, Tank Serial # 70574
House Type: Concrete block
Installed: HW system installed 25/7/97,monitoring system installed 30/7/97
Occupants: 5 Adults. The original occupants of this house vacated the premises during the monitoring period and the house was abandoned by the time the loggers were removed.
Notes: Considerable mechanical and electrical difficulties were experienced with the monitoring equipment for this system. By the end of the monitoring period the electricity supply had been disconnected.

Kalka/Wataru

Logistics

The systems for the Kalka/Wataru installation included 2x Quantum heat exchange units, 2x Edwards solar systems, 2 x Solahart solar systems, 1x Rheem electric system and 1x Hardie Dux electric system.

These systems were loaded onto the CAT 8 ton truck on Friday 27th June together with tools and camping equipment. Packing was not completed until midday on Saturday due to the fact that several of the systems had only arrived in Alice Springs on the Friday. Additional difficulties were experienced in obtaining permits for the plumbers contracted (Gould Plumbing) to operate in South Australia. Nevertheless, after the usual panic involved with bush trips, the truck set off from Alice Springs around 1pm on Saturday 28th with Bob Lloyd, Michael Travers and Michael Lerm, arriving in Kalka at 2pm on the Sunday. The size and weight of the two Quantum units required some ingenuity to off load but with the help of old tyres collected from the roadside this feat was accomplished and the truck moved on to Wataru reaching the community just before 10:00 am on the Monday. Stephan Rainow and Kirk Forbes from Nganampa Health arrived shortly after at 10:15 am. The plane carrying the two plumbers (Scott Anderson and Simon Anderson) and a representative from Edwards Energy Systems (Brian Anderson) arrived at 10:30am and after unpacking setting up camp and an early lunch the full crew started installation by 1:00 pm.

By nightfall one of the Solahart systems was in place and some progress had been made on installing the data logging equipment. Tuesday saw the installation of one more Solahart and the two Edwards units. Actually the last Edwards unit was not quite finished by nightfall and some work was needed on Wednesday morning. Considerable problems occurred with the installation of the Edwards systems that were supplied with the wrong mounting kits and more importantly with an obsolete batch of glycol- corrosion inhibitor. The batch supplied was known on occasions to gel solid if heated. Urgent phone calls, by Brian, to Edwards in Perth resulted in obtaining replacement parts and new glycol freighted to Alice Springs and then onto Wataru on the Thursday mail flight.

Around midday on the Wednesday the plumbers accompanied by the co-opted electrician Grant Whitaker (the ESO from Wataru) and the Nganamapa Health personnel drove to Kalka to start the installations there. Bob and Mike continued installing the data logging equipment until a halt in the main water supply forced a halt around 5 pm. The water flow meters on the last Edwards unit were thought to be faulty and were replaced only to find that they were in fact fouled with 2-3 mm sized pebbles in the water supply. The problem was almost certainly caused by a separate set of plumbers working on the main water supply. A new header tank was being installed for the community increasing the head from 6 metres to 9 metres. This increase actually meant that solar system performance was considerably improved.

The installations at Kalka went smoothly and by nightfall on the Thursday they were nearly complete. Friday morning saw the systems and data logging equipment complete with all systems operational. The plane to pick up the plumbers arrived at 11:00 am and departed at 12:00 am for Wataru taking Bob in addition to finish off the work getting the loggers operational at that site.

The Edwards systems were charged with glycol and the remaining data logger fixed by 2:30 pm after which the plane left for Alice Springs arriving at 4:30 pm. The truck with the two Mikes left Kalka around 3:00 pm arriving in Alice at 1:00 pm the next day.

Household Installations:

Static water pressure measured = 85kPa

Wataru:

House Identification: WA1 (House # W4)
System type: Solahart 300J 6/97, Tank Serial # 70894
House Type: Concrete block house
Installed: HW system installed 2/7/97, monitoring system installed 4/7/97
Occupants: 3 Adults and 3 Children
Notes: A two way valve installed to allow chip heater or solar system to supply hot water to house. No hot water in kitchen. Shower rose OK, laundry machine taps present and OK, shower taps OK, laundry tub taps OK

House Identification: WA2 (House #W2)
System type: Edwards L305X 11/96, Tank Serial # 29152
House Type: Concrete block house
Installed: HW system installed 2/7/97, monitoring system installed 2/7/97
Occupants: 4 Adults and 4 Children
Notes: A two way valve installed to allow chip heater or solar system to supply hot water to house. No hot water in kitchen. Shower rose OK, laundry machine taps present and OK, shower taps OK, laundry tub taps OK

House Identification: WA3 (House #W8)
System type: Solahart 300J 6/97, Tank Serial # 70896
House Type: Concrete block house
Installed: HW system installed 2/7/97, monitoring system installed 4/7/97
Occupants: Occupants 9
Notes: A two-way valve installed to allow chip heater or solar system to supply hot water to house. No hot water in kitchen. Shower rose OK, laundry machine taps present and OK, shower taps OK, laundry tub taps OK

House Identification: WASOL (House #W3)
System type: Edwards 305X 4/96, Tank Serial # T26558
House Type: Concrete block house
Installed: HW system installed 1/7/97, monitoring system installed 2/7/97
Occupants: 4 Adults, 3 Children
Notes: A two way valve installed to allow chip heater or solar system to supply hot water to house. No hot water in kitchen. Shower rose OK, laundry machine taps present and OK, shower taps OK, laundry tub taps OK. This installation included the pyranometer and the ambient temperature and water temperature data loggers (HOBOs). Shower rose on full delivering 5.8 litres/minute

Water pressure on hot water line 80 kPa. "Tubuflows" were installed to reduce problems due to calcification.

Kalka

House Identification: KA1
System type: Quantum Turbo 340T D_EC 6/97 serial # 92623T
House Type: Concrete block house
Installed: HW system installed 2/7/97, monitoring system installed 3/7/97
Occupants: 3 Adults and 3 Children
Notes: Kitchen taps ok. Shower rose OK, laundry machine taps present and OK, shower taps OK, laundry tub taps OK. Speedqueen washing machine installed.

House Identification: KA2
System type: Hardie Dux 50 L model HDE50V Serial # 97411724
House Type: Concrete block house
Installed: HW system installed 2/7/97, monitoring system installed 3/7/97
Occupants: 3 Adults and 5 Children
Notes: Kitchen taps ok . Shower rose showed some calcification , laundry machine taps present and OK, shower taps OK, laundry tub taps OK. Kleen maid washing machine installed.

House Identification: KA3
System type: Quantum Turbo 340T D_EC serial # 92622T
House Type: Concrete block house
Installed: HW system installed 2/7/97, monitoring system installed 3/7/97
Occupants: 8 Adults and 3 Children
Notes: Kitchen taps ok. Shower rose showed some calcification. Laundry taps ok. Washing machine taps present and OK (Speed Queen installed), shower taps OK, laundry tub taps OK

House Identification: KA4
System type: Rheem Electria 101 series 125 litre
House Type: Concrete block house
Installed: HW system installed 2/7/97, monitoring system installed 4/7/97
Occupants: 7 Adults and 6 Children
Notes: Kitchen taps ok. Shower rose OK, laundry machine taps present and OK, shower taps OK, laundry tub taps OK

Alice Springs Town Camps

Logistics

These systems were the first to start being installed with the Solahart, and the two electric systems being installed by Tangentyere council during the week starting 16th June. Both the Edwards units and the Quantum didn't arrive in Alice until just before the initial trip to Kintore. The Quantum systems were installed late in the week after arriving back from Kintore (30th July) but the units were not connected to the electrical supply until October. The Edwards systems were finally installed also in October. Although the units were in Alice Springs difficulties were encountered dealing with Tangentyere council and identifying houses that had stable occupancy. As it turned out several installations in Alice Springs were in houses that were not occupied for substantial periods during the project. In addition one house with an electric hot water unit installed did not have the power connected until the project ended. Another house burnt down part way through the project.

Household installations:

House Identification: AL1 **(Charles Creek house 6)**
System type: Hardie Dux unit Serial # 97411727 HDE50V , 3.6 kW element
House Type: Concrete block house
Installed: HW system installed 20/10/97, monitoring system installed 31/10/97
Occupants: not known
Notes: Kitchen taps ok. Shower rose OK, laundry machine taps present and OK, shower taps OK, laundry tub taps OK No one living in house. Some people living in shed at the back of the house. A new power card system had been installed the $5.00 emergency credit was activated and the power switch turned on

*House Identification: AL2 (***Karnte house #1)**
System type: Rheem 125 L electric
House Type: Concrete block house
Installed: HW system installed 20/10/97,
Occupants: not known
Notes: Access could not be obtained to this site and it was eventually abandoned.

*House Identification: AL3 (***Ilypye Ilypye)**
System type: Started as Rheem Gas 135 L
Installed: HW system installed 20/8/97, monitoring system installed 21/8/97
Occupants: 2 Adults 2 children.
System Installed 11/11/97
Installed Solahart Black Chrome serial 33000 380 with heat pipe and cut out.
Notes: Kitchen taps ok. Shower rose OK, laundry machine taps present and OK, shower taps OK, laundry tub taps OK. The occupants of this house complained of the gas system running out of hot water often and difficulties replacing the cylinder. The gas unit was replaced with a unit donated by Solahart in November. The gas system consumed two full (45kg) cylinders during the 3 months it was in place.

House Identification: AL4 **(Hidden valley house # 38)**
System type: Sunsaver plastic non pressurised system no serial #
House Type: Concrete block house
Installed: HW system prior to project, monitoring system installed 21/10/97
Occupants: not known
Notes: Kitchen taps ok. Shower rose OK, laundry machine taps present and OK, shower taps OK, laundry tub taps OK No one living in house. The water pressure and flow rate was very low. – The Sunsaver is a gravity fed system and should have 20mm plumbing on the supply side. This system only had 15 mm plumbing. Although electricity appeared to be connected the unit did not seem to use any electricity indicating that the element had burnt out. The unit was eventually replaced with a Solahart "Streamline" forced flow system but the project ended before meaningful data could be obtained from this latter system.

House Identification: **AL5 (Morris soak house # 4)**
System type: Solahart 300J unit Serial # 70575 5/97, 2.4kW element
House Type: Concrete block house
Installed: HW system installed /97, monitoring system installed 31/10/97
Occupants: not known
Notes: Kitchen taps ok. Shower rose OK, laundry machine taps present and OK, shower taps OK, laundry tub taps OK

House Identification: *AL6* **(Trucking Yards # 5)**
System type Quantum heat exchange unit Serial # 92621TD-EC 6/97
House Type: Concrete block house
Installed: HW system installed 20/10/97, monitoring system installed 31/10/97
Occupants: 1 Adult 2 children
Notes: Kitchen taps ok. Shower rose OK, laundry machine taps present and OK, shower taps OK, laundry tub taps OK

House Identification: *AL7* **(Abbots camp # 4)**
System type: Quantum heat exchange unit Serial # 92620TD-EC 6/97
House Type: Concrete block house
Installed: HW system installed 20/9/97, monitoring system installed 21/10/97
Occupants: not known
Notes: Kitchen taps ok. Shower rose OK, laundry machine taps present and OK, shower taps OK, laundry tub taps OK. A major leak was detected coming from the ceiling. This house used to have a solar system, which was deleted from the plumbing supply to take the heat exchange unit. Great difficulty was experienced in getting the Council to attend to this problem. In addition the electricity supply was disconnected. The result was that this site did not give data until near the end of the project.

House Identification: *AL8* **(Walpiri house #2)**
System type: Edwards HXL solar unit Serial # C4535, Element 3.6 kW
House Type: Concrete block house
Installed: Monitoring system installed 21/10/97
Occupants: not known

Notes: Kitchen taps ok. Shower rose OK, laundry machine taps present and OK, shower taps OK, laundry tub taps OK. The spacers to prevent the stone guard hitting the glass panel were not installed. There was no mains electricity meter installed.

House Identification: ASOL **(Morris Soak house # 5)**
System type: Edwards HXL solar unit Serial # C4885, Element 3.6 kW
House Type: Concrete blockhouse
Installed: HW system installed 20/10/97, monitoring system installed 21/10/97
Occupants: not known
Notes: Kitchen taps ok. Shower rose OK, laundry machine taps present and OK, shower taps OK, laundry tub taps OK