Measuring the rebound effect of energy efficiency initiatives for the future

A South African case study

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Addendum to final report:

Water heating in middle to high income households

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Contents

Summary of the addendum

This document represents an addendum to the report entitled "Measuring the rebound effect of energy efficiency initiatives for the future – A South African case study", which was completed in March 2010. The addendum summarises the outcomes of a data collection exercise which was originally undertaken with the aim of measuring the rebound effect resulting from large-scale rollouts of solar water heaters (SWHs) within the middle to high income demographic in the residential sector.

One of the challenges of conducting a micro-level study on the rebound effect arising from a technology intervention is that there is no control over the timing of the technology rollout. In the case of this research, the rollout of SWHs in the chosen study site was repeatedly delayed throughout the 3-year term of the study for a variety of reasons that were beyond the control of the researchers. The impact of the indefinite delays to the rollout was that a follow-up study could not be undertaken within a reasonable time-frame. At the time of writing, only one household had undergone a change from a traditional electric geyser to solar water heating system under the planned rollout, and hence it was not possible to determine the behavioural response by conducting a before versus after analysis on the houses being monitored. As such, the addendum only presents the "before" data. In addition to presenting the data, some insights generated from the literature search and from interaction with various stakeholders during the study period are presented.

42 households selected for the study were monitored for both geyser and overall electricity consumption. Of the 42 records, 25 were sufficiently comprehensive to be analysed. The consumption profiles generated serve to enhance the understanding of the contribution of hot water demand to total electricity demand in South African households, and assist in understanding of the potential of SWHs to contribute to reductions in electricity demand.

The main finding of the analysis is that, on average, 34.4% of household electricity consumption goes towards direct geyser usage. However, there appears to be significant intra-household variability when it comes to the proportion of electricity used for geysers. Given that hot water is also obtained through kettles, and heated internally in dishwashers, washing machines, and other appliances, this does not represent the average demand for electricity for hot water requirements, however does give a starting point for the calculation of potential electricity savings that can be achieved through the rollout of solar water heating in similar households. Profiles of the percentage of electricity attributable to geyser usage, and of geyser usage versus non-geyser usage, were also developed for weekend and weekday, summer and winter, together with an indication of variability between households. Variability of geyser electricity consumption in this sample tends to increase at the peaks, and seems to be the major contributor to the overall variability in total consumption, thus highlighting the importance of SWHs as a load shifting measure. Further qualitative findings are reported in view of the researchers' experiences during the course of the study with the various stakeholders such as municipalities, SWH suppliers, and exposure of SWH initiatives in the media and policy arena.

In the absence of any local data, the impact of rebound in water heating in the high income sector can thus only be estimated using assumed values for rebound based on previous studies, in conjunction with estimates of the contribution of water heating requirements to the overall electricity consumption of households. Given the current increase in the voluntary take-up of SWHs, as well as the various initiatives and mechanisms put in place by national, provincial and local government, future research should be carried out locally on the behavioural response to the rollouts to determine the extent to which (at worst) behaviour changes can erode the electricity savings potential, or (at best) contribute to reductions that are higher than the technical potential of the SWHs. Based on the findings of the main research report, it is recommended that such research be aimed at capturing both qualitative and quantitative attributes of the response. It is also recommended that the rollout policies are cognisant of the

need to have the appropriate pricing of SWHs and associated rebates, electricity tariffs and awareness measures in order to ensure that the substitution of electricity for solar is as effective as possible, and the full potential of the substitution of energy carrier for water heating can be obtained.

1. Introduction

1.1 Background

In recent years Demand Side Management (DSM[1]) has regained momentum as South Africa is once again faced with insufficient generation capacity to meet demand. DSM falls within the mandates of both NERSA and Eskom, with NERSA setting targets and allocating appropriate funds to Eskom to implement its DSM program. The DSM rollouts and the resulting savings are audited to determine their success.

During the electricity crisis of 2006 several DSM measures were pursued in the residential sector, such as installing geyser blankets, replacing incandescent lights with CFLs, replacing electric stoves with gas stoves, residential load management programs and the Power Alert initiative. In recent years, residential DSM initiatives have been extended to include a subsidy for SWHs and an awareness campaign through television, radio and other media. DSM targets are included in future build programs under the integrated resource plans (IRPs).

Following from the main report for this study (ERC, 2010), which analysed the rebound effect as it related to efficient lighting in all income groups and SWH in the low-income sector, the next steps identified in this research were:

- Completion (by December 2010) of the high-income solar water heater study in Nelson Mandela Bay.
- Stakeholder workshops to share the findings of this research, with the intention of working towards mitigating the rebound effect, and supporting development of policy options.
- Generation of research papers based on the contents of the main report.

This addendum covers the first of these bullets, while the second and third tasks are underway at the time of writing.

1.2 Rationale for the study

An “Energy Policy Discussion Document” produced by the South African government in 1995 estimates that electricity required for water heating in middle to upper income households makes up forty to fifty percent of total household electricity consumption (Meyer, 2000). South Africa has consistently demonstrated a commitment to pursuing solar water heating as an intervention towards reducing overall electricity demand in the country. These technologies (along with water heater timers) have a further potential benefit in load shifting (Koomey and Brown, 2002).

Many initiatives are in place to encourage the take up of SWHs in the residential sector, and in middle-to-high income households in particular. The primary example is the Eskom DSM program, but others include municipality-driven initiatives (e.g. City of Cape Town’s Saving Electricity Campaign (www.savingelectricity.org.za) and Nelson Mandela Bay (NMB) municipality’s pilot study funded by the Central Energy Fund (CEF)). The private sector has also come on board, with a marked increase in the number of solar water heating system suppliers and installers, many of whom have been accredited under the Eskom DSM rebate system (SESSA).

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[1] As of April 2011, Demand Side Management (DSM) has been renamed as Integrated Demand Management (IDM), however DSM is retained for the purposes of this report.

Given the high expectations of the potential for SWH to curb demand for electricity in the residential sector, it is important to understand the extent to which the technically achievable savings will be attained, as these will be determined to varying degrees by:

- Sub-optimal use of the systems by householders (see Hill et al, 2010) and;
- Potential rebound effects (as described in the main report (ERC, 2010)).

The research covered in this addendum was initiated to contribute to the understanding of the realistic potential of SWHs as a load management and ultimately as climate mitigation measure. A further intention of the research was to identify ways that the full potential of the SWH can be realised through awareness and pricing strategies that accompany the take-up of technology.

The pilot rollout in NMB Metro was chosen as the study site for this research project. The reason for choosing NMB was that it was the only rollout that was imminent at the time the research commenced, and the municipality were willing collaborators for the research. Having said that, only pre-rollout data could be collected as the SWH rollout had been repeatedly delayed.

1.3 Report outline

The layout of this document as follows. The next section gives a brief review of previous studies on water heating, with a focus on residential hot water profiling research in South Africa. The review also includes a brief summary of the potential size and sources of rebound in water heating as identified from international literature, as drawn from the main report. The third section covers the methodology used to collect and analyse the data, and includes a description of the data. A summary and analysis of the data is given in section 4, and section 5 concludes the addendum.

2. Background and literature review

A literature review was conducted to identify some of the relevant work which has been conducted relating to hot water usage and electricity, solar water heaters and the rebound effect. Given the limitations of the study in terms of obtaining post rollout data, the literature review serves largely to provide a resource base related to these topics for the reader's interest and edification, rather than guide the study itself or the interpretation of collected data.

2.1 Hot water usage and electricity consumption in South Africa

In South Africa, a number of studies have been conducted on profiling of hot water consumption. These include:

- Ljumba et al (2008) simulated graphs to illustrate the potential for SWH demand reduction for different SA regions.
- Gouws & Hager (2008) produce graphs of daily hot water demand (in terms of water volumes) and electricity graphs.
- Lane (2008) analysed the optimal economic allocation of water heating resources, based on a profile of water heating electricity from a sample dataset in Tshwane
- Heunis & Dekenah (2010) developed a load profile prediction model for residential consumers in South Africa that includes total electricity load profiles for different income groups.
- Meyer & Tshimankinda (1996, 1997) created profiles by month of the year and hour of the day for weekends and weekdays for shacks, with water volumes in developing, developed, and traditional homes in South Africa.

Some of the observations of these and other studies, as they relate to electricity consumption for hot water provision include:

- South Africa's Energy Policy Discussion document suggests an estimate of electricity for water heating at 40% to 50% of total electricity.
- Beute & Delport (2000) show that total hot water electricity load is 25% to 40% of total load. Their analysis also presents an after-diversity demand graph per municipality for hot water demand, considering variables such as outside temperature, average hot water cylinder inside temperature, element size, consumption patterns, etc.
- Meyer & Tshimankinda (1996,1997) found that consumption across the day ranged from 17% to 30% of the average. Data was presented as average daily consumption per person for different months of the year, differentiated by summer/winter and weekday/weekend.
- Meyer (2000) provides a number of insights about hot water in South Africa which are relevant to this current study. These include that:
    - On the whole, hot water consumption data is lacking and unreliable.
    - Hot water provision is the highest user of energy in households, with estimates varying from 40% to 50% of total electricity used.
    - Average daily per capita hot water consumption is between 50 litres in summer and 75 litres in winter for developed communities, and 35 litres for developing communities.

  - Hot water consumption increased by 70% from summer to winter (in Johannesburg, based on samples of size 30 in various housing densities).
  - Four time categories are recommended for analysing hot water consumption profiles: summer weekdays, summer weekends, winter weekdays and winter weekends. The differentiation between categories is recommended due to timing of peaks and consumption levels.
  - A 95% confidence interval for houses is within 17% of the average consumption in summer and within 30% of the average in winter. For apartments and townhouses the limits are 8%/23% summer/winter and 9%/14% summer/winter for apartments and townhouses respectively.
  - Corrections for ground water temperature can be made.
- Cawood and Morris (2002) summarise Eskom data and conclude that water heating consumes 45.9% of total electricity in suburban households, 30.2% in townships, and 18.0% in shacks. The one other main electricity consuming activity is cooking (15.1%, 33.2%, and 14.0% respectively).
- Marketing efforts of solar water heater suppliers advertise the much higher proportions of around 50% for geysers alone, but these figures ostensibly have an upward bias.

It is thus suggested that the data on household hot water requirements in South Africa is somewhat limited, and estimates of the proportion of a household's energy budget for hot water vary significantly between reports.

The methodology employed for the analysis in Section 4 of this current study is consistent with that of Meyer (2000) in that it separates summer weekdays, summer weekends, winter weekdays and winter weekends. It also computes summer and winter standard deviations, and hourly profiles per month. It is noted that in his analysis Meyer also incorporates ground water temperature differentials, per person water consumption and normalises data by dividing each hourly consumption / total daily consumption to get percentage of total daily consumption used per hour. These aspects are not considered in this study.

2.2 Solar Water Heating (SWH)

SWH presents an opportunity for reducing both overall and peak electricity demand and is suggested to have a significant role to play in this regard in South Africa. Previous studies estimate up to 50% penetration of SWHs among the urban rich by 2030 (Table 1).

Table 1: Penetration rates of geyser blankets and SWHs for 2030
Source: Winkler (2009)

Household	*SWH 2030*	*Geyser blankets 2030*
Urban rich (UH)	50%	20%
Urban poor (UL)	30%	20%
Rural rich (RH)	30%	20%
Rural poor (RL)	20%	20%

The study to which this addendum applies focuses on the rebound effect of energy efficiency interventions. Although SWH is not strictly an energy efficiency intervention, it is suggested that there is as much a need to consider behavioural response to fuel switching interventions as improved efficiency interventions, such as CFLs.

It is clear that the objectives of the entity responsible for the rollout will influence the nature of the consumer's response to the rollout. The aims of a SWH supplier, for example, will be to generate revenue from sales of SWHs; a municipality may wish to attract carbon financing through the Clean Development Mechanism (CDM); and national government has carbon emission mitigation targets which it aims to meet. The awareness about the technology, prevailing electricity prices, the level and quality of the advice given by installers, and the actual consumption patterns and climatic conditions and dwelling properties will also all influence the potential electricity (and GHG) savings.

2.2.1 Barriers to rollouts of SWHs

Despite various incentives offered by Eskom, and an increase in marketing by SWH suppliers and NGOs, the uptake of SWHs has been slower than expected. However, more recent indications in the media and among energy practitioners indicate an increase in the rate of uptake in the middle and high income sector. Various regulations are being explored at a government level to make solar water heating mandatory on new homes.

An analysis of the barriers to technology uptake provides an understanding of why targets of voluntary implementation campaigns do not adopt new technologies, continue to use old technology or replace solar water heaters with old technology when they break. Barriers to adoption include: aesthetics, maintenance cost (in time, money, and convenience), adaptability to current systems, limited distribution and marketing, poor consumer understanding, limited ability to monitor savings, and poor support systems for repairs (Anable et al, 2006). Guagnano et al (1995) argue that contextual barriers can encourage consumers to frame their values to support convenient behaviours and reject information about new technologies and even reject the technologies themselves.

There is to date no formal evidence of the level of satisfaction among new users of the technology, and the emergent response will most certainly have an impact on understanding the extent of rebound. Further qualitative studies would be of value in order to determine satisfaction levels, extent to which potential savings are achieved, and where households choose to spend the monthly savings on the energy bills (indirect rebound). Little has been published locally about the long-term viability and life cycle environmental impacts of large-scale uptake of SWHs, despite the emerging importance of considering such impacts.

2.2.2 Potential for Rebound in Solar Water Heating

As discussed in the main report (ERC, 2010) the rebound effect can classified in one of three ways: take-back (or direct rebound), indirect rebound, and reversion or substitution. Rebound can also have economy-wide implications and technology can be used sub-optimally. Particular considerations with respect to rebound as it relates to SWH include:

- **Take-back/direct rebound:** In the case of SWH, this would happen when householders increase their usage of hot water in the knowledge that it won’t cost them any more – i.e. by taking longer showers or using geyser water for cooking and laundry. Direct rebound is related to price and income elasticity.
- **Indirect rebound:** Consumers who perceive or notice a reduction in their electricity consumption after the installation of a SWH may spend that money on other electricity (or energy) consuming devices, or increase their usage of other devices.
- **Rebound through reversion:** Rebound through reversion back to electric geysers is less likely than the other types of rebound, given the high capital cost of a SWH, and the installation requirements. However the failure of a device may lead to a reversion to traditional geyser. Reversion may take place through having the back-up element permanently switched on after experiencing a shortage of hot water (this is a type of reversion but also fits under sub-optimal usage as per the following bullet).
- **Sub-optimal usage of the technology:** Examples of this may be a result of lack of knowledge of the optimal functionality, poor advice given to the householder by an installer, or sub-optimal installation at the outset.
- **Economy-wide rebound implications:** As households begin to have lower fuel costs through improved appliance efficiency, their energy budget is relaxed, making way for other energy consuming practices (indirect effects), but the improved efficiency (or

lower cost) at which an economy can fund its hot water requirements will mean that the economy consumes more energy overall as demand for other goods and services increase.

Table 2 summarises the estimates of rebound that have been obtained from a wide range of literature sources, including those for water heating and other interventions. The table comes from Greene and Greening's (1998) review of over 75 estimates of rebound in the literature, not only from water heating interventions. They restricted their study to examining the effects of fuel efficiency on a specific energy service rather than on fuel consumption. Duplicate results have been removed where identified.

Table 2: Detailed overview of rebound effect estimates from previous studies

EE intervention	*Notes*	*% Rebound*	*Ref*
Water Heating	Industrialised country (5 studies – limited methodology and inconclusive results)	10-40	Greening
Home Appliances	Industrialised country (2 studies - – limited methodology and inconclusive results))	0	Greening
Home Appliances	Based on lit review of other studies i.e. IEA 1998; Greening, Greene and Difiglio 2000.	Less than 10	Geller et al, 2005
Economy Wide		0.48	Oikonomou, 2008
Various residential		8-12	Dubin et al, 1986
Various residential	Empirically estimated direct rebound effects for UK policies	75% in early years due to energy poverty. 28% in 2005 and 23% in 2010	Barker, 2006
Commercial and residential in 2020	Direct and micro-economic estimated	44.3	Barker, 2009
Residential various	Australia	20- 30 increase in consumption	Polimeni et al 2008
Residential	Sweden (based on carbon emissions)	20% efficiency leads to 5% more carbon emissions	
UK residential	total RE, i.e. (assumed) direct rebound plus (projected) indirect rebound	33 in 2005, 30 in 2010	Barker, 2006
Electrical appliances	Based on actual measurements on various electrical appliances. Original ref hard to locate	0 - 40	Grotton, 2001
Water heating	US Residential	0	Nadel, 1993
Macro-economic rebound	UK averaged across all sectors	11	Herring, 2006
Direct rebound	UK averaged across all sectors	15	Herring, 2006

Macro-economic rebound effects are identified to be insignificant in developed countries but significant in developing countries. It is clear from the above table that rebound with regards to water heating can be significant, and should therefore not be ignored in energy systems planning work.

3. Study Methodology

A rollout of 500 high pressure SWHs was planned for Nelson Mandela Bay in 2006, with the intention of serving as a comprehensive pre-feasibility study for large-scale rollouts of SWHs in middle and high-income areas. CEF, the project funders, and NMB municipality agreed to share the comprehensive data they were collecting as part of that rollout with this current study's project team. The monitoring activities planned for the rollout, initially for a sample of 50 houses, included baseline and follow-up monitoring of water consumption, measurements of electrical usage of geysers, and overall household electricity usage at 10-minute intervals over an extended period of time, so that seasonality and natural variation can be accounted for. In addition to the water and electrical consumption data, survey interviews were planned by the ERC, so that the analysis could parallel the other two studies described in the main report.

At the time of writing the physical rollout had not taken place, and since the dates of the rollout could not be confirmed, it was not possible to either gather post-implementation data or conduct the survey. This report therefore focuses on pre-rollout data supplied by the municipality.

3.1 Description of collected data

The data collected in this study was that for the total and hot water electricity in kilowatt-hours (kWh) consumed every ten minutes from 1 July 2008 to 30 June 2010 for 42 of the 50 households identified previously (NMB Municipality, 2010). Of this data set, 25 households were chosen for further data analysis. The others were eliminated from the dataset for a variety of reasons:

- Missing data for either total electricity or electricity for water heating
- More than half the observations were missing (excluded to prevent bias towards certain times of the year)
- Average of zero for total or water electricity (i.e. readings came through, but as zeros)
- Data where the summed electricity for water was higher than total (likely due to a working geyser meter and broken total meter)
- Data for the one household where a solar water heater was installed in August 2009 was excluded

A Visual Basic program was used to aggregate the ten-minute intervals for each household to half-hour measurements. The resultant data set consisted of half-hourly consumption for both total and geyser usage. In the following section's analysis, gaps in half-hour measurements are excluded individually.

Profiles were created for total electricity consumption, electricity consumption for geysers, and non-geyser electricity consumption by calculating the difference between total electricity consumption and geyser consumption. Observations of the profiles for days of the week justified an aggregation into weekdays and weekends. A similar process was used to create half-hourly profiles for each month of the year. Separating profiles by weekday and weekend and by seasons of the year are the most commonly used methods seen in previous studies (Meyer 2000, Meyer & Tshimankinda 1997, Vine et al, 1986).

In addition to the quantitative metered data, the research team gathered informal qualitative information including the experience of various stakeholders over the course of the study. These insights are reported in the concluding section of this report.

4. Results and discussion of the analyses

This section presents the analysis of the metered data described in section 3, and is divided into three sections. Firstly, the relationship between geyser consumption and total consumption is analysed. The second section discusses the hourly profiles, and the third looks at variability in data.

4.1 Relationship between total electricity and geyser electricity

For the 25 households, the average electricity consumption was 743 kWh/month (standard deviation = 218 kWh/month), and average geyser electricity consumption was 259 kWh/month (standard deviation = 78kWh/month).

On average, electricity use for water heating represents 34.42% of total electricity, where electricity use is averaged across all households and half-hours of the entire year. This is lower than the value estimated by both the South African Department of Mineral and Energy Affairs and Eskom.

A scatter plot with electricity for water on the x-axis and total electricity on the y-axis was created to explore the correlation between these two parameters (Figure 1). A line of linear regression and associated coefficient of determination were also computed, as shown in the Figure.

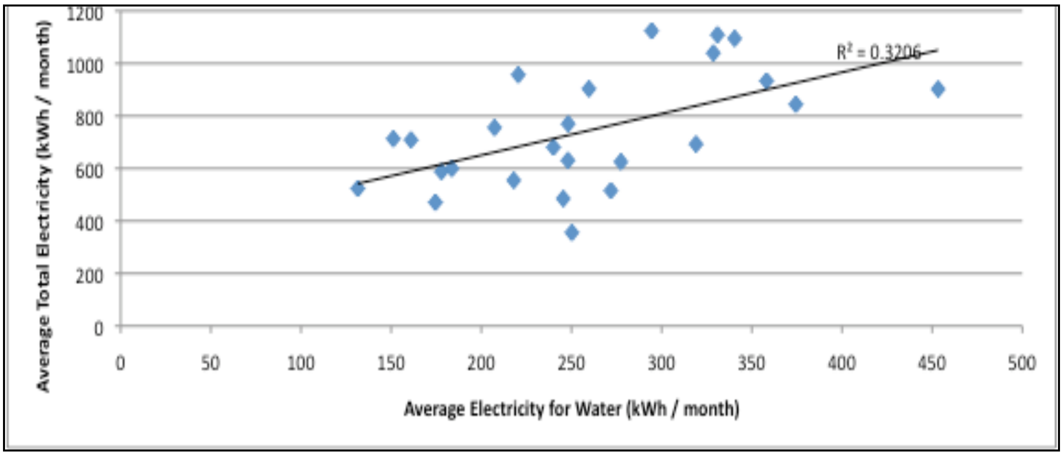

Figure 1. Scatter plot of total electricity consumption and geyser electricity consumption

The coefficient of determination of 0.3206 suggests that 32% of the variation in average total electricity consumed is explained by the average electricity consumed by geysers.

Although the strength of the linear relationship shown in Figure 1 is weaker than expected, the scatter plot and regression line show that the variabilities of electricity consumption for geysers and total electricity are connected, and indeed much of the variability in total electricity consumption can be attributed to variability in the usage of geysers. This is supported by the profiles in figure 2 that show similar shapes for total electricity and water heating. The presence of variability in Figure 1 is an indication that the potential for savings from solar water heating substitution, and by deduction any rebound effects, will also be highly variable.

Figure 2 illustrates that consumption of non-geyser electricity is relatively flat over the year, averaging around 500kWh/month for this region. The flatness can be attributed to the likely absence of space heating by electrical appliances in winter months in this region of South Africa. On the other hand, the geyser usage peaks in the winter month of July, indicating an increase in water heating requirements, and revealing that the presence of SWHs would almost certainly flatten the overall consumption of electricity over the year

No data was available to account for the effects of input groundwater and the electricity rating of the geysers in each household. It is also not known whether any of the households had more than one geyser, and how the presence of the additional geyser would have been accounted for in the data.

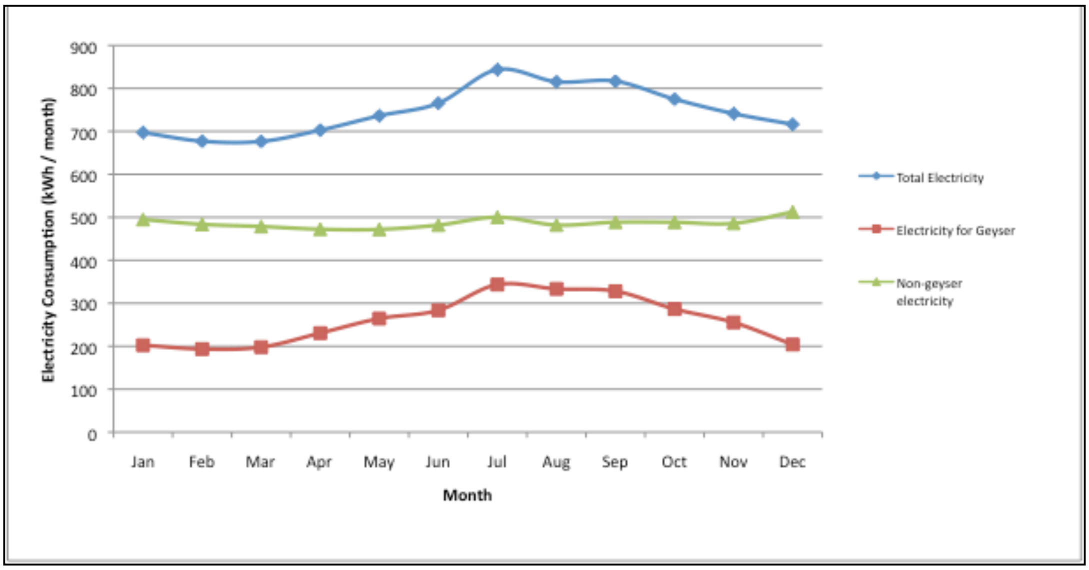

Figure 2. Profile of monthly electricity consumption figures

4.2 Hourly profiles

Figure 3 to Figure 6 show hourly consumption profiles. There appear to be double peaks in both the morning and evening, with one of each dual peak being higher than the other (see Figures 3 and 4). The higher peak precedes the smaller in the morning and follows the smaller in the evening. Both the morning peaks in total energy usage are matched by peaks in electricity for water heating.

Non-zero values late at night and in the early morning may indicate system leaks as suggested by Vine et al (1986), who conducted a study of hot water consumption in San Francisco. However, this may also simply be a result of variability across the data set.

A comparison of Figures 3 and 4 shows that electricity required for geysers is almost as much as that required for other purposes, particularly during the winter months. The consumption peaks tend to last for longer in winter than in summers as evidenced by the wider peaks.

Figures 5 and 6 show that the double-headed morning and evening peaks tend to become single-headed on weekends, as expected from typical household behaviour patterns over the weekends where there is a less of a need for hot water in mornings and evenings than during the week. Differences between weekday and weekend days are most likely attributable to different schedules and activities on these days. Higher variability in weekend profiles suggests a higher variability in weekend activities across the sample.

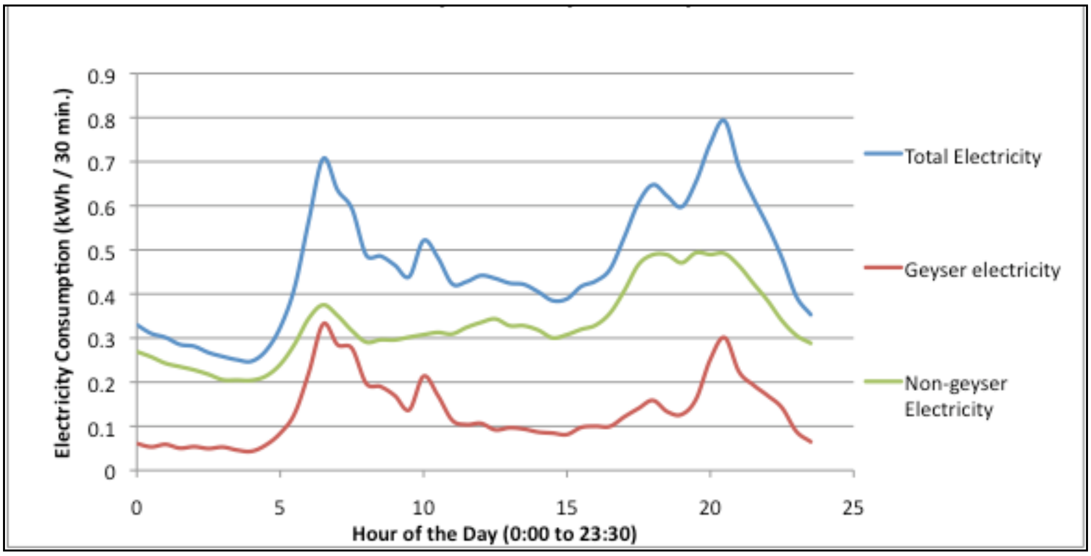

Figure 3. Hourly consumption profile for a typical summer's day (February).

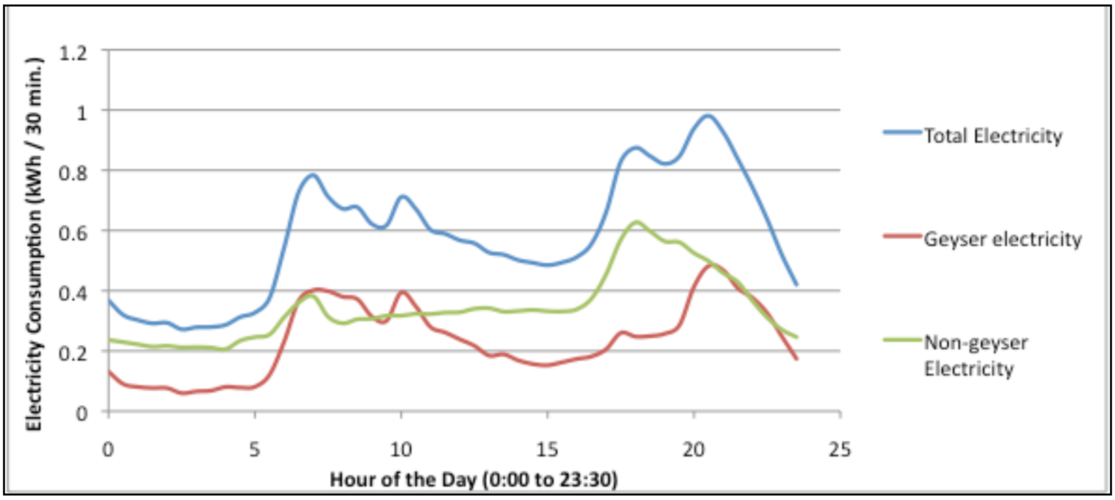

Figure 4. Hourly consumption profile for a typical winter's day (July).

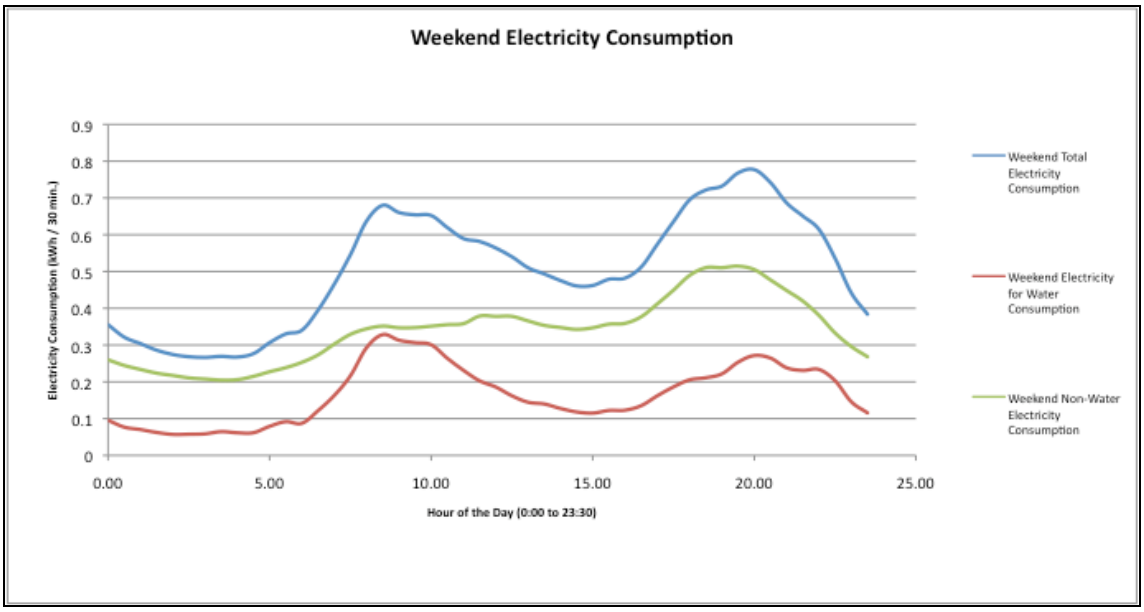

Figure 5. Hourly consumption profile for a typical weekend day.

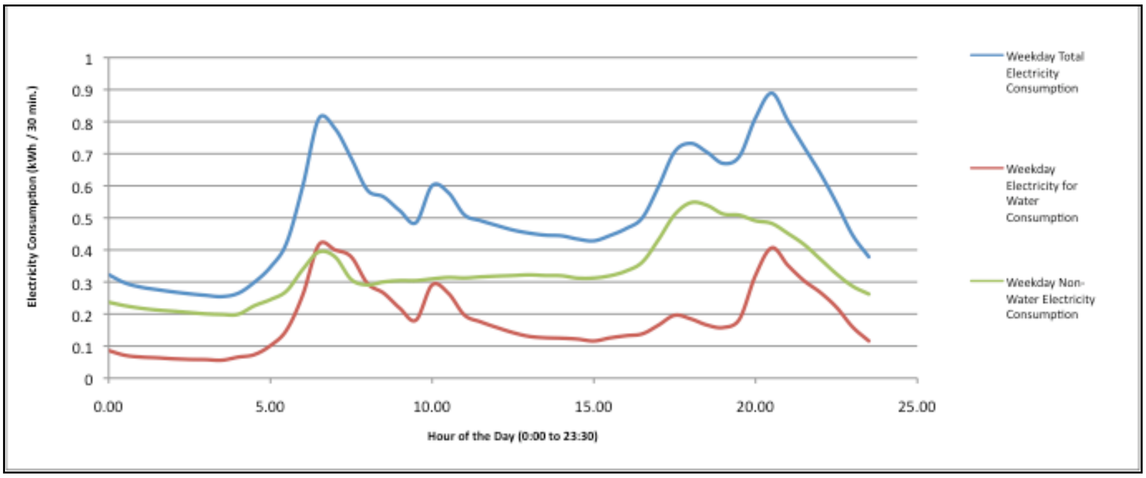

Figure 6. Average consumption profile for a weekday.

4.3 Variability by hour of the day

Variation in data by hour of the day was observed by computing the standard deviations of half-hourly consumption for the average weekday and weekend profiles. An upper and lower bound were created on the profiles that represent two standard deviations from the mean, and separate curves graphed to represent 95% confidence bands. It should be noted that these profiles aggregate inter and intra-household variability into a total. Further analysis is required to separate the variability into inter and intra household variability, but this was only examined for inter household variability in the histograms below (Figures 11 and 12).

It is evident from Figures 7 to 10 that profiles for non-water heating electricity do not follow total electricity profiles as closely as water heating electricity does, and has smaller variations over the course of the day. This suggests that eliminating electricity demand for water heating through solar water heaters or similar technology would not only reduce overall demand, but would reduce variability in overall demand. This also suggests that non-water variability is a result of ongoing energy service requirements that remain relatively constant throughout the course of the peak (lighting, heating, appliances constantly plugged in) and peak when residents are home and using appliances more heavily (for example at meal-times, watching television, etc.).

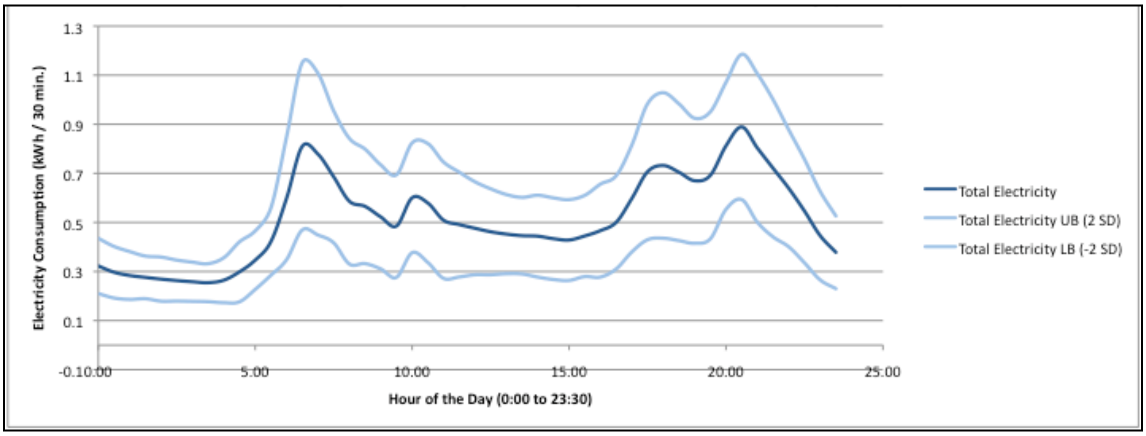

Figure 7. Weekday total electricity consumption profile with variability.

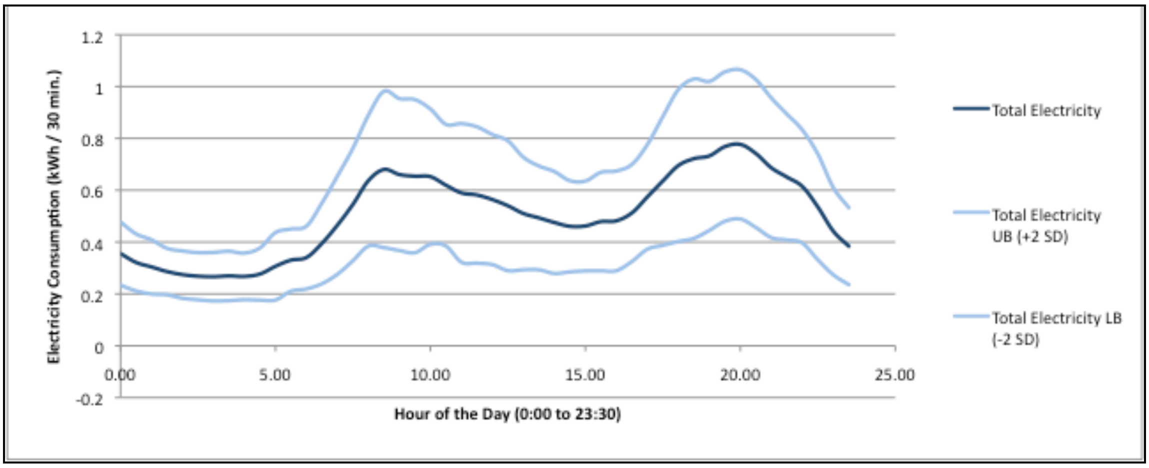

Figure 8. Weekend total electricity consumption profile with variability.

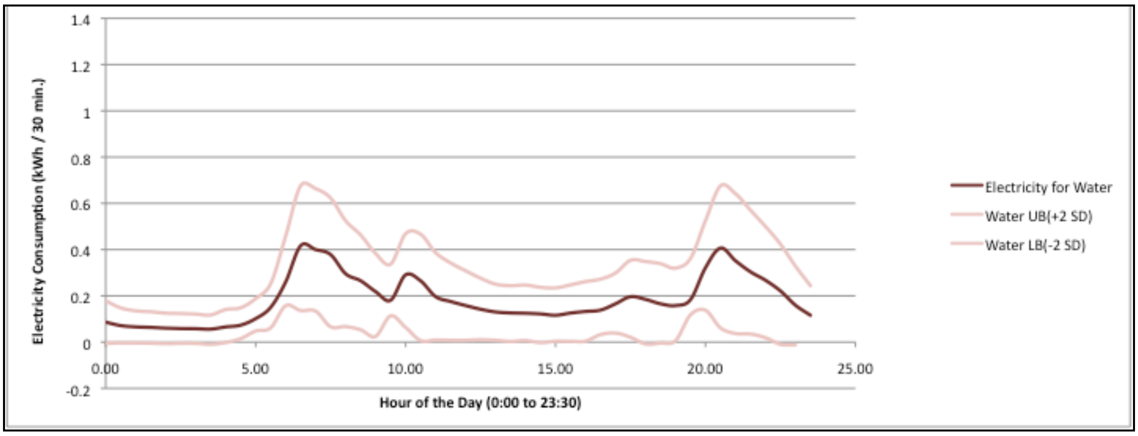

Figure 9. Weekday geyser electricity consumption profile with variability

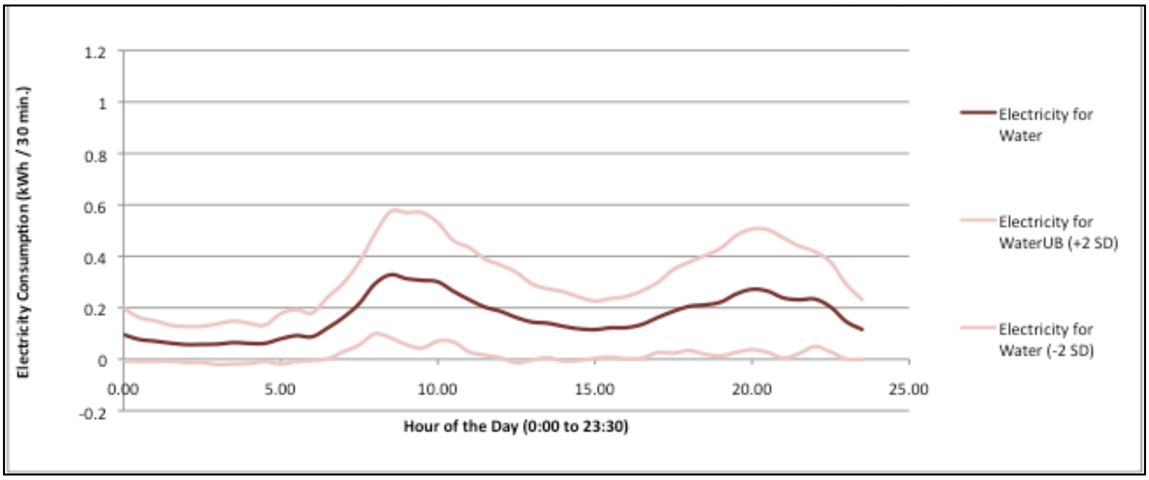

Figure 10. Weekend geyser electricity consumption profile with variability.

Variation across households was analysed with histograms for average monthly total electricity (Figure 11) and average monthly electricity for geysers (Figure 12). Average monthly consumption was computed by scaling up average half-hourly consumption. The bins have been chosen to best illustrate the underlying ranges of average consumption values. From both graphs it is evident that the distribution is “heavy-tailed” with low frequencies in the lower ranges and higher frequencies above the modal category. Modal categories are 511-653kWh for total consumption and 197-260kWh for geyser consumption.

The wide distribution is indicative of the high variation between households as shown in Figure 1, and can be explained by variability in household characteristics such as house size, number of residents, etc. Information on the characteristics of households and the behavioural characteristics would help explain the histograms, however such details were not collected for this study.

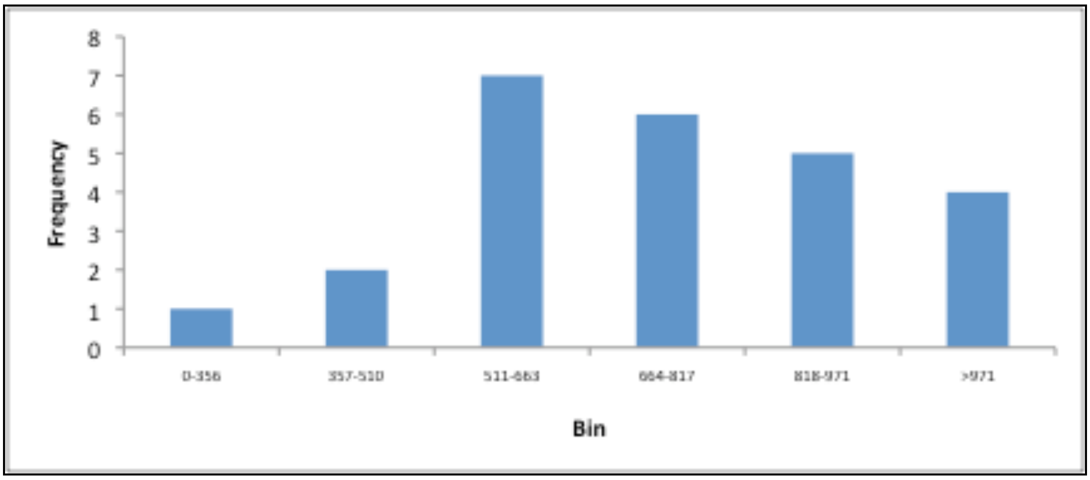

Figure 11. Histogram showing the distribution of total average monthly electricity usage.

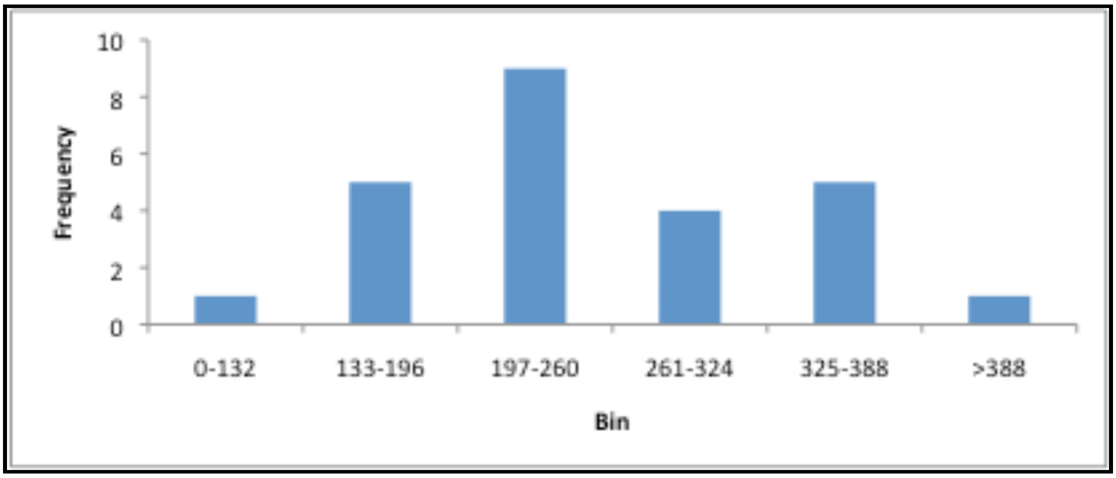

Figure 12. Histogram showing the distribution of total average monthly geyser usage.

5. Conclusions and recommendations

This chapter concludes the report by summarising the achievements of the study, and presents some recommendations for policy and planning in the area of SWH. It then covers the impacts of SWH rollouts, and discusses where future work in this area resides.

5.1 Study outcomes and implications

This addendum has presented a paired dataset of the electricity consumed for hot water and total electricity consumption for a usable cohort of 25 households. Despite the small sample size, it is suggested that a large enough history of data was collected for those households to generate some interesting and useful insights.

The fact that 34.4% of electricity usage can be attributed to geysers indicates that expected savings in electricity that can be achieved are a proportion of those savings, depending on the type of SWH installed, and the behavioural characteristics of the households. It is also apparent that the inter and intra-household variability in electricity and hot water demand is significant and variations take place over the year, and even between weekdays and weekends. It follows that installers/suppliers should indicate that the expected savings (and thus pay-back periods) of SWHs are highly variable, dependent on how well efficiently device is used (for example the programming of electrical backups), and that changes in usage patterns can influence actual savings. DSM programs would be advised to give ranges of expected savings for a typical household size rather than expected savings, and policy and planning ought to pay attention to the high variability. Although the data was applied to a sample from a particular region, and little was known about the number of people in each house, the patterns are likely to be repeated in other areas, notwithstanding climatic differences.

Indirectly, further insights about the behavioural response to SWHs were generated through the work presented in the main report, and to a larger degree through a combination of the engagement with stakeholders, media resources during the research project, and anecdotal evidence. Although there are technical guidelines for installation (for example, those required by Eskom prior to the payment of rebates), the actual information passed on to the purchaser of the technology does not consider the likelihood of reversion or potential to run continuous electrical backups, nor the additional savings that can be achieved through smart usage and behavioural shifts when it comes to SWH usage. In general, the absence of associated awareness and training appears to be a much neglected area of implementation of energy efficiency and DSM, and the over-reliance on technology to achieve the savings is both unrealistic and a missed opportunity.

The implementation and the behavioural response associated with the rollout of SWHs are likely to have a significant known effect on the actual electricity savings achieved (as evidenced throughout the literature on the subject), these are rarely acknowledged, nor factored in to policy and planning work. To a certain degree, technical implementation standards are enforced through the rebate scheme, but these appear to be loosely applied when it comes to transfer of information to the users.

The obvious failure of the study to conduct a thorough before and after comparison of electricity usage is indicative of the fact that the approach to studying behavioural response is unlikely to succeed unless much larger time frames for the study are allocated, and greater certainty of rollout dates can be achieved. Although attempts were made to collaborate with SWH suppliers in this regard, it was not in their immediate interest to collaborate with researchers. It is therefore suggested that future work should use the approach of collecting retrospective billing data for households that have already received solar water heaters, and that qualitative information about the households be collected alongside the billing data (or metered data where possible).

Such qualitative data should include:

- Demographics of the household before and after the installation
- Attitudes and values
- Narrative accounts of the experience with the appliance
- Perceptions about the performance of the technology

In conclusion, some of the positive and negative aspects of the rollout of SWHs are shown in the following table, and these factors should be considered in the formulation of policy and installation standards.

Table 3: Advantages and disadvantages of SWH rollouts

Advantages	*Disadvantages*
Potentially substantial electricity savings (up to 35% on average depending on household size, usage, weather, and type of solar water heater)	Large capital outlay and uncertain payback period. Not always appropriate given the orientation of the roof and the location of the roof (under trees etc)
Can serve to reduce peak demand	Conversion from electric geysers only possible for homeowners. Flats and apartments require the approval and cooperation of the body corporate
SWH tend to give the user more control over when the water is needed and the required temperature since a control panel is supplied for the electrical backup.	Users are not always correctly informed about how to maximise potential savings in electricity (including behavioural impacts) and may be disappointed if purchased with high expectations.
Growing number of accredited suppliers to select from, and a range of systems to choose from	Renewable energy appliances are perceived to be a “grudge” purchase
Incentives and rebates offered through Eskom DSM	Users are not fully enabled to get the most out of the technology and are not provided with adequate information and advice. Rollout programs have been much slower than anticipated despite the many incentives.
Improved energy autonomy for households as a result of decreased reliance on grid electricity for hot water.	Long-term sustainability and recycling of SWH components have not been fully considered / communicated
Burgeoning market and range of suppliers and technologies is on the increase	The number of different suppliers and the range of available systems can make the choice of which supplier to use difficult for potential buyers.
Jobs can be created through the growth in the demand for SWHs in the form of production, installation and energy adviser roles.	Local manufacturing capacity is not well-established and most of the technology is currently imported

5.2 Recommendations for future research

The opportunities for further research were outlined in the main report. In summary, for the study of the rebound effects arising from large-scale SWH rollouts, the following areas are worth exploring:

- Combined multi-disciplinary approaches for studying behavioural response
- Researching householders’ experiences of current users of solar water heaters and understanding how they interact with the technology, and their perceptions of SWHs, how these vary according to demographics, region, levels of awareness, and values.
- Investigating the long-term performance sustainability of SWH initiatives, potentials for use as under floor heating, and comparison with newer technologies.

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