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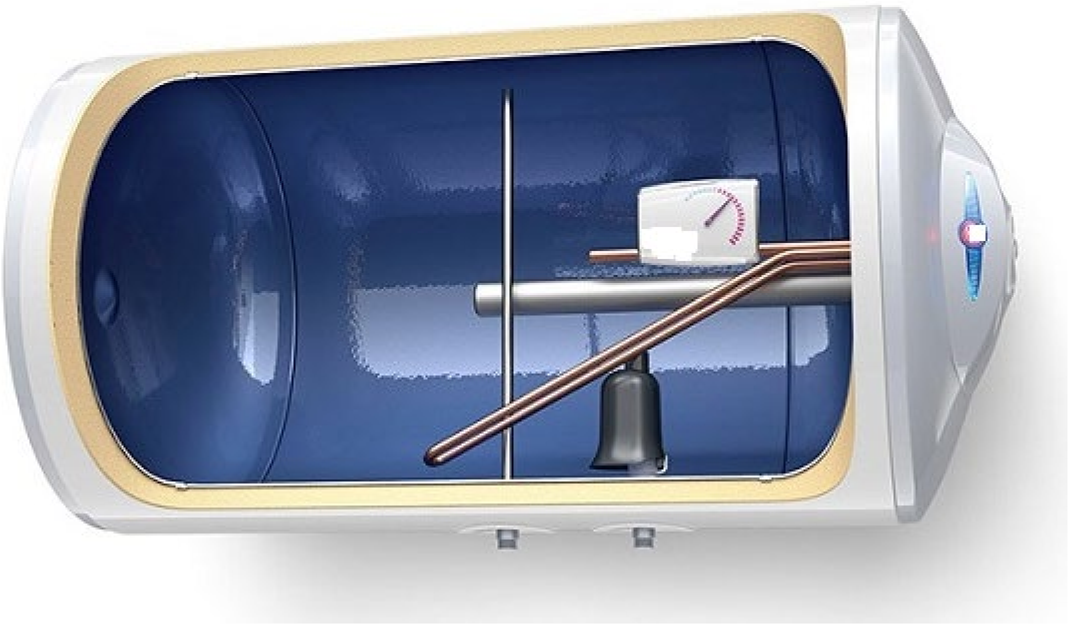

Residential Water Heating Demand Side Management (DSM) - South Africa

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ABSTRACT

The electricity crisis in South Africa has deteriorated significantly, with the country experiencing frequent and prolonged rolling blackouts. These outages have severe economic repercussions, leading to decreased growth and productivity. Demand Side Management (DSM), particularly focusing on electric water heaters due to their significant energy consumption and peak demand contribution, is identified as a key strategy. The study aims to assess opportunities for DSM programmes targeting water heating to reduce energy consumption and peak demand. It entails developing a bottom-up simulation model to establish a baseline scenario of water heating electricity load demand in 2023 and 2033, identifying technologies for energy reduction, estimating the impacts of a selected number of measures and providing recommendations to inform policy makers.

The baseline assessment found that the maximum demand was 6,643 MW in 2023 during winter season and will increase to 7,478 MW in 2033, which is almost an increase of one stage of load shedding (1,000 MW). Therefore, this suggests that if no intervention is implemented in the short term, there will be more detrimental issues on the grid in the next 10 years than currently experienced in 2023.

Among the ten technologies described, five measures were selected to be simulated to assess their impacts one energy and demand reduction. The study found that all interventions demonstrate a reduction in overall demand. However, the interventions that have a large impact on reducing demand during peak times have the consequence of high restorative loading effects, except **indirect water heating load reduction through rooftop PV augmented with external switch**. This intervention also shows the highest energy savings from the grid but at the trade-off of some level of user comfort. **Insulation of Pipes** shows a uniform reduction of demand for all 24 hours in a day and energy reduction of 1.1TWh in 2033 with no discomfort impact to consumers. **Reducing the heating element rating** has the potential to passively reduce morning and evening peaks and elongate the peak period resulting in a small increase in energy consumption of 0.2TWh. **Controlled Switching** shows a slight reduction in demand during the switching period with a slightly elevated demand after the switching period. Interestingly, energy is reduced in this scenario by 0.1TWh. **Time of use electricity tariffs** show a significant peak demand reduction with the consequence of a high restorative load when elements are turned back on. Results show significant energy savings of 1.1TWh due to the shifted load in the morning peak, where the PV systems are absorbing a portion of the restorative load from 10am onward as PV systems are forecasted to increase 30% penetration by 2030 in the baseline scenario.

In light of these results, it is clear that no silver bullet exist but that a comprehensive policy package is necessary, combining various strategies, regulations, incentives, and enforcement mechanisms to optimize load management and reduce energy consumption.

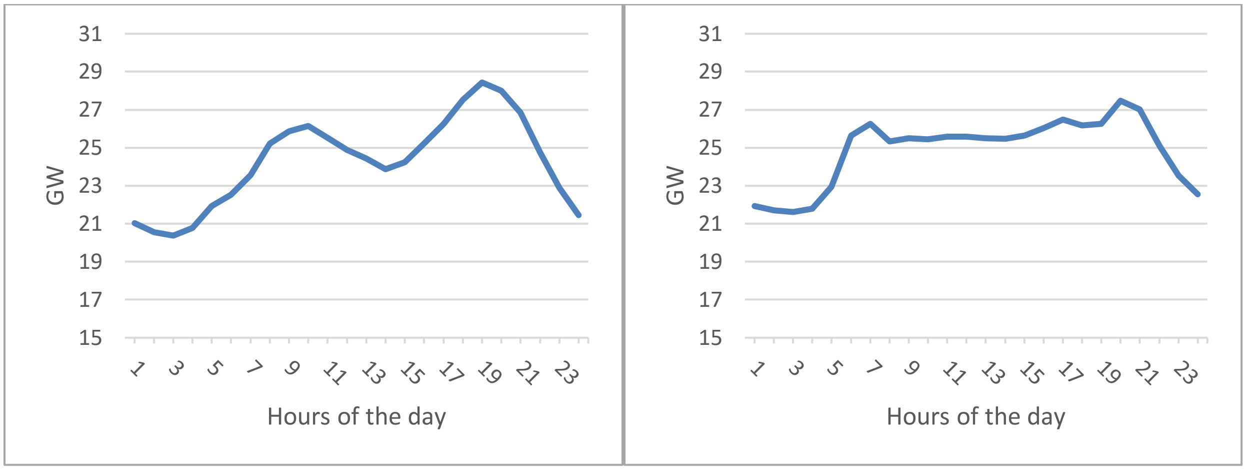
1. INTRODUCTION

South Africa's electricity crisis deteriorated significantly in 2022, with rolling blackouts surpassing 200 days. The frequency and severity of load shedding, consisting of deliberate shutdown of electric power in a part or parts of the power-distribution system to protect the overall system, escalated even further in 2023, with records showing that the country has experienced 4 149 hours, or 173 days, in the first seven months of the year (up to 17 July). Electricity outages have a severe economic impact on the economy, affecting business revenue, productivity, and customer satisfaction. The South African Reserve Bank (SARB) estimates that load-shedding has reduced economic growth in 2023 by approximately 1.8 percentage points (SARB, 2023). The national utility, Eskom, has warned that government procurement of additional generation capacity will not ease energy shortages before 2025.

Demand Side Management (DSM) can play an important role in alleviating the supply deficit. In July 2022, President Ramaphosa established the National Energy Crisis Committee (NECOM) to oversee the implementation of an Energy Action Plan to end load shedding and achieve energy security (SA Gov, 2022). DSM is one of the workstreams of the plan and the recently appointed Minister of Electricity, Kgosientsho Ramokgopa, reiterated the need to look at DSM solutions to ease the pressure on the national grid (IOL, 2023).

In South Africa, electric water heaters represent a major draw of power, especially during peak demand and during winter months. Figure 1 shows South Africa's load demand profiles for the whole system during a typical day in Winter and in Summer (Eskom, 2024). As it can be observed, there is a peak demand in the morning and in the evening, which coincide with increase demand for the residential sector (UCT, 2024), which has been estimated to account for about 35% of total peak demand (Eskom, 2012) and (Jacobs, 2023). Water heating alone represented 33% of total residential electricity consumption (LBNL, 2020) with a range of 6% for low income households to 54% in high-income households (UCT, 2024). Research also found that geysers have a high peak capacity coincidence, meaning that they are large contributors to peak demand (UCT, 2024). Residential electricity consumption also has the fastest growth among sectors and increased from 17% in 2011 to 19% in 2021, in part due to population growth, ongoing urbanization, economic development and the national government's target of achieving universal electrification.

Figure 1: 2022 Eskom Contracted Demand in a Typical Day in Winter (left) and in Summer (right)



Source: Eskom, 2024

Due to its significant contribution to peak demand and electricity consumption, water heating represents a prime opportunity to mitigate load shedding. However, South Africa is a very diverse country with the implication that the generation of hot water is not homogenous. Factors influencing the potential electricity savings from geysers includes:

- Inequality: Access to and usage of water heating differ significantly across income levels
- Climate: South Africa has three different climatic zones where usage is different
- Installation: Historical installations have not prioritized insulation, resulting in high standing losses. In addition, water heaters can be installed in vertical or horizontal orientations, resulting in different electrical draw patterns for the same hot water use.
- Load shedding: After high levels of power outages, water heating needs become less distributed as more water heaters activate at the same time, increasing sudden peak demand

Given these factors, it is evident that a single solution cannot reach all residential hot water users. It is likely that a multi-pronged approach should be considered to reach a greater number of consumers and make clean water heating more accessible to all.

The goal of this study is to assess the opportunities for developing a DSM programme to reduce energy and peak demand for water heating. The study identifies technologies and measures that reduce electricity consumption and peak demand through a combination of permanent load reduction (energy efficiency) and load shifting (demand response).

The next section describes the water heating market in South Africa and its specificities like water tank horizontal installation. The following section describes the methodology used to develop a bottom-up simulation model and establishes a baseline scenario of water heating electricity and peak demand in 2023 and in 2033. Section 4 identifies technologies that help reduce energy demand and prioritizes them according to a set of criteria determined with stakeholder consultation. Once a set of technologies is prioritized, Section 5 assesses the energy and demand reduction of five measures to reduce energy consumption and peak demand. Finally, Section 6 discusses the results and provides recommendations to inform government of the most viable solutions in its policy decision making, considering regulations and investment strategies for DSM programme implementation within cities or at a national level.

2. SOUTH AFRICA'S GEYSER MARKET

South Africa’s geyser market is mature and controlled by a small number of well-established local manufacturing companies. The vast majority of middle- and upper-income households use the same technology, which is a 150-liter (l) tank with a 3 kW resistant element to heat the water. As the technology is straightforward, products are largely homogenous and manufacturers compete on price, guarantees, distribution and support. Market volumes are stable and predictable from year to year but can increase by as much as 20% during construction booms (Covary, 2015).

2.1 INSTALLATION PRACTICES AND MARKET PLAYERS

Gravity fed geysers dominated the market up until the 1950’s. In the 1960s, 100 kilopascals (kPa) copper geysers entered the market, followed by 400 kPa steel geysers in the 1980s. The steel geysers were transformed to 600 kPa in the 1990s, which became and remain the market standard. Fibreglass and plastic geysers were also introduced in the 1990s, but these make up a very small percentage of the market. The use of gravity-fed geysers required that they be placed at the highest point in a house. This meant that all residential geysers were installed in the space between the ceiling of the top floor and the roof, otherwise known as the attic. With the introduction of pressurised geysers, it was no longer necessary for geysers to be installed in the attic, but the practise was entrenched and architects continued to design and specify that geysers be installed in the attic, seemingly to keep them out of sight and place them closer to service points, such as above bathrooms and kitchens. All bathrooms must have access to an exterior wall due to effluent plumbing requirements. Geysers which have minimum dimensions of 1.1meter (m) x 0.6m were often not able to fit vertically in this limited space due to the pitch of the roof, and as a result the practise developed of installing geysers in a horizontal rather than vertical position.

These unique practises as well as other factors such as the quality of the water in different geographical areas with some regions having particularly hard water (high content of calcium and magnesium), the relatively straightforward technology, and the high costs to import means that almost all geysers in South Africa are locally manufactured. The country's oldest manufacturer (Kwikot) with the biggest market share was established in 1903 and purchased by Electrolux in 2017. Around the same time period, the Italian multinational Ariston acquired the country's second biggest manufacturer, whilst two smaller companies closed down, leading to changes in the market structure. Kwikot remains the biggest supplier, but Ariston has increased its market share. Collectively these two companies control 85% of the market. A few high-end products are imported, such as gas-fired water storage heaters. These historically niche products are growing in popularity as consumers seek to diversify their supply away from electricity due to the energy crisis and increasing tariffs. Discussions with various market players pointed to a shift in installation practises for newly constructed homes in the last decade. As consumers move to smaller, multi-unit housing (townhouses, flats, estates), which must also comply with the building code SANS10400-XA2, developers are installing geysers under staircases, in the kitchen or in laundry rooms. This is to eliminate water pipes running through multiple storeys and improving access to the geyser. These geysers are installed in a vertical position (Covary, 2015).

Because geysers are stored in the attic, households have little to no contact with the unit on a day-to-day basis. A peculiarity of the South African market is that it is a legal requirement for all houses that are financed (bonded) to take out building insurance which covers geysers. Thus, when a geyser fails, households contact their insurance company and not a plumbing service to replace it. The insurers have agreements with plumbing companies to remove and install a new unit and the service is seamless and often on the same day if the claim is approved early enough. Other than reporting the incident and granting access, the household has little involvement in the process. The balance of sales is made up of sales to newly built houses or renovations, where once again the homeowner is unlikely to be involved. Thus, the decision makers have no incentive to install a more efficient model, which can be more expensive. Their only obligation is that the unit they install is certified and meets the mandatory health, safety and energy requirements as set out by the South African Bureau of Standards.

2.2 CURRENT REGULATION

Electric resistance storage geysers are most common in South African households, with solar water heaters gaining in popularity due to government support.

An electric water storage heater is a relatively straight forward appliance. An electric element is fitted into a steel storage tank which heats up water. As the household draws water from the tank it is replaced with cold water and the element, via the thermostat, is activated to heat the water to the set temperature. The steel tank is covered by a steel jacket. The area between the tank and the jacket is filled with insulation material to reduce standing losses due to convective and radiative heat loss from the jacket. The thermostat which controls the water temperature has various set points which are typically 55, 60, 65 and 70° Celsius. Some geysers have a continuous dial. However, these thermostats have been found to have high levels of variance (inaccuracy) due to the generous allowance under SANS181, which states that the temperature differential should be >3°C and <10°C. It has also been confirmed that common practise is for units to leave the factory with the thermostat set on the maximum set point (70° C). The transfer of electrical heat from the element to the water is efficient and almost no opportunities exist to improve this performance under the current design. The only opportunity for energy savings is to improve the design or configuration of the unit to reduce the heat losses occurring during storage. There are two types of losses: the first are standing losses which are controlled by the insulation efficiency (thickness of the insulation); the second are the continual 'bypass' losses which occur through the fittings, structural supports, and from heat conduction out through the attached pipes.

All electric geysers in South Africa must comply with the South African National Standard (SANS) 151:2022 Edition 8.03 Fixed Electric Water Storage Heaters. This is a South African standard and it is not linked directly to the International Electrotechnical Commission (IEC) or any other Standards. Under the SANS 151 there is a requirement that all units meet or not exceed a minimum standing loss over a 24-hour period. This is the minimum energy performance standard (MEPS) for geysers since the 1970s. In 2016, the MEPS was revised with VC9006 (legislation) to a level B. This meant that the maximum allowable 24-hour standing losses for a 150l geyser may not exceed 1.40 kWh (previously this was 2.59 kWh). This has had the effect of saving 3.8 TWh of electricity by 2030 (McNeil et al, 2015).

South Africa introduced a mandatory building code in 2011 (SANS 10400 XA), which requires that at least 50% of the annual average hot water requirement of all new buildings be provided by means other than electrical resistance heating including but not limited to solar heating, heat pumps, heat recovery from other systems or processes and renewable combustible fuel.

2.3 MARKET CHARACTERISTICS

Electric geysers dominate the household water heating market in South Africa. However, low-income households often use other sources of energy to heat water, such as coal, wood, or electric stoves. Similarly, some middle- and high-income households have installed solar water heaters (SWH) and heat pumps in recent years but these volumes remain small despite the government rebate programme. Geyser sizes increase in 50L increments, except for a few specialised units, and start at 50L and go up to 300L. The most common unit size and which dominates the market is 150L. Table 1 provides the market share of sales of geysers per size according to volume and heating elements.

Table 1: Market Share of Geyser per volume and heating element

Size (litres)	Element (kW)	Share (%)
200	4	15
150	3	75
100	2	8
50	2	2

Source: Industry interviews (2023)

As with most appliances, sales of electric geysers follow economic cycles and increase during construction-based expansion. Annual sales figures are not readily available as the industry does not disclose data. The market is split into two categories: the replacement market and new builds, with the former responsible for 60% of sales and the latter the other 40%. However, during building booms, experienced in South Africa in the period 2004-2008, the new build market increased its share and accounted for as much as half of annual sales. Meetings held with the various manufacturers and insurance companies during this study have confirmed that annual sales of electric geysers vary between 400-550k (2015) units per annum depending on the economy, with 450k being the mean. Sales were in the upper band in 2022 at 550k units per annum. This number includes SWH with electrical back-up (estimated at between 30 to 40k units per annum) but excludes the low pressure non-electric solar units. SWH sales have been driven by the introduction of SANS10400-XA (updated in 2021 to Edition 2 or XA2) which requires that 50% of hot water be sourced from non-electrical supply for all new homes and renovations (SABS, 2021). The annual sales of other water heaters to meet the building requirement (heat pump, gas and other technologies) is not known, but based on feedback from the industry interviews is estimated to collectively be similar to that of SWH.

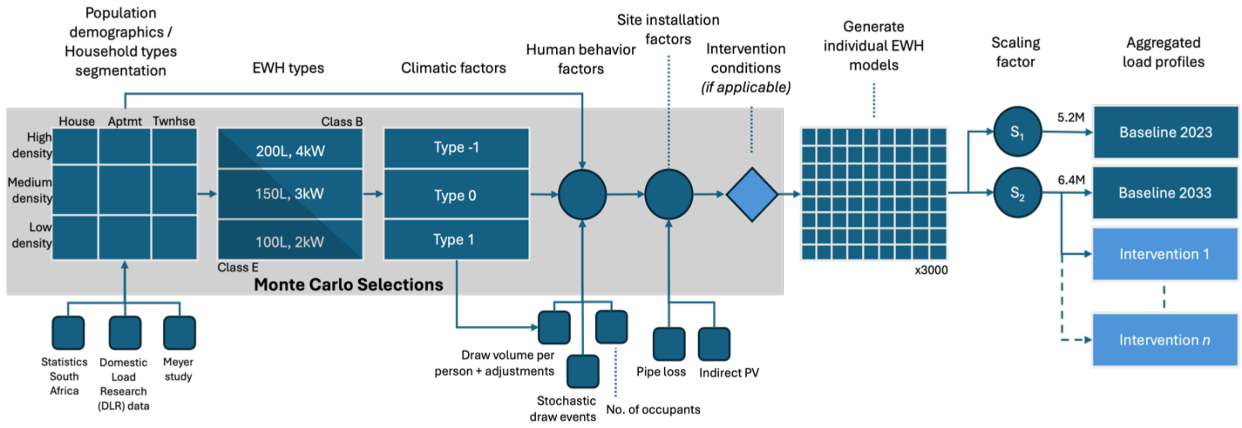
3. METHODOLOGY

This study aims to investigate the impact of regulatory intervention strategies to reduce water heating load on the national electricity grid using demand flexibility in residential water heating load. The following objectives have been established:

- Estimate national baseline for residential water heating power load demand for current year and a 10-year projection.
- Select technology options that are available to the South African market and regulatory structures for reduction of water heating load.
- Simulate the impact of interventions against baselines.

A tool was developed to simulate water heating power load profiles for multiple electric resistance water heaters (geysers) using a bottom-up approach and a Monte Carlo method. The results from the simulation tool take the form of a baseline load profile for summer and winter weekday for the year 2023 with a 10-year forecast into 2033. For this study, several energy efficiency (EE) and demand response (DR) interventions are identified and simulated to compare the impacts of electricity demand on the national grid. An overview of the method used is presented in Figure 2 and further explained in the next sections.

Figure 2: Flow diagram demonstrating bottom-up approach used for the simulation tool to generate national load profiles of water heating load.



This study uses a Monte Carlo method to develop a simulated representative population of water heaters interacting on the grid. Monte Carlo methods are a way of modelling interventions when there is significant uncertainty in the inputs for the analysis. It relies on repeated random sampling from probability distributions of the various inputs to approximate the diversity expected in the field.

Each of the simulation tool inputs are discussed in the following sections.

- **Population demographics**: Segmented by housing type and income accounting for forecast growth through 2033.
- **Electric water heater (EWH) types**: Size, horizontal and vertical orientations, insulation class
- **Climatic factors**: Ambient temperatures for climatic regions
- **Human behaviour factors**: Domestic hot water usage profiles and draw volumes
- **Site installation factors**: PV indirect and pipe standing losses

3.1 POPULATION DEMOGRAPHICS

To determine the national water heating load, an evaluation of the total number of residential water heaters and associated population demographics that drive hot water demand was performed using a combination of data from Statistics South Africa and from the National Rationalised Specification Load Research Programme, also known as Domestic Load Research (DLR). Section 9.2 - Annex 2 provides the full details of the data collected. The primary assumptions made include that dwellings need to have piped water, have an electrical connection, and have affordability of electric water heater ownership. This results in households LSM 6 and above being considered for this study. The estimation for 2023 suggests that 5.2M dwellings across 4.5M different erven (i.e. metered properties) may have access to electric water heaters. For a 10-year forecast, the 2033 prediction is projected to have 6.4M dwellings with electric water heaters.

Hot water usage is highly dependent on the income levels of occupants. Population demographics for each province are further mapped to high, medium, and low-density classifications across housing types to match against water usage profiles, discussed further in Section 3.1 and Section 9.3 - Annex 3 provides a description of the mapping process.

3.2 ELECTRIC WATER HEATER TYPES

Electric water heaters in South Africa are primarily resistance heating using a single element with a cylindrical shape at various sizes and insulation levels. The heaters are installed in both vertical and horizontal orientation, with most installations in the horizontal orientation (approximately 90%). Table 2 shows the weightings used as input variables in the Monte Carlo simulation to estimate the national water heating load.

The orientation of the electric water heaters impacts the demand pattern in the load profile, due to the stratification of thermal layers inside the tank. This is demonstrated by the measured temperature and load profiles for the same geyser installed in vertical and horizontal orientation in Note: (1) Simplification made for simulation purposes. The 50l tanks at 2% share in Table 1 have been assumed as 100l tank. (2) Horizontal tanks dominate the market, all tanks simulated have been assumed to be horizontal. The impact of the 10% share of vertical tanks is calculated to produce an additional 6% on peak demand using ratio from Yen et al (2019).

Figure 3 (a) and (b). Due to the difference in thermal stratification present in the tank, the restorative load from each orientation presents different load profiles, where the horizontal orientation demonstrates a transient effect before reaching steady-state.

The transient effects present in the horizontally-oriented geyser have significant results on the overall impact on the aggregated peak demand for a large population due to simultaneous draw events, as demonstrated in (Yen et al, 2019). Source: (Yen, 2021)

Note:T1 is bottom, matching with Figure 5

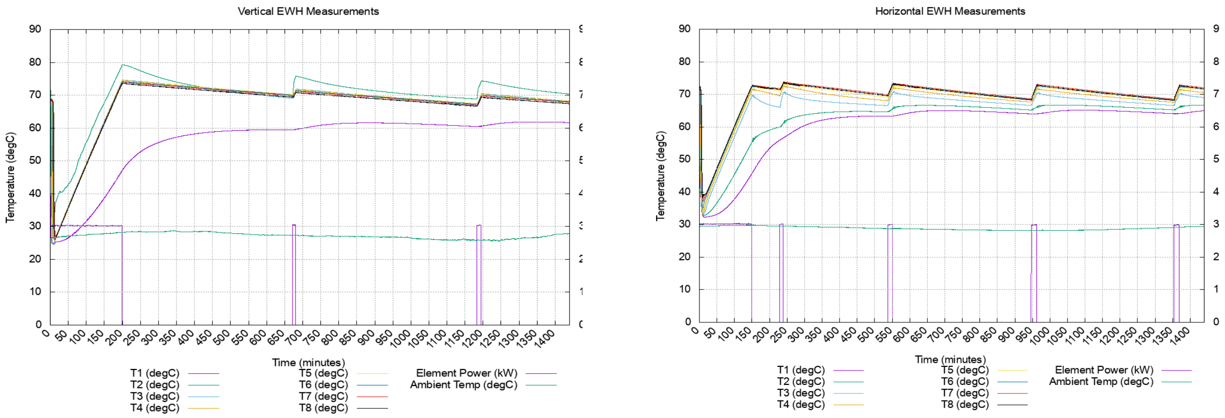
Figure 4 (a) and (b) show a comparison in power demand from a simulation of 1M vertical and horizontal EWH that initiates a single 50L draw each with a Gaussian probability function within a 4-hour time window (grey area). The aggregated effects of the horizontal electric water heaters show a lower coincident peak demand with longer peak periods before steady-state is reached, whereas vertical electric water heaters show a larger coincident peak demand.

Table 2: Weightings for the Monte Carlo water heater selection for 2023 and 2033 projections.

No.	Dimension description	Dimension categories	Weighted average (2023)	Weighted average (2033)
1	Geyser (EWH) size	200l, 4kW	15%	15%
		150l, 3kW	75%	75%
		100l, 2kW (1)	10%	10%
2	Installation orientation	Horizontal (2)	100%	100%
3	Tank insulation	Class E	44.8%	13.8%
		Class B	43.8%	86.2%

Note: (1) Simplification made for simulation purposes. The 50l tanks at 2% share in Table 1 have been assumed as 100l tank. (2) Horizontal tanks dominate the market, all tanks simulated have been assumed to be horizontal. The impact of the 10% share of vertical tanks is calculated to produce an additional 6% on peak demand using ratio from Yen et al (2019).

Figure 3: Measured internal temperature traces after a single 50l draw for horizontal and horizontally-oriented 150l, 3kW element geyser with different comeback loads indicated in load profiles.



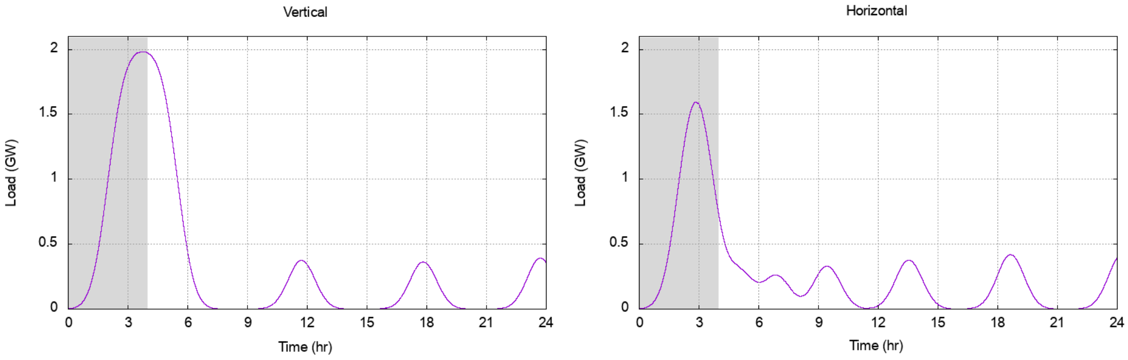
(b) Vertically oriented.

(a) Horizontally oriented.

Source: (Yen, 2021)

Note:T1 is bottom, matching with Figure 5

Figure 4: Simulated aggregated load profile for 1M population 50l draw with Gaussian distribution for water usage events for a 150l, 3kW EWH.



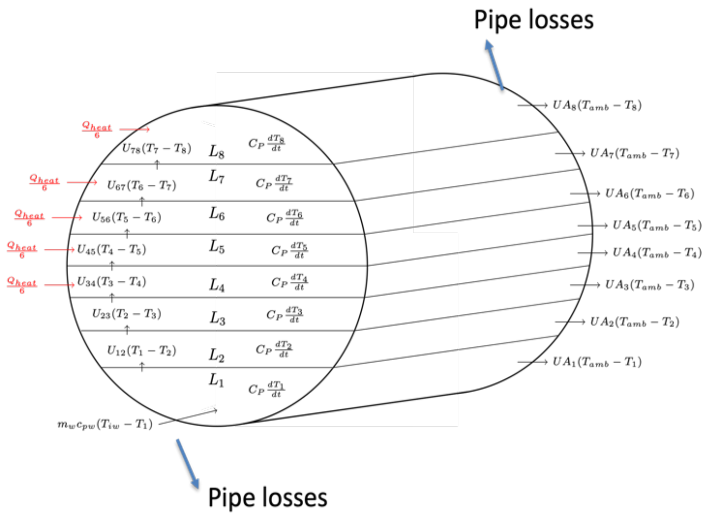
(a) Vertically oriented.

(b) Horizontally oriented.

Source: (Yen et al, 2019)

The horizontal electric water heater model used in this study simulates the transient effects of the heat replacement process of the tank by resolving the stratified layers, especially necessary for horizontal tanks. The load profiles of a population of electric water heaters are simulated using an experimentally validated model (Yen, 2021). Layers 1-8 are the temperatures for each of the layers from Figure 5. The model is based on heat stored, transferred, and lost in a horizontally cylindrical structure split into layers of unchanging volume sizes. Mass transfer is also considered when a draw event occurs. Pipe losses are modelled as additional standing loss uniformly distributed around the structure.

Figure 5: Electric water heater model for horizontal tank.



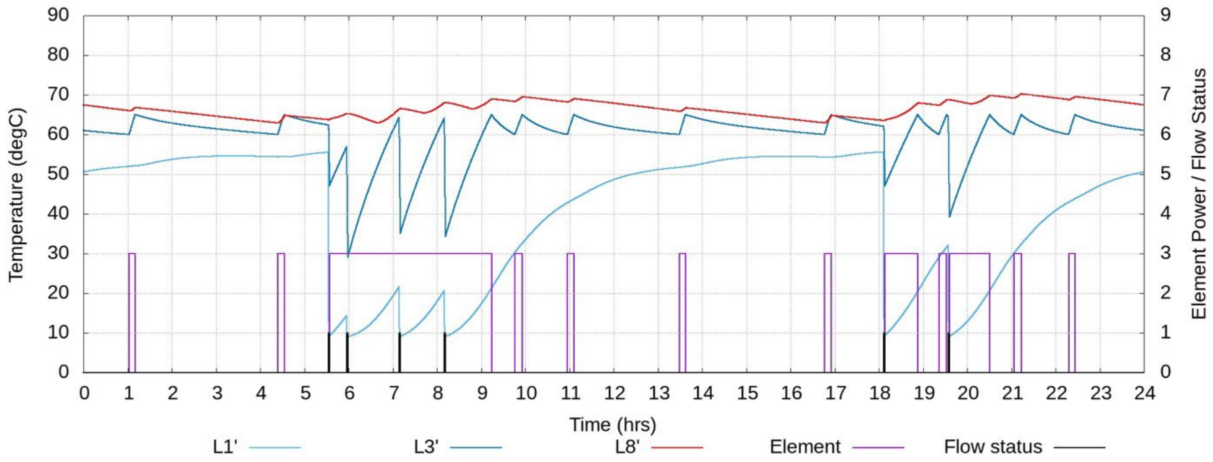
Stratified thermal layers:	L_n where $n = \{1;8\}$
Heat stored in layer:	$C_P\frac{dT_n}{dt}$
Heat transfer between layers:	$U_{(n)(n+1)}(T_n - T_{n+2})$
Heat transfer through insulation (standing loss):	$UA_n(T_{amb} - T_n)$
Inlet flow:	$m_\omega c_{P\omega}(T_{i\omega} - T_1)$
Heat from element:	$\frac{Q_{heat}}{6}$

Source: (Yen, 2021)

The location of the thermostat is identified as Layer L3. When the temperature drops below a set thermostat threshold, the element turns on and power demand is drawn from the grid. As the thermostat layer reaches the set point, the element turns off. Demand events are initiated when standing losses and hot water consumption reduce the temperature at a layer below the threshold. In general, the longer pulses are power draw events due to hot water consumption of the 3kW element and the shorter pulses are power draw events due to standing losses (or transient effects of the horizontal tank). The inlet temperature is assumed to be ambient temperature less 3°C.

An example of the horizontal tank model output is shown in Figure 6. Only three layers are shown from inside the tank, L1 (bottom), L3 (thermostat) and L8 (top). Six occupants with 25l draws are shown for a high-density house.

Figure 6: Example of simulated geyser for a 150L, 3kW tank for a house in a high-density community with 6 occupants and 6 draw events of 25L in a 24-hour period in winter.



Volumetric draw events occur as stochastic events due to human activity. This is based on domestic hot water usage profiles discussed further in Section 3.3. The ambient temperatures and inlet temperatures are defined by the region selection and season, which forms part of the Monte Carlo selection, discussed further in Section 3.3.

Regulated insulation class: As mentioned in Section 2.2, the VC9006 was enacted in 2016 regulating electric water heaters to Class B insulation rating. The Class E insulation has a maximum allowable standing loss of 3.06kWh/day, whereas the Class B insulation has a maximum allowable standing loss of 1.38kWh/day (SANS151). An assumption of a 10-year lifespan is made on an electric water heater, resulting in a 10% turnover of old stock. The weighted averages are provided in Table 2. Geysers that have not yet been replaced to Class B insulated tanks have been assumed with Class E insulation.

3.3 FACTORS AFFECTING POWER DRAW

The work by Meyer et al. (2000) represents the most comprehensive study on hot residential water usage profiles across all socio-economic profiles in Johannesburg, which is the largest city in South Africa. Hot water average daily usage profiles per persons developed by Meyer et al. (2000) are used for a range of household types and income categories (defined by density of houses per km^2: high, medium, and low density) as shown in Table 3. In this context, a high-density household is a proxy for lower income, and low density would imply higher income households. As draw patterns were limited to Johannesburg and conducted 23 years prior to the current baseline, this study extrapolated the water draw at the national level and adjusted water usage from the time of the Meyer studies to present day. Residential hot water usage profiles are impacted by regional climates, behaviours and cultural norms. The following sections explains these adjustments in more details.

Table 3: Hot Water Consumption for Houses (Meyer et al., 2000) and Variables Used for Seasonal Correction.

Household (HH) type	Density	Average number of occupants	Average daily usage per person (litres)	T_{amb} coefficient	T_{amb} intercept
House	Low	3.1	124	-5.16	171.09
	Medium	3.8	80	-3.35	110.77
	High	6.2	34	-1.43	46.96
Apartment	Low	2.2	106	-5.82	179.37
	Medium	3.3	66	-3.83	115.19
	High	3.8	24	-1.56	44.72
Townhouse	Low	2.1	116	-5.00	165.37
	Medium	3.3	89	-3.71	123.61
	High	3.7	80	-3.42	113.72

3.3.1 Climatic Factors: Ambient temperatures for climatic regions

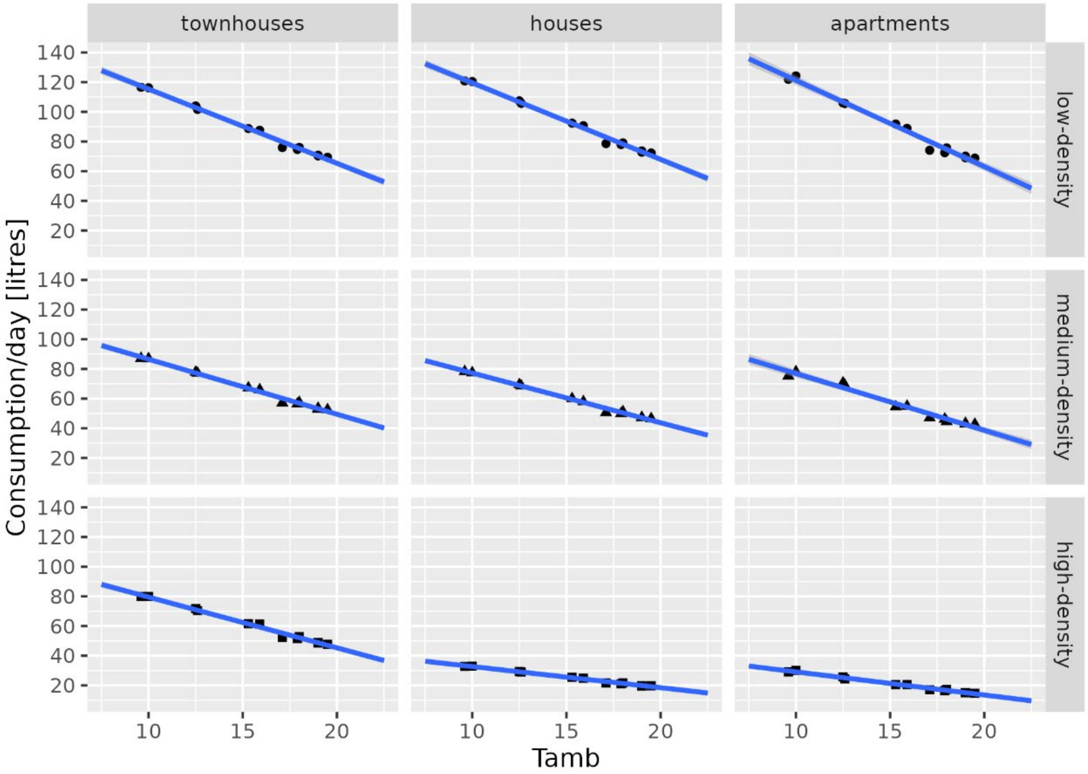
The ambient temperatures are key variables for modelling water heating load and standby loss. Average hourly temperatures are selected for each simulated location using weather station data. For this study, the country is separated into three climate regions as described in Table 4. Representative temperatures from these climatic regions for each season and population segmentation per household type are the climate variables that define the regional variations in the simulation. Winter and summer weekday averages are chosen to represent the seasons. Winter is averaged for months May to August. Summer is averaged for months November to February. Further details on climatic factors can be found in Section 9.3, Annex 3.

Table 4: Categorised climatic regions and averaged summer and winter ambient temperatures (T_{amb}).

Climatic Region	Provinces	Total number of water heaters		Average Ambient Temperature T_{amb} (°C)	
		2023	2033	Summer	Winter
Region 0: Inland hot and dry	Gauteng, Free-State, Mpumalanga, Limpopo, North-West, Northern Cape	3.0M	3.7M	22.22	11.91
Region 1: Cold and wet	Western Cape, Easter Cape	1.5M	1.9M	20.21	13.64
Region -1: Subtropics	KwaZulu Natal	0.7M	0.8M	23.03	15.46

A comfort level of 40°C is the assumed temperature requirement at the point-of-use. The daily hot water usage volumes produced in Table 3 suggest a fixed volume, that does not vary with ambient temperatures. However, with ambient temperatures, and by implication, the inlet and temperature at the cold faucet is known to vary between the range of 10°C and 30°C depending on season, time of day or region. Therefore, the volume of hot water required from the electric water heater for a fixed point-of-use volume varies with hot water supplied by the water heater at 65°C due to thermostat setpoints. Figure 7 indicates the volume adjustments made on monthly average daily hot water consumption per person for each household type and density from Meyer compared to the monthly average ambient temperature for Johannesburg. Linear regression curves are derived for each household type and density and the T_{amb} coefficients and T_{amb} intercepts are provided in Table 3

Figure 7: Volume adjustments for daily hot water consumption for each household type and density for ambient temperature variations due to seasonality.



3.3.2 Human Behaviour Factors

Insights from stakeholder interviews suggest that per person volume draws in the Meyer study appear high in comparison to modern usage habits. Water prices have risen appreciably in SA over the last decade. Price elasticity demand of water would apply and tend to reduce overall usage of water. Behaviour change in hot water consumption is modelled using price elasticity of water, with hot water consumption reduction for each household type as indicated in Table 5.

Table 5: Further hot water reductions from Meyer consumption volumes for 2023 adjustments using price elasticity.

Estimated reduction in water demand (%)				**Meyer water class reduction estimate (2021 %)**				
				House / Apartment			**Town House**	
Low	**Mid**	**High**		**Low density**	**Med density**	**High density**	**Low density**	**Med density**
1-6	**6-8**	**8-10**	**LSM range**	**9-10**	**7-9**	**5-7**	**9-10**	**6-8**
3	**7**	**9**	**LSM middle**	**9.5**	**8**	**6**	**9.5**	**7**
-43.76	-44.67	-30.42		-26.86	-37.54	-35.58	-26.85	-44.67
-44.72	-40.14	-24.87		-21.05	-32.50	-41.28	-21.04	-40.14
-60.46	-27.30	-17.07		-14.51	-22.18	-35.58	-14.51	-27.30

3.3.3 Pipe Standing Losses

Several additional known factors that impact the water heating load due to specific site installation factors are considered in the simulation, including standing losses due to pipe connections and whether the geyser is supported by a rooftop PV system. Since the model is derived in the laboratory, these additional factors need to be included to represent variations in site installations factors in the field.

In addition to the standing losses from the tank itself, heat is lost continuously from the pipes and fixtures that are attached to the geyser. These standing losses are in addition to those addressed in the standing loss test of section 7.4.3 of SANS 151. The plumbing setup in a SANS 151 standing loss test is not the same as typical field installations. These standing losses are driven by the temperature difference between the heated water inside the geyser and the cooler air surrounding it. The standby loss is the energy used to keep the water in the tank hot when no hot water is being used.

The standby loss was calculated as the total duration of a water heater cycle when no hot water is used, divided by the energy used when the element is heating the water back to setpoint temperature at the end of the cycle. This was done for all the standby cycles that could be identified in the Domestic Load Research (DLR) data.

The size of these losses was estimated by extracting the electrical load signal of the geysers from DLR data (See Section 9.2 in Annex 2) supplied by ESKOM. The DLR data covered was from studies in Westridge in 2004 and Summerstrand in 2000. Each study covered about 60 erven. The supplied data were the instantaneous power consumption of all loads at each meter at 5-minute intervals for approximately one year per meter. For this analysis, the geysers were assumed to be horizontally installed. They were all assumed to be rated Class E under SANS 151 because VC9006 was not yet in effect.

The resistive elements of water heaters draw 2, 3, or 4 kW depending on the size of the tanks. The incremental change of total electrical power load between subsequent 5-minute recording intervals will increase by this amount when the water heater starts heating and will decrease by this amount when the element stops heating. Because other electrical appliances, such as lights and refrigerators, are also turning on and off, the power change will not be exactly the amount of the geyser element. To determine the size of the geyser heating element, the absolute value of these incremental power changes was tallied into 50-watt bins. The weighted average of the bins with the most counts of incremental power change were taken to be the wattage of the geyser element associated with that meter. This wattage was then used to identify the volume of the geyser cylinder.

Once the element watt size was determined, then water heater cycles were identified by noting when the heating element cut in and cut out. For this analysis a water heater cycle was defined as from when the element turned off, turned on, and then turned off again. The duration of the cycle is the duration of the off time and the on time. Water heater cycles were identified as recovery, subsequent, and standby depending on the duration of the on and off times of the cycle (Yen, 2021). A recovery cycle occurs when hot water has been drawn from the tank and the replacement cold water needs to be heated. A subsequent cycle happens in horizontal geysers after a main recovery cycle and is distinct from a steady-state standby cycle. Standby cycles occur when the water in the tank has not been drawn for use but has cooled off enough so that the element turns on to heat the water back up to the setpoint temperature.

Table 6 shows the median standby loss as watts by geyser size. Also included in the table is the steady-state standby loss as watts allowed for Class E geysers under SANS 151. The difference between the field standby loss and the loss allowed by SANS 151 is the extra heat loss due to the connected pipes and fittings.

Table 6. Field Standby Loss compared to SANS 151 Standing Loss

Volume (L)	Field standby loss (W)	SANS 151 standing loss (W)
100	136.79	112.19
150	172.24	127.36
200	249.55	139.73

3.3.4 Photovoltaic Rooftop Installations

Due to the current load shedding situation in South Africa, there has been a shift in the market toward the installation of rooftop photovoltaic (PV) for residential homes. Based on interviews and publications, the current residential market is estimated at 14% of households, with a projected penetration of 30% in 2033.

Rooftop PV installations include the use of PV panels with an inverter and battery to supply essential loads within a home when the sun is not providing energy and during load shedding. In most systems, geysers are connected as a non-essential load, and therefore do not draw power from the battery. Most batteries are sized to supply essential loads (such as lighting, entertainment, IT and security) during load shedding periods (2-4 hours per day). Residential PV systems are typically sized by the inverter rating; standard installation sizes include 3kW, 5kW and 8kW units.

Depending on several factors, geyser load can be offset by the PV supply at adequate Global Horizontal Irradiation (GHI) levels and low essential-load demand. This can result in a situation where either all the geyser load, or a fraction of the geyser load is supplied by the PV source, thereby reducing the demand required of the grid. Figure 8 depicts hourly averaged GHI for the three climatic zones for summer and winter months. Figure 9 demonstrates an example of the simulated PV offset demand of a geyser as observed by the national grid. The top graph shows the geyser demand without PV installed, and the bottom graph shows the fraction of the geyser load removed from the grid depending on the GHI level during the correlated hour. The electrical savings occur primarily in the middle of the day, between the morning and evening geyser peaks.

The 2023 penetration of residential rooftop solar PV is estimated at 14% of the electric water heaters that are indirectly impacted. The baseline 2033 projection is based on the IRP plan to end load shedding by 2028, resulting in an estimated penetration rate of 30%. This has an indirect impact on geyser loading, particularly during solar production hours, where geyser load can be absorbed by PV generation.

Figure 8: Averaged Global Horizontal Irradiance (GHI) curves for summer and winter for three climatic zones (source: SAURAN).

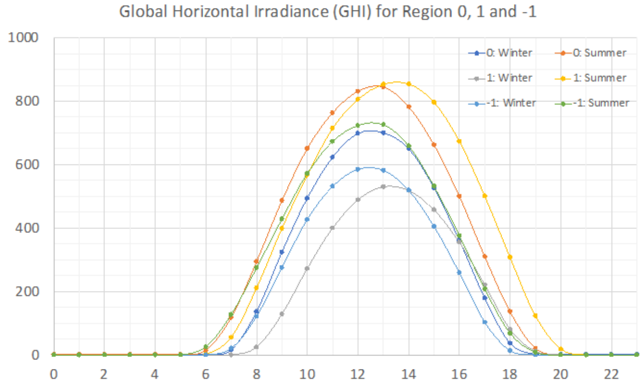
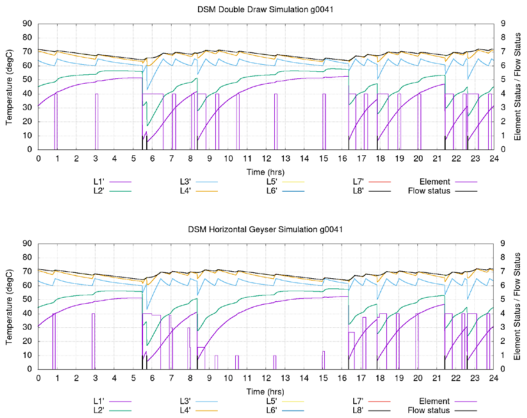


Figure 9: Example of PV offset geyser demand as seen by the national grid (top: no PV, bottom: PV offset).



Several factors are contributing to the geyser grid energy demand offset. The following high-level assumptions were made:

- Hourly averaged irradiation (GHI) is considered for the three climatic zones; summer (September to February) and winter (March to August), as depicted in Figure 8.
- In reference to Meyer household classifications, it is assumed that high-density households have a 3kW PV system, medium-density households have a 5kW system, and low-density households have a 8 kW system.
- For all GHI values above 400 W/m², a PV system will be operating at its rated output (3, 5, 8 kW).
- There is no other significant load in the household during the day that the PV system is able to supply.

These high-level assumptions are made to provide an estimate of PV impact on water heating load. A more detailed study is required to ratify the assumptions made.

3.4 MONTE CARLO SELECTIONS AND POPULATION SCALING

A population of 3 000 geysers is simulated with the Monte Carlo method to generate a representative load profile based on the weightings for each attribute. The same random seed is used for the baseline and the scenarios, such that any simulated intervention scenarios is directly comparable. A representative aggregated load profile is produced by summing the element activity for each simulated geyser. To estimate the total impact of water heating on the power grid for a specific region, the total number of geysers is determined by number of dwellings with access to services (electricity and water) in that region. This total number of geysers is used as a scaling factor for the representative load of 3 000 simulated geysers in the same region to determine the total morning and evening peak demand.

The number of occupants per household are the primary drivers of residential hot water usage load. The number of occupants per household are determined from the average number from Meyer et al (2000) and verified using DLR data. The Monte Carlo selections are performed on a selection of occupant sizes ranging from 1-8 occupants as shown in Table 7. The combinations of weightings and number of occupants produce an average number of occupants as provided by Meyer.

Table 7: Weightings used for number of occupants based on household type.

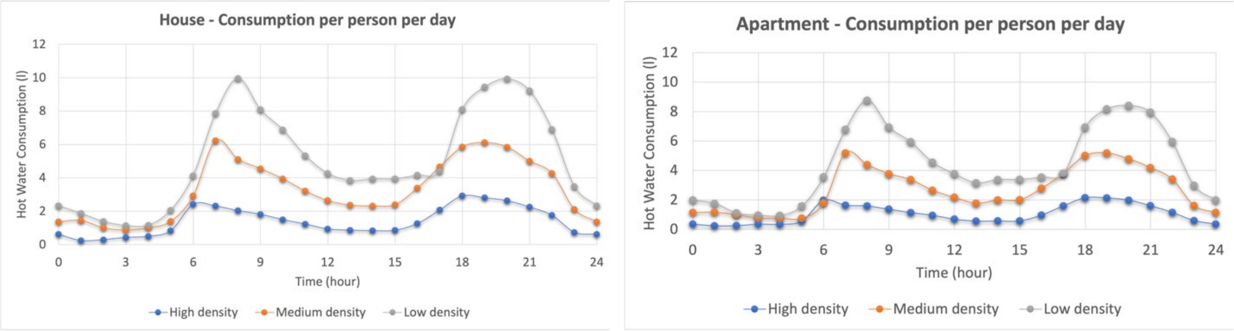
			Number of Occupants							
Household (HH) type	**Density**	**Ave Occ**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
House	**Low**	3.1	2.5%	20%	50%	20%	7.5%			
	Medium	3.8		5%	37%	30%	28%			
	High	6.2				2.5%	15%	50%	25%	7.5%
Apartment	**Low**	2.2	15%	50%	35%					
	Medium	3.3		10%	50%	40%				
	High	3.8			35%	50%	15%			
Townhouse	**Low**	2.1	20%	50%	30%					
	Medium	3.3		10%	50%	40%				

Human behaviour is a stochastic process and is subject to change depending on cultural norms, environmental factors, and personal habits. To model this stochastic process, hot water usage patterns are required for use in Monte Carlo selections. The Meyer (2000) study characterised household usage patterns through field-measured data.

An example of the hot water consumption curves for each household density type is shown in Figure 10 (a) and (b). The mathematical integration of each curve provides the total average daily usage of hot water per person, which is shown in Table 1. The water consumption curves in Figure 10 are converted to probability distribution curves and cumulative distribution curves. Each occupant in each household is stochastically assigned a time to initiate a hot water draw event, using a random number to select from the cumulative distribution curve relating to household type and density.

Figure 11 shows the discrete simulated events produced by the model that demonstrates a close correlation with the Meyer curve for a house type with high density. This is defined by the demographic study performed in Section 9.2 to determine a representative sample of households by building type and income level. The daily hot water usage profile for each sampled household is based on the household type and density.

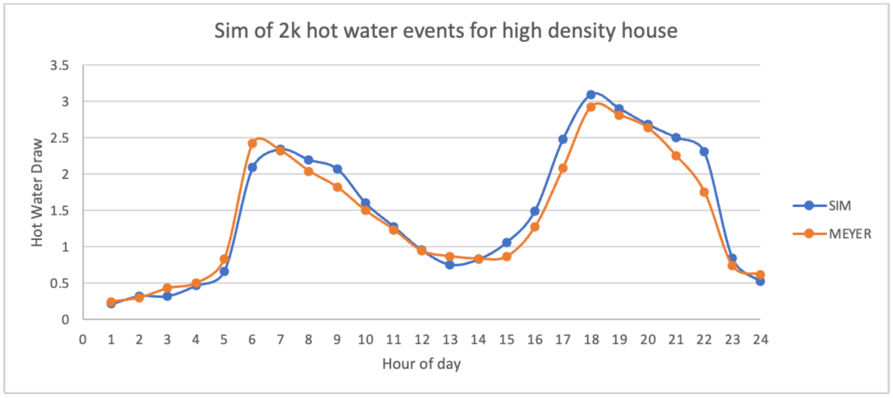
Figure 10: Daily residential hot water consumption per person per day for household types consumption for high, medium and low-density households (Meyer, 2000) [footnote, townhouse not depicted here].



(a) HH type: House

(b) HH type: Apartment

Figure 11: Stochastically determined hot water usage events from the simulation scaled in comparison with the average daily per person usage profile from Meyer.



3.5 BASELINE ANALYSIS

A baseline analysis is established to provide a national water heating baseline energy demand for the current year 2023 and projected in a 10-year forecast baseline scenario to 2033. The baseline analysis is only considering water heating load from residential electric water heaters. The national profile is derived by identifying the number of households / dwellings with access to electricity and water nationally, implying hot water access. There are an estimated 5.2M geyser units nationally connected to the grid for 2023 and forecasted projections of 6.4M in 2033.

Each of the climatic regions are distributed by LSM into the study by Meyer et al. (2000) HH type classifications, as discussed in Annex 9.2.8. Typical summer and winter temperatures are used for each climatic region. All geysers have a thermostat setting of 65°C. All simulated geysers are assumed to be residential use, as there are no available usage profiles for the commercial sector. No other water heating technology is considered, other than electric water heaters. Effects of climate change are not considered.

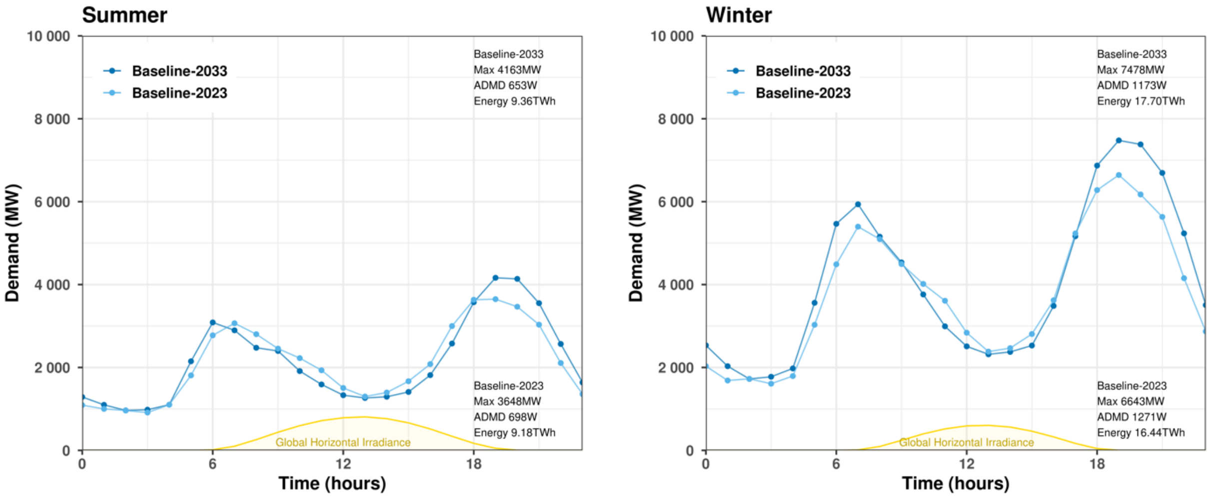
There is an estimated total of 6.4 M geysers forecasted for 2033, resulting in an increase of 1.2 M additional electric geysers entering the market in the next 10 years. The change in distributed weights for HH types and volume adjustments for draw events is discussed in Section 9.2.

A load profile is developed for the national baseline in each season, as shown in Figure 12 (a) and (b). The results are summarised for maximum demand, After Diversity Maximum Demand (ADMD) and annual energy consumption in Table 8. This study presents results in hourly averaged demand, which do not include the details of system dynamics on several profiles; for higher time resolution profiles, refer to Annex 9.4. An artefact of scaling from 3,000 to 5.2M and 6.4M geysers results in load profiles with localised peaks and troughs that are exaggerated. Inclusion of 10% vertical geysers would increase the reported maximum demand values by approximately 6%.

The maximum demand is forecasted to increase from 6 643 MW to 7 478 MW in winter, which is almost an increase of one stage of load shedding. Therefore, this suggests that if no intervention is implemented in the short term, there will be more detrimental issues on the grid in the next 10 years than currently experienced in 2023.

From the load profiles, the 2033 forecast shows a significant reduction in day-time load. This significant reduction is due to an increase in residential rooftop PV installations that indirectly service geyser load during solar production hours. The increase to 30% PV penetration is the forecasted scenario for load shedding to end in 2028, following the IEP plan. Interestingly, doubling rooftop PV penetration has the potential to reduce day-time water heating load to below 2023 levels.

Figure 12: Representative load profiles for estimated 5.2M (2023) and 6.4M (2033) geyser units nationally with set points at 65°C for (a) summer and (b) winter.



(a) Baseline summer

(b) Baseline winter

Table 8: Summarised results from national baseline load profiles for 2023 forecast to 2033.

Simulated Scenario		User Comfort [%]	Hourly Averaged Max Demand [MW]		After Diversity Max Demand (ADMD) [W]		Energy Consumption [TWh]	
Scenario	**Description**	**S/W**	**Summer**	**Winter**	**Summer**	**Winter**	**Annual**	**Change**
Baseline-2023	No action, Year 2023, 5.2M	100/100	3 648	6 643	698	1 271	25.6	-
Baseline-2033	No action, IEP Plan, Year 2033, 6.4M	100/100	4 163	7 478	653	1 173	27.1	+1.5

A calibration point for checking the load profiles for water heating load is the use of After Diversity Maximum Demand (ADMD) published by Forlee (1998). The ADMDs listed for 13 participating municipalities in geyser notch test using ripple relays have winter values ranging from 440 – 1 270 W per relay. It is unclear how many geysers are connected per relay, or the number of by-passed relays. In addition, the hot water usage profiles indicate a morning peak instead of an evening peak. This study is limited by the use of hot water usage profiles determined by Meyer (2000), which indicate an evening peak across all household types and income levels. The baseline winter ADMD for 2023 matches remarkably well to the values published by Forlee. The ADMD listed in Table 8 is per geyser.

The reduction in ADMD for 2033 from 1 271 W to 1 173 W in winter and 698 W to 653 W in summer is attributed to increase the ratio of geysers with insulation ratings of Class E to Class B. In 2023, it is estimated that 44.8% of the population remain a Class E insulation and in 2033, it is estimated to reduce to 13.8%. The reduction of geysers with higher standing losses (Class E), will see an overall reduction in standing losses and ADMD.

The total annual energy consumption due to water heating load is increased from 25.6 TWh to 27.1 TWh from 2023 to 2033. This relatively small increase of 1.5TWh for a 10-year duration and a 1.2M increase in population can be attributed to the combination of increased Class B insulated geysers and increased rooftop PV penetration.

4. TECHNOLOGY OPTIONS

This section describes the initial technologies and measures considered in this study to reduce energy demand of water heating. This study initially considered ten potential water heater technologies as interventions. These are listed and briefly described in this section and each description is followed by a table summarizing their main characteristics. Six of those interventions were selected and their impact on load demand was assessed in Section 5, Simulated Interventions.

4.1 TANK AND PIPING INSULATION

Extra insulation on the pipes and fittings close to the geyser will reduce heat loss whenever there is hot water in the tank, not just when hot water is being used. SANS 10252-1 has requirements to insulate hot water pipes, valves, couplings, and cold-water pipes within 1 m of the geyser.[1] This requirement is not consistently applied, especially in older buildings. The insulation also tends to wear over time, especially if exposed to the elements.

Additional lagging can also be applied to the geyser itself. Geyser blankets are readily available and have been promoted by ESKOM in the past. Costs are below R500. Installation is relatively simple and can be done in less than 1 hour. The standards for standing losses for geysers have since been strengthened and adding geyser blankets to these more efficient geysers will have a diminished impact. Research undertaken in 2009 by the Cape Peninsula University of Technology estimated that, if correctly installed, geyser blankets would reduce standing losses by up to 0.2kWh per day (based on the old level D insulated geysers) whereas pipe insulation on the first 3 meters of the hot water outlet pipe provides 0.3kWh per day Energy savings are due to the reduced standby losses. As such this technology will provide genera l load reductions, not just during on-peak times.

Table 9: Tanks and Piping Insulation Technology Assessment

Cost	Reasonably low cost for the insulating material. Installation is time consuming and will add significantly to the overall cost but will also be the source of local jobs.
Installation	Easy
Risks	Insulation material may not meet the R value prescribed by the national standard.
Standards	Insulation standards: SANS 10232-1
Existing policy tools	SANS 10400 XA2 (all pipes must be insulated to an R-value of 1.00)
Potential policy tools	Expand SANS 10400 XA2 to home transfers
Implementation cost and administrative burden	Low

4.2 GEYSER ELEMENT

Installing lower wattage elements in geysers will reduce the instantaneous electricity demand of aggregated geysers at all times including peak times. The time to reheat water will take longer at individual geysers.

Whereas limiting the rating of the element will not reduce the overall electricity use, it will reduce the instantaneous electricity demand of aggregated geysers in peak times (if peak times coincide with the time that geysers are on).

Table 10: Reduced Geyser Element Size Technology Assessment

Cost to consumers	No incremental cost compared to current technology
Installation	During manufacturing process
Risks	Water could take too long to reheat and may increase energy consumption slightly
Standards	SANS151
Ease of use	No user input needed. When used in combination with a timer, might have to be adjusted.
Potential policy tools	Legislation
Implementation cost and administrative burden	Low

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[1] AHRI Standard 1430-2022, Standard for Demand Flexible Electric Storage Water Heaters, https://www.ahrinet.org/system/files/2023-06/AHRI%20Standard%201430-2022%20%28I-P%29.pdf

4.3 TIME OF USE ELECTRICITY TARIFFS

A time-of-use (TOU) tariff is a pricing structure for electricity consumption where the rate varies depending on the time of day, typically divided into peak, off-peak, and sometimes shoulder periods. This type of tariff is designed to encourage consumers to shift their electricity usage away from peak times when demand and costs are highest, thereby helping to balance the load on the electrical grid.

TOU works best when control devices are installed to allow to adjust the temperature and energy demand according to the prevailing tariff. This option will provide load reductions during peak times. Total energy use may not be affected as demand will be shifted to other times of day. To avoid issues with hot water runouts a means of consumer over ride should be considered.

Table 11: Time of Use Electricity Tariff Technology Assessment

Cost to consumers	Depending on usage pattern, consumers may incur a cost or a benefit
Installation	During manufacturing process
Risks	Water could take too long to reheat and may increase energy consumption
Standards	SANS151
Ease of use	No user input needed. When used in combination with a timer, might have to be adjusted.
Potential policy tools	Legislation
Implementation cost and administrative burden	Low

4.4 SMART CONTROLS

Smart control technologies refer to systems and devices that enable automated and intelligent control over electrical equipment by utilizing sensors, communication networks, and data processing capabilities to monitor, analyse, and manage the operation of electrical devices more efficiently. These technologies can help optimize energy demand at best time of day while minimizing impact on service comfort to users. The control mechanism can be either adjusting the timing of the thermostat or reducing its temperature setting. The energy and peak load savings will depend on how much the thermostat temperature is reduced and how long the elements are turned off. The means of control will depend on the specific technology used. An issue with all smart technologies is ensuring adequate hot water is provided to the consumer.

Important considerations are 1) whether the consumer benefits from the intervention through lower operating costs or financial incentive for signing up to a programme and 2) how much the consumers' hot water use habits are impacted. Controls that disrupt the consumers' hot water experience will be more difficult to implement. Control algorithms that are understood by consumers and can be modified when they consider it necessary will be more readily adopted. The technologies for water heating can be classified based on where the control resides and who initiates the operation change.

Ripple Control

Ripple control is a technique used by utility companies to remotely manage electricity consumption by sending signals through the power lines to specific devices, such as water heaters, to turn them on or off. Ripple control involves superimposing a higher-frequency signal onto the standard 50–60 Hz of the main power signal. When receiver devices attached to non-essential residential or industrial loads receive this signal, they shut down the load until the signal is disabled or another frequency signal is received. This helps to balance electricity load on the grid and reduce strain during peak demand periods.

There is a legacy control system operated at the municipal level in South Africa using a ripple relay for switching off geysers during peak periods. Relays are encoded with one of the 13 keys and are uniformly distributed in the population. Municipalities operating the relays during peak periods switch off one of the keys on a rotational schedule for a maximum period of 2.5 hours, i.e. one key off for the period, then returned to service and the next key turned off - thereby denoting the name "ripple control". Due to the one-way communication of the relays, consumers are known to bypass the relay on the first onset of cold-water service. It is unknown how many ripple control relays are currently in service. Several municipalities in South Africa are still operating a ripple control programme. However, these programmes do not offer any incentives to consumers to participate.

Load-limiting

This could be an automatic response when the frequency starts dropping or in response to an ESKOM load-limiting warning signal or announcement. Although not currently available, it should be possible to automatically reduce power to the geyser elements to stay below the load limits imposed by smart meters. This will save consumers money, although less than turning off power to geyser elements when hot water is not needed. The load on the grid during critical times will be reduced.

Consumer Control

Some technologies allow for automatic operation changes initiated by local devices. These devices may include smart thermostats, timers, or sensors installed within the water heating system. They can adjust temperature settings, schedule heating cycles, or activate energy-saving modes based on predefined conditions or user preferences.

In the United States, a demand flexibility option is emerging to address the variable availability of renewable energy involves "loading up" water heaters, allowing them to retain heat during periods of expensive electricity and "shedding load" during times of reduced electricity availability. This approach ensures adequate hot water service to consumers while optimizing energy usage. The water heater loads up by heating the water in the tank to higher than normal temperatures[2]. Hot water is delivered from the tank at a normal temperature by a mixing valve that combines an appropriate amount of cold water with the overheated hot water. This provides the consumer with adequate hot water during load shedding periods.

This type of control enables water heaters to heat at higher than normal temperatures during periods of cheap electricity or high renewable energy availability. This stored heat can then be utilized during peak demand periods when electricity is more expensive or renewable energy is less available. Geyser timers, often associated with energy savings, typically reduce standing losses by limiting geyser temperature or by providing hot water only when needed. All solar water heating technologies that have a backup element installed need a timer to ensure optimal use of solar energy.

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[2] It takes less than 2,5 hours to heat 150 liters of water from 15 degrees C to 60 degrees C. Typical set temperatures in the US are ~52 deg C (125 deg F). Load Up brings all water to ~52 deg C. Advanced Load Up brings the water to 60 deg C. s

Table 12: Smart Controls Technology Assessment

Cost to consumers	Costs range from simple timers to sophisticated energy management systems.
Installation	Can be done by a qualified electrician
Risks	Privacy, reliability, and technical failures
Existing policy tools	Many municipalities and Eskom have ripple relay devices in place that are controlled remotely. How many of these are still operational needs to be investigated.
Potential policy tools	DSM programmes run by municipalities, utilities or government agencies
Cost and administrative burden	Governments may offer financial incentives to encourage the adoption of smart control systems for water heaters to offset some of the upfront costs for consumers or businesses to increase adoption rates. Policies mandating smart control on water heaters may require data management and reporting systems to track compliance, monitor energy savings, and evaluate the effectiveness of the policy.

4.5 HEAT PUMP WATER HEATING

HPWH are typically 200-300% efficient, compared to no better than 100% efficiency of resistance electrical heating. HPWH use an electrically powered compressor to operate a refrigeration cycle to extract heat from ambient air. The heat pump is essentially a small air conditioner or unit that heats water in the storage tank. The heat pump can be integral to the tank or mounted remotely with water pumped between the tank and the compressor. There is an ISO standard for the rating of the performance of heat pump water heaters. The heat pump can be coupled to an existing geyser and assembled by the manufacturer. The connections between the heat pump and the geyser are done in the field with standard plumbing materials and skills.

Costs for HPWH are currently high at an estimated R25 000 for an installed system (United States Dollar (USD) 1 331[3]). There is no domestic heat pump production, however, South African companies design systems and have them manufactured in China to their specifications (ITS, 2024). Kwikot also have heat pumps that can be installed with their geysers (ISO, 2019). As these systems are similar to air conditioners (and fridges) they can theoretically be installed and serviced by the same technicians. However, since the market is still limited in South Africa, there is limited experience and installations can be a challenge. After-sales service is a particular problem for a variety of reasons including lack of qualified technicians, original installers going out of business, and high costs to correct poor installs.

Table 13: Heat pumps Water Heater Technology Assessment

Cost	High
Installation	Needs to be installed by a qualified technician.
Equity	Medium and high income (as replacement for geyser with electric element)
Risks	Water that is not considered hot enough, compressors that run continuously due to low ambient temperature and the noise can be preserved as negative.
Existing policy tools	SANS 10400 XA2
Potential policy tools	Expand SANS 10400 XA2 to home transfers
Cost and administrative burden	Very high for rebate and other incentive schemes Low for expansion of 10400 XA2

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[3] Using an exchange rate of 0.053 United States Dollar per rand as of 1.30.2024.

4.6 HIGH PRESSURE SOLAR WATER HEATERS

High pressure solar thermal water (HPSWH) heating systems comprise a solar collector, which can be either a flat plate or evacuated tube, a storage tank, and a network of pipes to transfer heated water from the collector to the geyser. HPSWH are typically installed in middle- to high-income households to supplement standard electric geysers. Most HPSWH installers in the country have transitioned their offering to the installation of solar PV systems. To ensure a consistent supply of hot water, these systems are equipped with electric backup elements, particularly useful during rainy periods. These systems have to be installed with a timer on the backup element to ensure maximum solar usage.

These systems can be manufactured with relatively standard materials and with normal plumbing techniques. The solar collectors can often be coupled to an existing geyser.

A HPSWH system that is correctly sized for the specific hot water demand will reduce annual electricity use for water heating by as much as 63%.[4] The costs of these systems vary depending on technology and type. A typical SWH system is estimated at R25 000, including the geyser (USD 1 331[5]). However, there is always a risk that the backup element will switch on in peak demand hours. This will happen on rainy days when the larger electricity system is more likely to be under stress. Geyser timers are extremely easy to override.

Table 14: High Pressure Solar Water Heaters Technology Assessment

Cost	High (for a full system)
Installation	Requires north-facing rooftop without significant shading. Can be installed by a plumber and electrician with the necessary qualifications Needs to be installed with a timer to optimise solar heating
Risks	Some households opt for solar PV in response to the electricity crisis and include the geyser element in their load to maximise self-consumption
Standards	There are ISO[6] and Solar KEYMARK[7] standards for solar water heating systems. In South Africa, the locally developed SABS standards are used to test and certify for efficiency and durability.
Ease of use	If correctly sized, correctly installed, and if the timer is optimally set, the system needs minimal manual intervention (manual intervention is also easy) Pumped systems operate with electricity
Existing policy tools	SANS 10400 XA2
Potential policy tools	Expand SANS 10400 XA2 to home transfers
Cost and administrative burden	High for financial incentives and other incentive schemes Low for expansion of 10400 XA2

A national HPSWH rebate programme was administered by Eskom from 2008 to 2012. While this programme managed to stimulate the supply side, it did not sufficiently stimulate the demand for HPSWH. This led to an oversupply resulting in many new and existing installers and manufacturers closing their businesses. Whereas there are still some specialized HPSWH installers in the country, most have expanded their offering to the installation of solar PV systems.

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[4] https://www.iea-shc.org/Data/Sites/1/publications/Solar-Heat-Worldwide-2022.pdf

[5] Using an exchange rate of 0.053 United States Dollar per rand as of 1.30.2024.

[6] ISO 9459

[7] https://www.electrolux.co.za/appliances/heat-pumps/

In 2011, a new part that addresses energy efficiency in buildings (SANS 10400) was added to the National Building Regulations. Part XA2 of this regulation deals with water heating and reads: "50% (volume fraction) of the annual average hot water heating requirement shall be provided by means other than electrical resistance heating including but not limited to solar heating, heat pumps, heat recovery from other systems or processes and renewable combustible fuel". This regulation is meant to be enforced for all new builds and renovations which was expected to result in a significant growth in installations, but this has not materialised.

The industry has consolidated since the Eskom rebate ended in 2016. Most new and replacement HPSWH systems currently installed in South Africa, are made by Kwikot and are installed by regular plumbers who theoretically have the necessary training. The installed base in the residential sector is estimated at about 580k systems installed[8]. This includes both high pressure and low pressure SWH.

4.7 LOW PRESSURE SOLAR WATER HEATERS

Low pressure solar water heaters (LP SWH), also called non-pressure or passive solar heater, means that the water in the tank is under low pressure and is equal to the gravity of the water. The water is delivered to the tank on the roof by a pump or water from a water tank, then the water circulates in the evacuated glass tubes exposed to the sun, thus heating up. As the specific gravity of cold water is heavier than hot water, the hot water in the glass tubes starts rising in the insulated water tank on the roof, and the cold water in the insulated water tank sinks into the glass tubes. As this cycle is repeated, water in the solar geyser gets heated. This process is known as thermosiphon and is based on natural convection.

They are typically installed in low-income households to provide hot water on tap where this was not previously available. These systems typically do not have back-up electric elements installed, and even though these systems do not replace geysers with electric elements, they could still add to the reduction in electricity use from kettles and stove tops for hot water. Importantly, they also improve living standards.

The South African Government launched an ambitious mass rollout LP SWH Programme in 2009. However, the initiative had limited success and failed to meet the target of one million systems installed by the end of 2015 (Worthmann et al. 2017). Only 380 000 units were installed country-wide by 2017. Most of these systems installed in South Africa are low quality systems imported cheaply from China.

Table 15: Low Pressure Solar Water Heaters Technology assessment

Cost	Medium
Installation	Requires north-facing rooftop without significant shading. Can be installed by plumber with the necessary qualifications. No back-up element is required so no electrical installation is needed.
Risks	Low quality products with short life expectancy gives the technology a bad name. The rebate programme resulted in high levels of corruption and threats to government employees.
Standards	SANS standards for solar water heating systems
Existing policy tools	Some South African manufactured systems ordered by DMRE in storage in various warehouses.
Potential policy tools	Rebate
Cost and administrative burden	High

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[8] These include standards for solar collectors (flat plate, tube, and PVT), whole solar thermal systems, storage tanks, and controllers. https://keymark.eu/en/products/solar-thermal-products

4.8 DIRECT PHOTOVOLTAIC WATER HEATING SYSTEMS

Electricity generated by PV can be conducted directly to heating elements in geysers. In some ways this is analogous to a SWH, but without the extra installation and maintenance issues of plumbing water to collectors on the roof that may freeze, overheat or corrode. In the case of multi-storey buildings, running wires down from the roof to the geyser also ensures that the hot water is closer to the tap as is the case with hot water piping. This has the added benefit of reducing installation costs and reducing unsightly piping.

The PV module is the same as the one used for standard PV systems generating electricity. The electrical connection work is, however, simpler than wiring a PV system for household electrical consumption as the installation does not include an inverter. The direct current (DC) power from the PV panels is converted to heat via a maximum power point tracker (MPPT). The PV panels and DC element can be installed by a plumber with the necessary qualification and an electrician with a DC wiring license. When set point reached, there's lost PV production.

Table 16: PV Water Heating Systems Technology Assessment

Cost	Medium high: R19 000 excluding the geyser[9]
Installation	Installed by an electrician with DC qualifications Installed on a north facing roof with minimal shading Only wires from the roof to the geyser, so less installation cost and less heat losses in the pipes (and less waiting for the hot water to arrive at the tap) Needs to be installed with a timer to optimise solar heating
Risks	Low solar fraction could negatively impact the utility of the technology Incorrect installation can create a DC arc which may create a fire and/or damage the equipment
Standards	No known specific standards, but all standards for electric wiring applicable
Ease of use	If correctly sized, correctly installed and if the timer is optimally set, the system needs minimal manual intervention (manual intervention is also easy) Will provide hot water during power cuts
Existing policy tools	SANS 10400 XA2
Potential policy tools	Expand SANS 10400 XA2 to home transfers
Cost and administrative burden	High for rebate and other incentive schemes Low for expansion of 10400 XA2

This is a relatively new use of PV in South Africa. However, several companies are already offering this technology[10] [11]. The system can be installed with an existing geyser with the alternative current (AC) element either kept as additional backup or replaced with the DC element. Controlling the elements to prioritize PV electricity is important to reduce grid electricity use, so this technology should also be installed with a timer.

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[9] Adrie Fourie, Marloes Reinink, and Sara Demartini. "In-Depth Assessment of Water Efficiency Opportunities in South Africa." CLASP, January 2021. https://storage.googleapis.com/clasp-siteattachments/South-Africa-Water-Efficency-Report.pdf.

[10] https://www.geyserwise.com/our-products/pv-water-heating-systems/

[11] Estimate numbers source from industry interviews.

There are over 25 000 of these systems already installed in South Africa, with over 7 000 installed in 2022 alone[12]. Most of these systems are installed in new multi-story developments.

Solar PV panels that convert sunlight to electricity have a significantly lower efficiency per area than solar thermal collectors that convert sunlight to heat. These PV to heat systems would thus have to cover a significantly larger area on the roof (at least three times larger for the same amount of heat).

The SANS standards for SWH includes a minimum system size of 50 liter of tank size per person with each bedroom equalling two persons, with the collector size per storage size indicated by the geographic area of the installation. As these PV water heaters do not have a similar size limit, the PV panels most often have a lower energy potential that would have been required by the SANS standard for a solar thermal collector. As these new developments often do not have an occupancy of two persons per bedroom, it might be that the energy saving from these PV panels are sufficient for their application.

The ISO 9459 Solar Heating - Domestic Water Heating Systems standard can likely be applied to this water heating system. Field performance is likely better than SWH, especially given the reduced level of maintenance required.

4.9 INDIRECT PHOTOVOLTAIC AND TIMER SWITCH

Installing a photovoltaic (PV) system on a residential rooftop with an inverter and battery allows consumers to offset some of the energy use by geysers. In most systems, geysers are connected as a non-essential load, which do not draw power from the battery, therefore indirectly supplying the geyser. Most batteries are sized to supply essential loads (such as lighting, entertainment, IT and security) during load shedding periods (2-4 hours) and evening. Water heating happens primarily at the times of day when there is not much solar resource. The controls on the inverter and geyser will have to be coordinated to send excess PV electricity to heat water.

Table 17: PV, Inverter and Battery Technology Assessment

Cost	High
Installation	Requires suitable rooftop location with limited shading and space Installed by certified electricians
Risks	Unless controls are set properly, will not provide much water heating
Ease of use	Installer will set controls to prioritize geyser heating during daylight hours
Existing policy tools	Tax incentives
Potential policy tools	DSM incentives to link PV system with geyser thermal storage demand
Cost and administrative burden	High for rebate and other incentive schemes

4.10 LOW-FLOW SHOWERHEADS AND TAPS

One intervention to reduce hot water use is low-flow showerheads. Low flow showerheads are designed to reduce the amount of water flow while still providing an adequate shower experience. With a low flow showerhead, less hot water is used per minute, resulting in less energy needed to heat water overall. This can lead to substantial energy savings, especially in homes where water heating is a significant portion of

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[12] https://www.sustainable.co.za/products/geyserwise-offgrid-pv-solar-water-heating-kit?variant=4089862 7272897

the energy bill. Technologies are readily available to reduce water used in showers by from about 15 l/m to 7.5 l/m. A recent assessment of water efficiency opportunities in South Africa shows that low-flow showerheads could lead to up to 17.6 TWh/yr of energy savings potential (Fourie et al, 2021).

Equipment and installation costs would be low, from about R80 to R800, depending on the type of showerhead. Implementing this technology would have the additional benefit of reducing water consumption. The water savings will provide additional savings for consumers.

Consumers will not accept showerheads which do not perform satisfactorily. Low-flow showerheads only make sense if a performance requirement is included. Examples of this sort of performance criteria exist in Australia and the US.[13]

Adapting existing standards to South Africa and developing manufacturing, testing and certification capabilities may take longer than is appropriate for this project, however, the experience with low-flow showerheads in Cape Town during the recent drought there should be considered in the standards process. The City of Cape Town water bylaw restricts the water flow from shower heads to 10 liters per minute and that of taps to 6 liters per minute.

Table 18: Low flow shower heads and taps

Cost	Low – R50 – R1 000 depending on type and quality
Installation	Easy – can be done by the homeowner as no plumbing skills or special tools needed (this is also a disadvantage as the technology can also easily be replaced by a higher flow unit)
Risks	Low quality products on the market
Ease of use	Easy to install and no user intervention needed after installation
Existing policy tools	City of Cape town Water Bylaw
Potential policy tools	Bylaws and building regulations
Cost and administrative burden	Reasonably low (bylaws, regulations written, approval, enforcement)

5. SIMULATED INTERVENTIONS

A limited number of interventions were selected for simulation. The interventions will be presented in the following order:

- Piping insulation
- Reducing element rating
- Controlled switching
- Electricity tariff and incentives
- PV indirect

Each intervention is simulated with a forecasted penetration estimating the rate of adoption within a 10-year period. The results from each intervention are presented as a 24-hour load profile with hourly averaged power demand values and compared against the 2023 baseline (Scenario Baseline-1) and 2033 baseline (Scenario Baseline-2). Higher time resolution load profiles illustrating the dynamics in the system and impacts of interventions are presented in Annex 9.4. System dynamics are more prevalent in interventions

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[13] SANS 10252-1:2018, Water supply and drainage for buildings Part 1: Water supply installations for buildings

augmented by an external switch and in these cases the higher time resolution load profiles would be greatly beneficial.

Difference curves are developed to show the difference between 2033 baseline load profile and the 2033 intervention profile. These difference curves indicate whether the intervention will increase or decrease demand from the 2033 baseline, and what the change in impacts on demand are for the proposed intervention. If the difference curve indicates a zero value for an hour, it means that no change is expected from the 2033 baseline. If the difference curve shows a negative value, demand is reduced and if it shows a positive value, demand is increased.

For each intervention, a table summarising each set of scenarios for interventions is also presented. The hourly averaged maximum demand is reported for each load profile within the 24-hour period and the associated After Diversity Maximum Demand (ADMD). The hour of the maximum demand can change depending on the scenario considered. The prediction for total annual energy consumption due to residential water heating is provided. Finally, a user comfort level for potential hot water service is also reported. This metric provides a percentage of geysers in the simulation that have hot water below 40°C at the outlet, to give an indication of the possibility of unserviceable hot water.

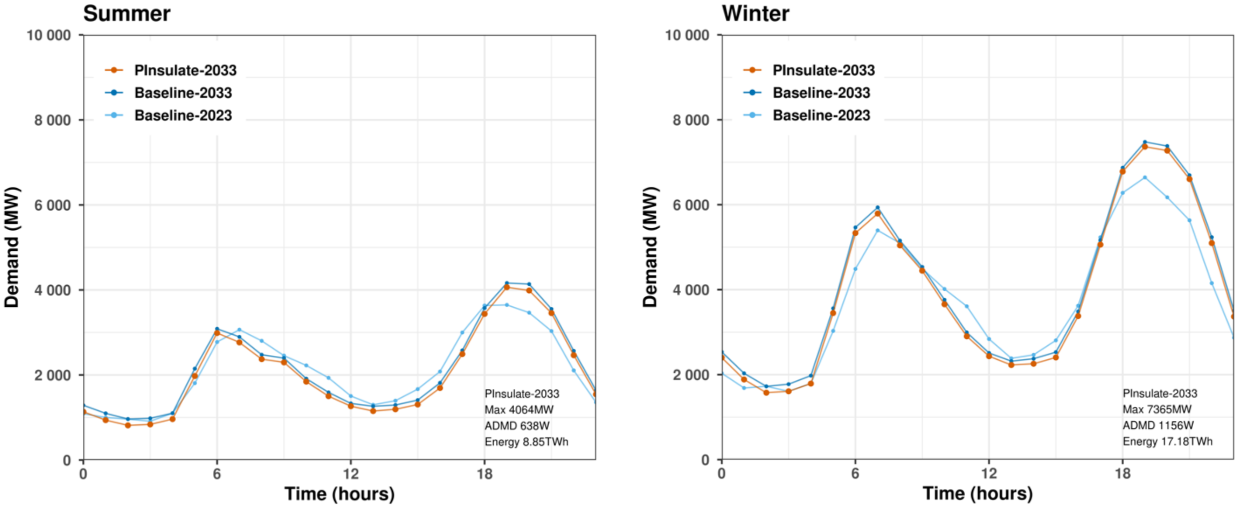
5.1 PIPING INSULATION SIMULATION

Heat losses through the pipes connecting to a geyser have an impact on the overall energy efficiency of the tank. Regulations to insulate pipes up to 1-m from the geyser tank connection exist but are not widely implemented in most installations.

Pipe losses are simulated for each geyser as discussed in Section 3.3.3. Pipe insulation is simulated by reducing the pipe losses to half. Pipes losses are simulated for changing ambient temperatures. Other environmental factors such as windchill and impact of enclosures are not included. For the ten-year forecast, the simulation considers the full adoption of this intervention by 2033 with 100% penetration.

The simulated results for this intervention are presented in Figure 13 (a) and (b) for typical summer and winter days. The comparison of the 2033 intervention with 100% adoption against the 2033 baseline shows a uniform reduction of demand for all 24 hours. With the full adoption of this intervention, benefits and savings are passively observed on the system. Figure 14 shows the difference curve for this intervention.

Figure 13: Simulated results for pipe insulation intervention in national geyser population against baseline for 2023 and 2033 (a) Summer forecast (b) Winter forecast.



(a) Scenario Pipeloss-1: Insulation of pipes 100% (Summer).

(b) Scenario Pipeloss-1: Insulation of pipes 100% (Winter).

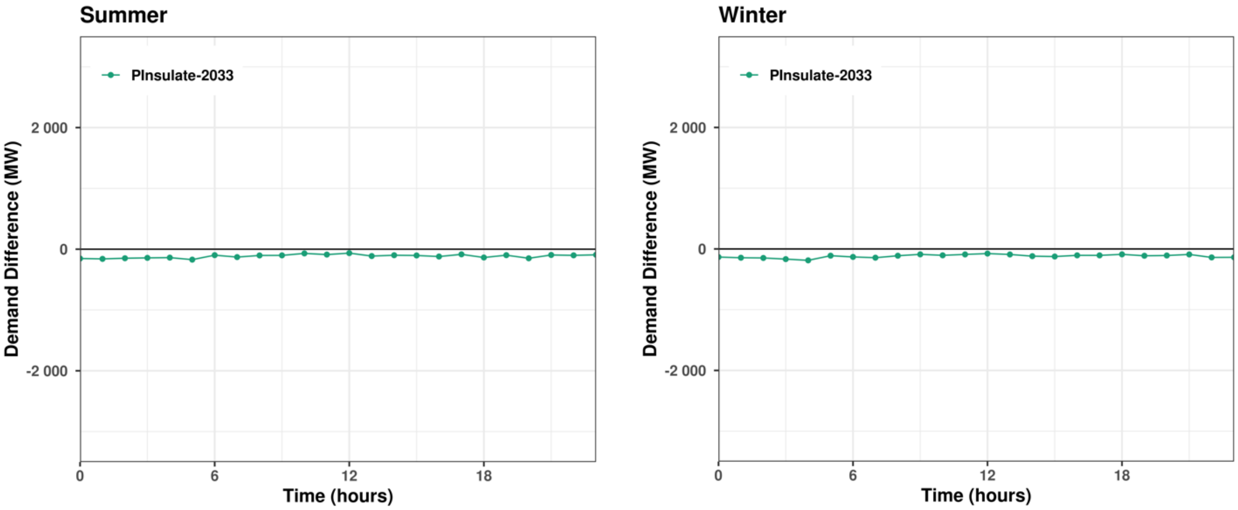
The overall summary of results for the pipe insulation intervention (Scenario Pipeloss-1) are presented in Table 19 with the user comfort, maximum demand, ADMD and annual energy. The comparison of the 2033 intervention with 100% adoption against the 2033 baseline shows an overall reduction in energy demand for the full 24-hour period. This results in a reduced maximum demand, ADMD and energy consumption of 1.1 TWh in 2033. The user comfort is not affected by this intervention.

The hourly difference in demand between 2033 pipe insulation intervention and 2033 baseline is presented in Table 4 for summer and winter. Both trends show similar uniform reductions in summer and winter for the full 24-hour period.

Table 19: Summarised results for impact of pipe insulation intervention indicating the maximum demand [MW] and ADMD [W] for summer and winter and annual energy [TWh].

Simulated Scenario		User Comfort [%]	Hourly Averaged Max Demand [MW]		After Diversity Max Demand (ADMD) [W]		Energy Consumption [TWh]	
Scenario	**Description**	**S/W**	**Summer**	**Winter**	**Summer**	**Winter**	**Annual**	**Change**
Baseline-2033	No action, IEP Plan, Year 2033, 6.4M	100/100	4 163	7 478	653	1 173	27.1	-
Interventions forecasted for Year 2033								
PInsulate-2033	Insulate pipes up to 1-m from tank at 100% penetration	100/100	4 064	7 365	638	1 156	26.0	-1.1

Figure 14: Demand difference of pipe insulation intervention against 2033 baseline.



(a) Demand difference for pipe insulation intervention: Scenario Pipeloss-1 (summer).

(b) Demand difference for pipe insulation intervention: Scenario Pipeloss-1 (winter).

With 100% adoption of this intervention, there is a low impact observed in maximum demand and energy metrics. However, this is a passive effect which requires no active monitoring, which aggregated over a year could result in an estimated 1.1 TWh of energy savings.

5.2 REDUCING THE GEYSER ELEMENT RATING SIMULATION

The element rating in geysers has an impact on the speed at which water is heated in the thermal storage tank. A larger element rating heats water faster, whereas a smaller element rating heats water slower. An intervention to reduce the element rating in the geysers for a significant population is expected to “flatten” the aggregated peak demand and therefore reduce the strain on the power grid.

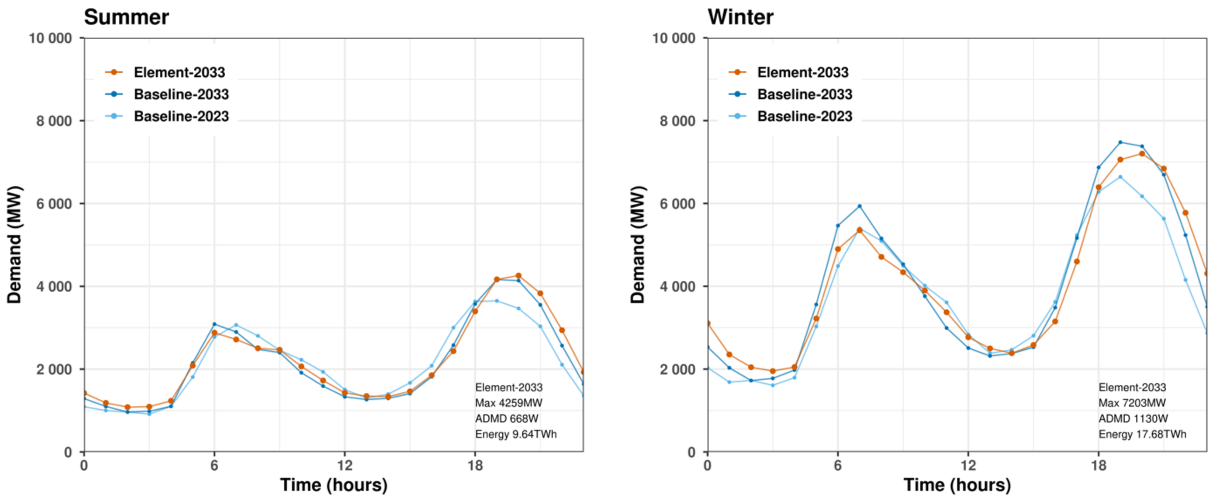
The proposed changes in element ratings are presented in Table 20, using readily available element ratings currently on the market. Element ratings considered reduce by 1kW for the 200-litre and 150-litre geyser systems, whereas 100-litre and 50-litre systems remain unchanged. For the ten-year forecast, it is simulated that this intervention is fully adopted by 2033.

The simulated results for intervention to reduce the element ratings are presented in Figure 15 (a) and (b) for typical summer and winter days. The comparison of the 2033 intervention with 100% adoption against the 2033 baseline shows a reduction peak demand for the morning and evening peak and a slightly longer peak duration. In summer, the evening peak demand is shifted above 2033 levels at an hour delay. An additional benefit to this intervention with a 30% PV penetration included in the 2033 baseline forecast shows the morning shifted peak can be absorbed by the rooftop PV generation since sun is more available at this time of the day. The pattern is more pronounced in the winter months than the summer months.

Table 20: Element rating changes and distribution for 2023 and ten-year forecast for 2033.

Geyser (litres)	Element Rating (kW)	Share (%)	Intervention adoption (2023)	Intervention adoption (2033)
200	4 to 3	15	0%, same as 2023 baseline	100%
150	3 to 2	75		
100	2, no change	10		

Figure 15: Simulated results for intervention reducing element ratings in national geyser population against baseline for 2023 and 2033 (a) Summer forecast (b) Winter forecast.



(a) Scenario Element-1: Reduce elements at 100% penetration (Summer).

(b) Scenario Element-1: Reduce elements at 100% penetration (Winter).

Table 21: Summarised results for impact of element rating intervention indicating the maximum demand [MW] and ADMD [W] for summer and winter and annual energy [TWh].

Simulated Scenario		User Comfort [%]	Hourly Averaged Max Demand [MW]		After Diversity Max Demand (ADMD) [W]		Energy Consumption [TWh]	
Scenario	**Description**	**S/W**	**Summer**	**Winter**	**Summer**	**Winter**	**Annual**	**Change**
Baseline-2033	No action, IEP Plan, Year 2033, 6.4M	100/100	4 163	7 478	653	1 173	27.1	-
Interventions forecasted for Year 2033								
Element-2033	Reduce element ratings at 100% penetration	99/92	4 259	7 203	668	1 130	27.3	+0.2

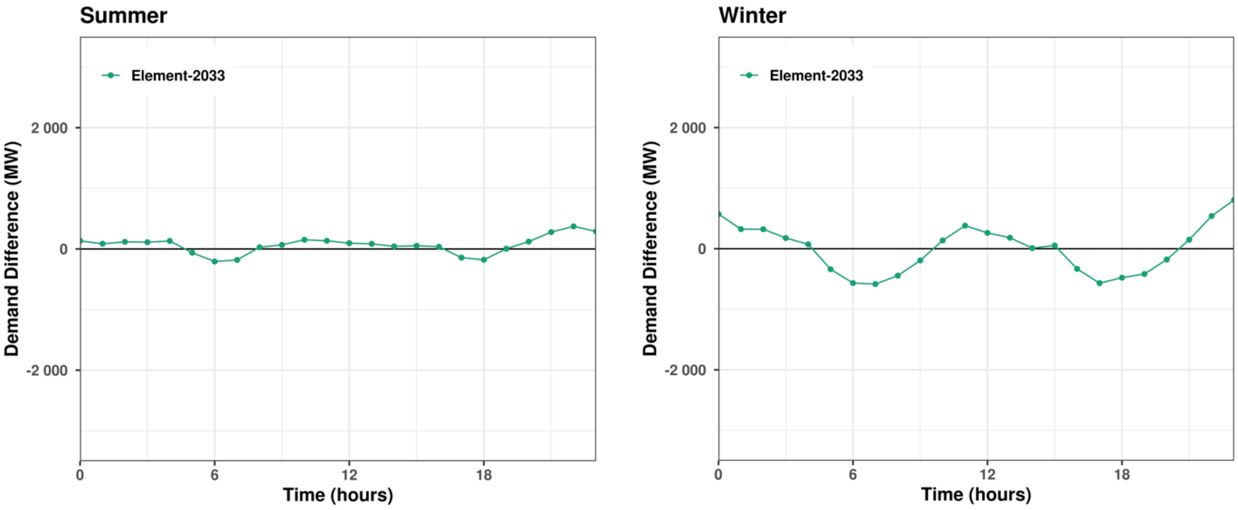
The overall summary of results for the reduction in element ratings intervention (scenario Element-1) are presented in Table 34 with the user comfort, maximum demand, ADMD and annual energy. The impacts of this fully-adopted intervention has the potential to passively reduce morning and evening peaks and elongate the peak period. Overall, this intervention will result in a slightly elevated annual energy consumption (0.2TWh).

The impact of the intervention on summer months on user comfort is minimal, with 99% of geysers supplying water temperatures above 40°C for all draw events. However, the reduction of element ratings has a much greater impact on winter hot water usage, resulting in 92% of geysers supplying hot water at user comfort levels.

The hourly difference in demand between 2033 element intervention and 2033 baseline is presented in Figure 16 (a) and (b) for summer and winter. The summer trend indicates a slightly increased demand for most of the day and a reduction during Eskom morning and evening peaks when hot water demand is highest. The winter trend follows a similar pattern, reducing demand during Eskom morning and evening peak, but increases demand outside of these times.

With 100% adoption of this intervention, it is suggested that peak periods are positively impacted. The trade-off of this intervention is the reduced level of hot water service in winter months.

Figure 16: Demand difference of element rating intervention against 2033 baseline.



(a) Demand difference for element rating intervention Scenario Element-1 (summer).

(b) Demand difference for element rating intervention Scenario Element-1 (winter).

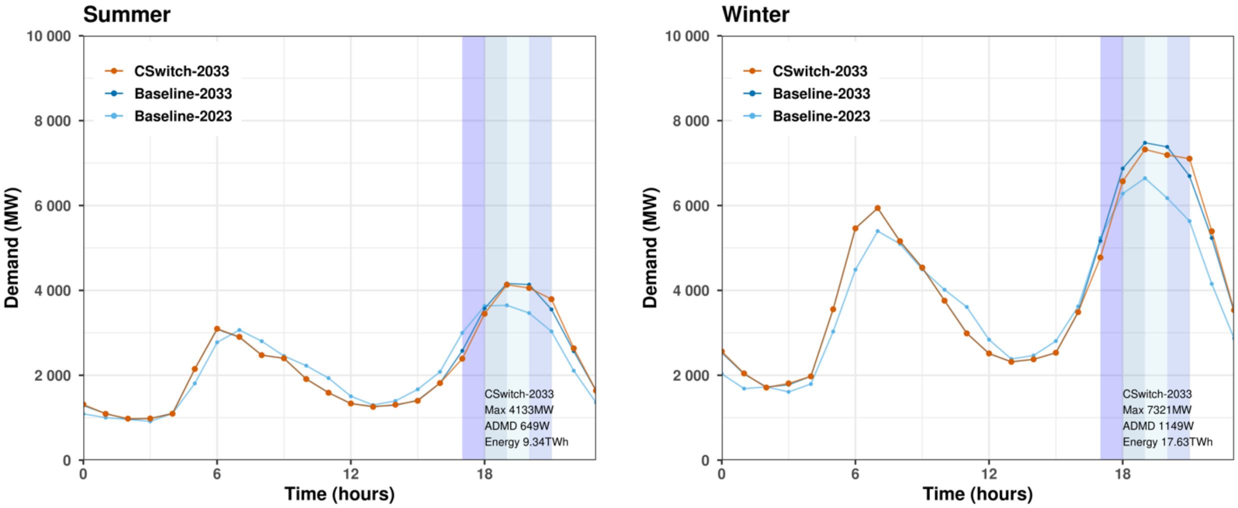
5.3 CONTROLLED SWITCHING SIMULATION

Legacy "ripple control" systems are considered an option for revitalisation and their benefit includes the restoration of existing systems. The usage of relay switches has the potential for high impact; however, if all switches are synchronized to fixed times, there is an unintended consequence of a high restorative load due to a high coincidence of geysers turning on at the same time. A coordinated approach to controlling the switches can reduce the restorative load, similar to the "ripple control" scheme used at the municipal level. This intervention is not limited to the usage of the legacy ripple control system, but rather represents a control mechanism with centralised control, such as a municipality or aggregator.

The controlled switch scenario is simulated with 30% geyser penetration. For the evening peak period (17:00-21:00), one quarter of the 30% switched geysers are sequentially turned off each hour and returned the next hour, i.e. the first quarter turn off at 17:00 and return at 18:00, the second quarter turn off at 18:00 and return at 19:00, and so on.

The simulated results for intervention with 30% controlled switches are presented in Figure 17 (a) and (b) for typical summer and winter days. Each shaded bar represents an hour that a quarter of the intervened population is turned off. As the hour ends, that quarter is returned to service and the next quarter is turned off. The comparison of the 2033 intervention shows a slight reduction in evening maximum demand with an extended peak duration after 21:00. The trend is more pronounced in winter.

Figure 17: Simulated results for controlled switching intervention in 30% of the geyser population against baseline for 2023 and 2033 (a) Summer forecast (b) Winter forecast.



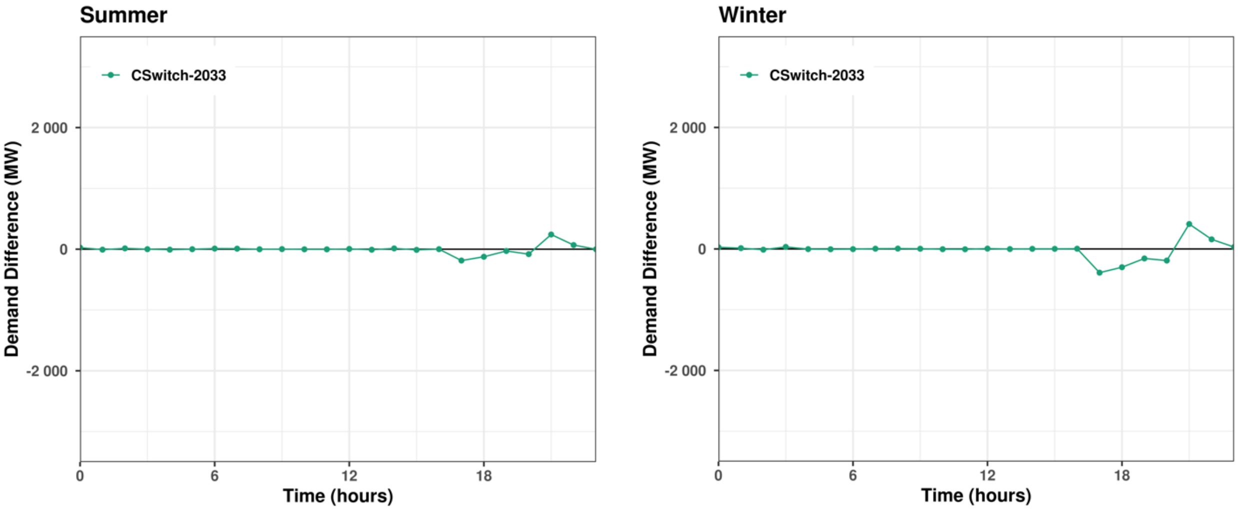
(c) Scenario ControlSwitch-1: Controlled switching 30% (Summer).

(d) Scenario ControlSwitch-1: Controlled switching 30% (Winter).

Table 22: Summarised results for impact of controlled switching intervention indicating the maximum demand [MW] and ADMD [W] for summer and winter and annual energy [TWh].

Simulated Scenario		User Comfort [%]	Hourly Averaged Max Demand [MW]		After Diversity Max Demand (ADMD) [W]		Energy Consumption [TWh]	
Scenario	**Description**	**S/W**	**Summer**	**Winter**	**Summer**	**Winter**	**Annual**	**Change**
Baseline-2033	No action, IEP Plan, Year 2033, 6.4M	100/100	4 163	7 478	653	1 173	27.1	-
Interventions forecasted for Year 2033								
CSwitch-2033	30% penetration of controlled switches	100/99	4 133	7 321	649	1 149	27.0	-0.1

Figure 18: Demand difference of controlled switching intervention against 2033 baseline.



(a) Demand difference for controlled switching intervention: Controlled switching 30% (summer).

(b) Demand difference for controlled switching intervention: Controlled switching 30% (winter).

The overall summary of results for the controlled switch intervention (scenario ControlSwitch-1) are presented in Table 22**.** with the user comfort, maximum demand, ADMD and annual energy. The comparison of the 2033 intervention with 30% adoption against the 2033 baseline shows a slight reduction in demand during the switching period with a slightly elevated demand after the switching period. User comfort is minimally affected, with 99% of geysers at water temperatures above 40°C in winter. Interestingly, energy is reduced in this scenario by 0.1TWh.

The hourly difference in demand between the 2033 controlled switch intervention and 2033 baseline is presented in Figure 18 (a) and (b) for summer and winter. Both trends show similarly uniform reductions in summer and winter for the full 24-hour period.

This intervention is directly comparable with Scenario TOU-3 (Section 5.4), where the evening demand reduction is much lower and the restoration effects are not as extreme. The evening peak demand of 7 321 MW is below Scenario TOU-1 peak demand of 7 520 MW with a 10% switch penetration. The effects of this intervention are more moderate than the Time-of-Use scenarios, and require a considerable level of coordination and consumer acceptance for successful implementation.

Interestingly, the impact of this intervention follows a similar trend to the 100% adoption of element reductions in Scenario Element-1 (Section 5.2). The results from the simulations suggest that the load shifting effects of this highly coordinated and controlled intervention with 30% penetration, can be replicated with a 100% adoption of element reductions that has a passive impact.

This intervention is effective for municipalities that are distributed at Megaflex tariffs and sell at a flat residential rate.

5.4 ELECTRICITY TARIFF AND INCENTIVES SIMULATION

The heat storage capability of the electric water heaters enables load shifting opportunities for the appliance. This means that the load demand from the grid does not need to be synchronized with the consumer's usage of the appliance, and heating up the storage tank can be delayed, with minimal impact to the service of the appliance. This delay could be incentivized with Time-of-Use tariffs and the use of externally controlled switches.

To aid utilities with reducing demand during peak times, externally controlled switches, such as time-controlled switches installed at a residential distribution board or product offerings with more advanced controls, can be used to prevent geysers from turning on during peak demand times. Incentives for consumers to participate could include a Time-of-Use tariff, where consumers are incentivized to remove load demand during times that the grid is strained. An important distinction between this switching strategy and the ripple control solution in Section 5.3 is that consumers are in control of the switch and can sporadically opt out of the switching scheme, if required.

Five TOU scenarios are considered with different TOU periods and varying percentages of the population participating in the intervention as summarized in Table 23.

Table 23. TOU Scenarios Description

Scenario	Elements kept off during Eskom peak times		Population Adoption Rate
	Morning	Evening	
TOU-1	06:00-09:00	17:00-21:00	10%
TOU-3	06:00-09:00	17:00-21:00	30%
TOU-4	None	17:00-22:00	10%
TOU-5	None	17:00-22:00	30%

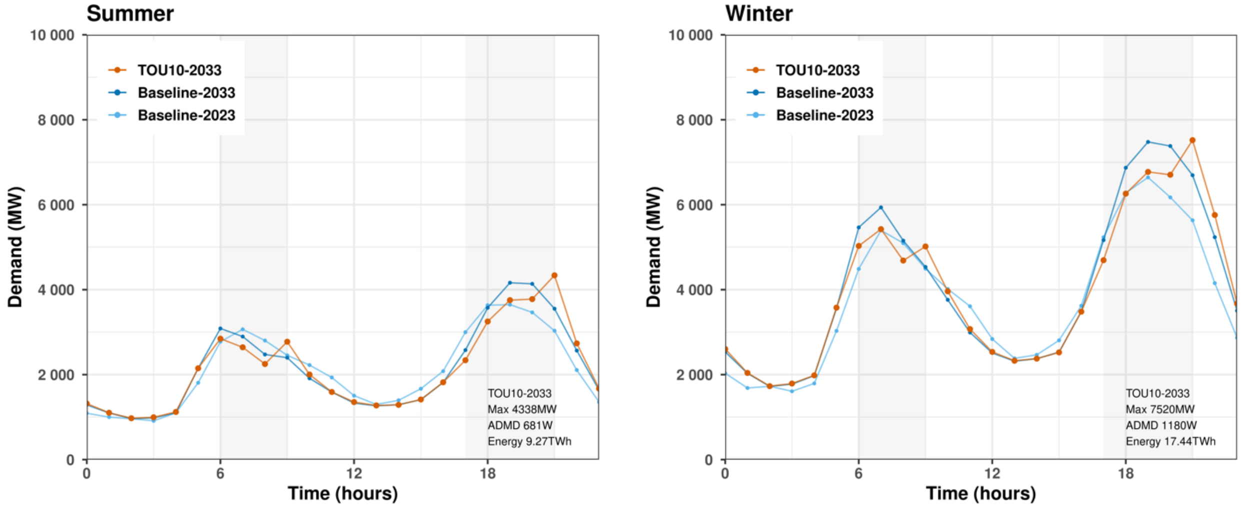
For each scenario, the impact of the intervention in 2033 is compared with baseline scenarios for 2023 and 2033 for summer and winter. Included in the load profiles is a grey-shaded area for times that the external switch keeps the elements off.

In TOU-1, the results of the simulation in Figure 19 (a) and (b) show the total impact of water heating load on the grid for typical summer and winter profiles.

For scenario TOU-3, there is a 30% penetration of external switches set to keep elements off during morning peak (06:00-09:00) and evening peak (17:00-21:00). The results of the simulation in Figure 19 (c) and (d) show the total impact of water heating load on the grid for typical summer and winter profiles.

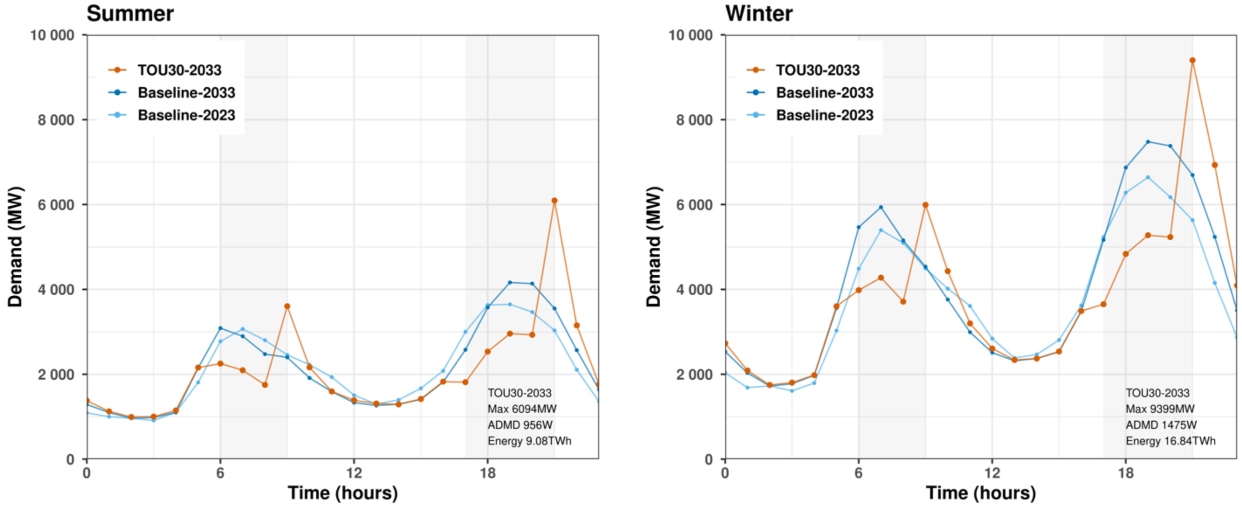
If the evening peak is of greater concern, an extended evening peak scenario is considered with external switches set to keep elements off during the evening for the period of 17:00-22:00 for 10% penetration (scenario TOU-4) and 30% penetration (scenario TOU-5). The results of the simulation in Figure 20 (a)-(d) show the total impact of water heating load on the grid for typical summer and winter profiles.

Figure 19: Simulated results for Time-of-Use intervention with elements off for Eskom peak times (06:00-09:00) and (17:00-21:00) (a) summer forecast (b) winter forecast.



(a) Scenario TOU-1: 10% penetration of switches, elements off morning and evening peak (summer).

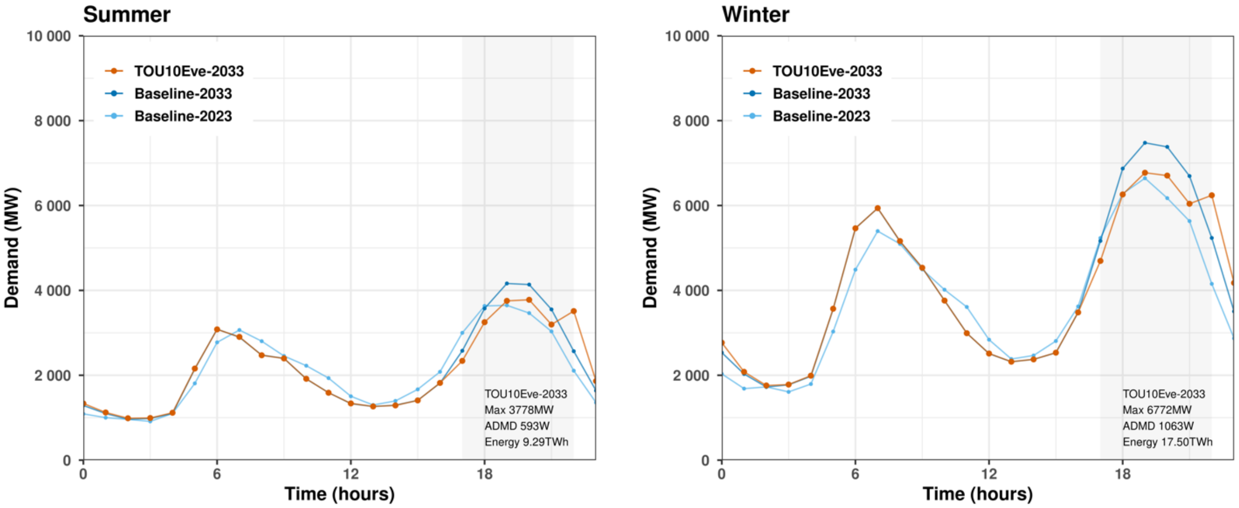
(b) Scenario TOU-1: 10% penetration of switches, elements off morning and evening peak (winter).



(c) Scenario TOU-3: 30% penetration of switches, elements off morning and evening peak (summer).

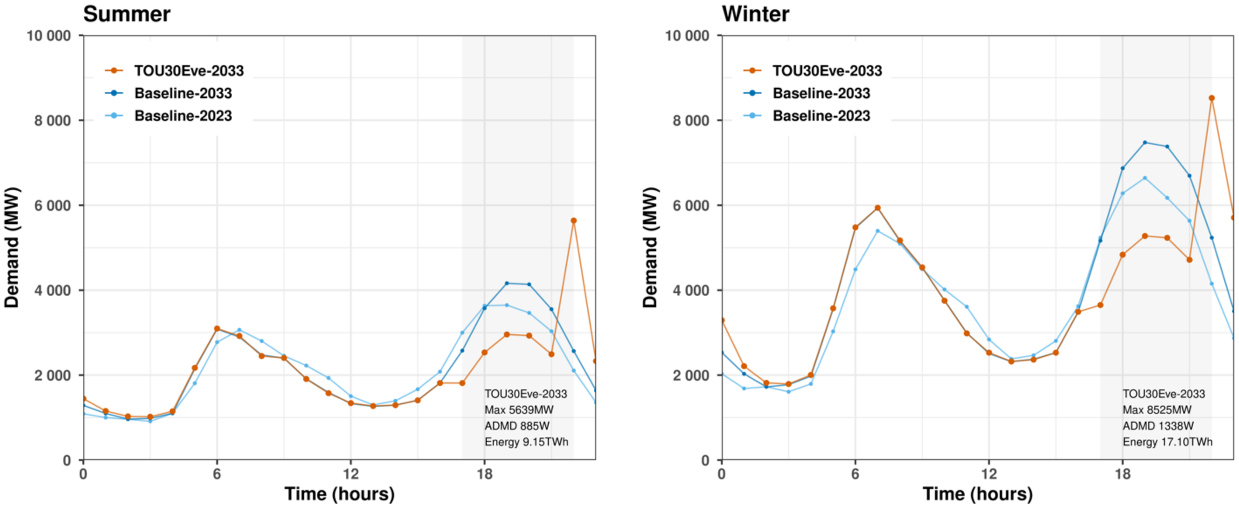
(d) Scenario TOU-3: 30% penetration of switches, elements off morning and evening peak (winter).

Figure 20: Simulated results for Time-of-Use intervention with elements kept off during extended evening duration (17:00-22:00) with a varying percentage of populations in national geyser population against baseline for 2023 and 2033 at minute time resolution (a) summer forecast (b) winter forecast.



(a) Scenario TOU-4: 10% penetration of switches, elements off extended evening peak (summer).

(b) Scenario TOU-4: 10% penetration of switches, elements off extended evening peak (winter).



(c) Scenario TOU-5: 30% penetration of switches, elements off extended evening peak (summer).

(d) Scenario TOU-5: 30% penetration of switches, elements off extended evening peak (winter).

Table 24: Summarised results for impact of TOU intervention indicating the maximum demand [MW] and ADMD [W] for summer and winter and annual energy [TWh].

Simulated Scenario		User Comfort [%]	Hourly Averaged Max Demand [MW]		After Diversity Max Demand (ADMD) [W]		Energy Consumption [TWh]	
Scenario	**Description**	**S/W**	**Summer**	**Winter**	**Summer**	**Winter**	**Annual**	**Change**
Baseline-2033	No action, IEP Plan, Year 2033, 6.4M	100/100	4 163	7 478	653	1 173	27.1	-
Interventions forecasted for Year 2033								
TOU-1	10% switch, elements off morning and evening peak	99/98	4 338	7 520	681	1 180	26.7	-0.4
TOU-3	30% switch, elements off morning and evening peak	99/94	6 094	9 399	956	1 475	25.9	-1.2
TOU-4	10% switch, elements off evening extended	99/98	3 778	6 772	593	1 063	26.8	-0.3
TOU-5	30% switch, elements off evening extended	99/95	5 639	8 525	885	1 338	26.3	-0.8

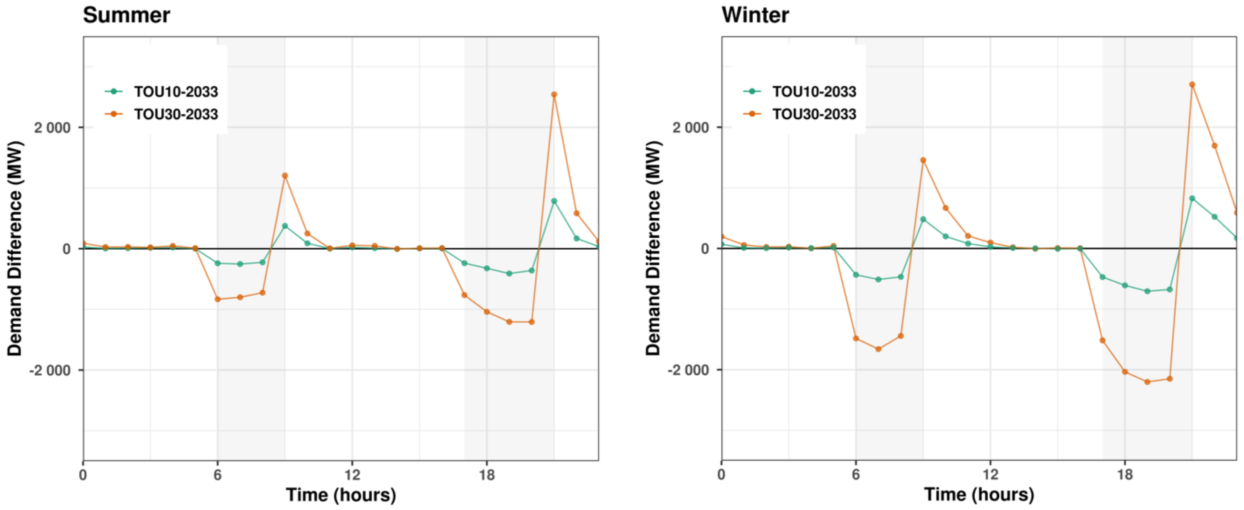
The overall summary of results for scenarios TOU-1 to TOU-5 are presented in Table 24 detailing the user comfort, maximum demand, ADMD and annual energy. For all TOU scenarios, the user comfort is relatively unaffected during summer months, with 99% of geysers supplying water temperatures above 40°C for all draw events. The user comfort levels drop to range between 94-99% in winter, requiring a manual override for specific geysers for households that experience a lack of hot water service.

The hourly difference in demand between 2033 TOU interventions and 2033 baseline is presented in Figure 21 (a)-(d) for summer and winter. The demand difference for timers set for elements off during Eskom morning and evening peak (Scenario TOU-1 and TOU-3) are presented in Figure 21 (a) and (b), with a grey shaded area for periods that elements are kept off. The 10% and 30% switch penetration have uniform impact on the load reductions and restorative load. The effects of the winter restorative load are evident 4 hours after the TOU period, whereas in summer, the effects are evident after 2 hours.

The energy reductions observed can be due to the shifted load in the morning peak, where the PV systems are absorbing a portion of the restorative load from 10am onwards. The PV system has forecasted to increase 30% penetration by 2030 in the baseline scenario. The highest energy reduction is seen with Scenario TOU-3, as 30% of the elements are shifting morning load.

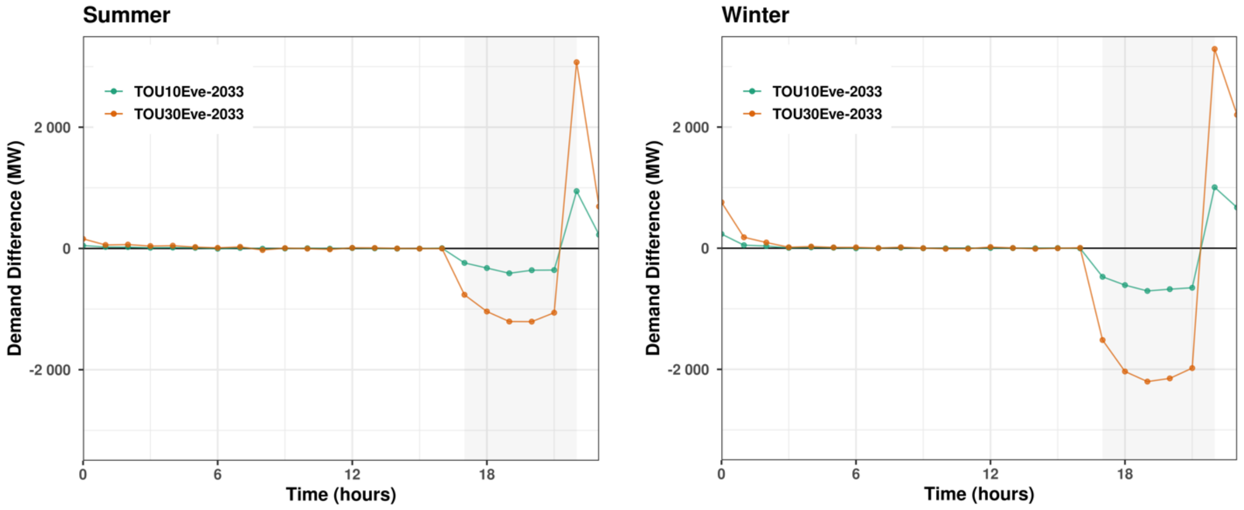
The demand difference for timers set for elements off during extended evening peak (Scenario TOU-4, and TOU-5) are presented in Figure 21 (c) and (d), with a grey shaded area for periods that elements are kept off. For the longer period that elements are kept off, the restorative load is significant, especially for the 30% penetration scenario (TOU-5). In winter, the effects of the restorative load are evident 5 hours after the TOU period.

Figure 21: Demand difference of TOU interventions against 2033 baseline.



(a) Demand difference for TOU interventions for Eskom morning and evening peak, Scenario TOU-1 - TOU-3 (summer).

(b) Demand difference for TOU interventions for Eskom morning and evening peak, Scenario TOU-1 - TOU-3 (winter).



(c) Demand difference for TOU interventions for extended evening peak, Scenario TOU-4 & TOU-5 (summer).

(d) Demand difference for TOU interventions for extended evening peak, Scenario TOU-4 & TOU-5 (winter).

Two timing-schemes are considered in the ten-year forecast period, with varying penetrations of external switches participating in a TOU tariff scheme. In all cases, peak demand can be greatly reduced, with the consequence of a high restorative load when elements are turned back on. The larger the penetration of TOU participation, the greater the restorative load for the hour after the TOU period. The introduction of TOU tariffs may introduce a significant loss of diversity to the system and result in high restorative loads as TOU periods subside. This loading pattern is likely evident with the return of load shedding periods, where many more loads are brought back onto the system at the same time; all thermally controlled appliances (air conditioners) and inverters will introduce similarly high restorative loads to the system.

5.5 PV, INVERTER AND BATTERY SIMULATION

The residential rooftop PV market was initially considered to be relatively small in early 2023; however, with the introduction of a tax incentive and continued load shedding residential, installations have grown significantly, with 5GW[14] of panels imported for the year. As load shedding continues, and products become financially accessible to households to leverage their electricity bills against a financed PV system for energy security, it becomes more likely that the rooftop PV market will see growth. On this basis PV could not be ignored as a factor, and especially for the period up to 2033, and has therefore been included in the baseline scenario.

Geyser load demand with a PV rooftop installation can be modified with the addition of a switch control to time the replenishment of the heat storage when solar energy is available and keep energy stored in batteries for essential loads during the evening and nighttime. The simulations presented in this section capture the day-to-day solar energy inputs from Global Horizontal Irradiation (GHI) but do not include fluctuations due to rainy days and days with high cloud cover. The scenarios for this intervention are considered as described in Table 25 – PV Scenarios Assumptions.

Table 25 – PV Scenarios Assumptions

Scenario	PV Penetration	Switch Off Periods	
		Morning	Evening
PVTOU	Baseline - 30% PV penetration	06:00-09:00	17:00-21:00
PVDay	Baseline - 30% PV penetration	Off all time except from 10:00-15:00	
PVHighEst	35% PV penetration (5 % above baseline)	Off all time except from 10:00-15:00	
PVLowEst	25% PV penetration (5 % below baseline)	Off all time except from 10:00-15:00	

An effective strategy to shift load with the presence of rooftop PV is to defer the water heating load using an external timer switch. Two time-strategies are considered in the simulations: 1) a conservative approach, where the switches keep the element off only during Eskom peak durations (scenario PVTOU) and 2) a more proactive approach, where elements are kept off for all times except during the day between 10:00-15:00 (scenario PVDay, PVHighEst and PVLowEst). The augmented switching strategies for each of the scenarios are considered for the full 30% of geysers with PV penetration. The times that the external switch keeps the elements off is indicated by the grey-shaded area in Figure 22.

The conservative switching approach for scenario PVTOU, presented in Figure 22 (a) and (b), demonstrates that residential water heating demand can be reduced during daylight hours and during the Eskom peak times.

The proactive switching approach for scenario PVDay, presented in Figure 22 (c) and (d), demonstrates that significant residential water heating demand could be removed during the day and night. The results of this intervention can reduce overall demand to levels below 2023 demand. There is a slight peak

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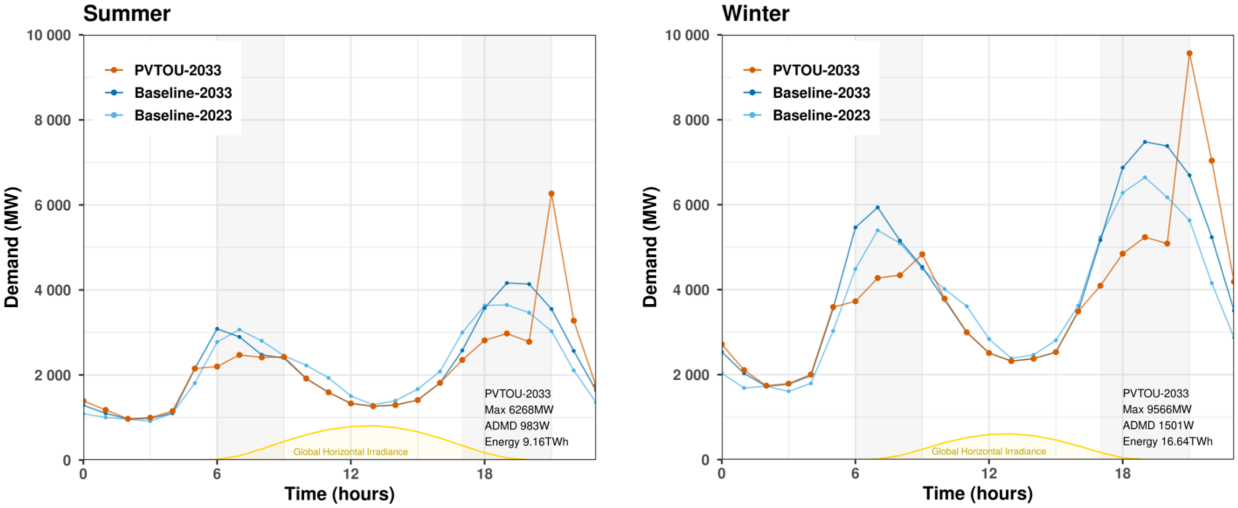
[14] https://dailyinvestor.com/energy/45761/south-africa-imported-r17-5-billion-of-solar-panels-in-2023/

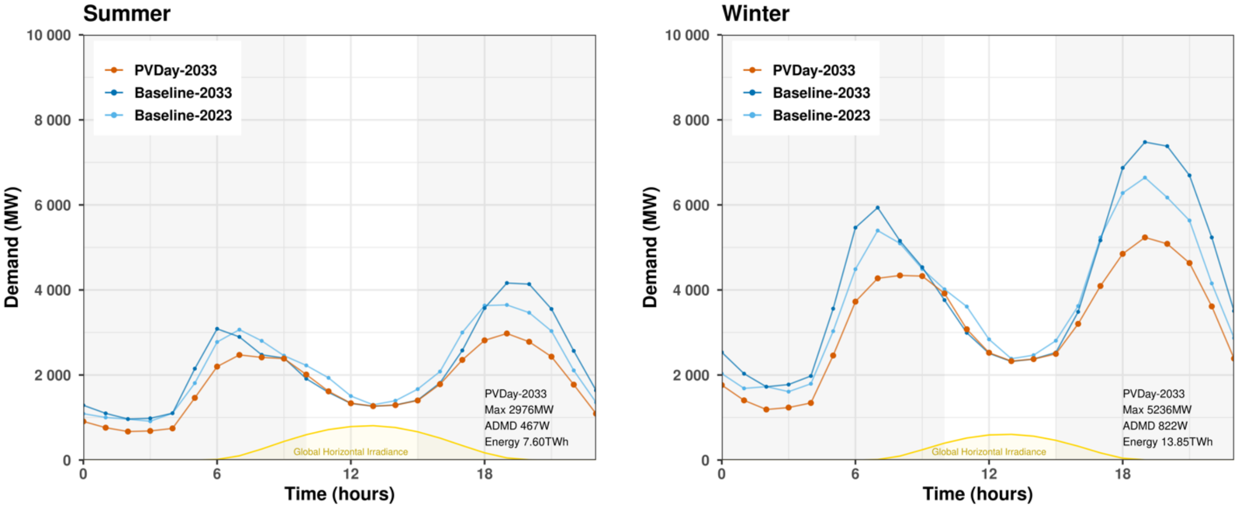
observed at 10:00, when elements can draw from the grid, and it indicates that not all geyser load is supplied by the rooftop PV generation. Individual households can adjust this time to suit the specific rooftop solar installation to defer more load onto the rooftop PV generation.

Figure 22: Simulated results for PV interventions scenario PVTOU and PVDay, summer and winter hot water usage profiles for 30% PV penetration augmented with an external switch in 2033.



(a) Scenario PVTOU: 30% PV penetration augmented with elements off between 06:00-09:00 and 17:00-21:00 (Summer).

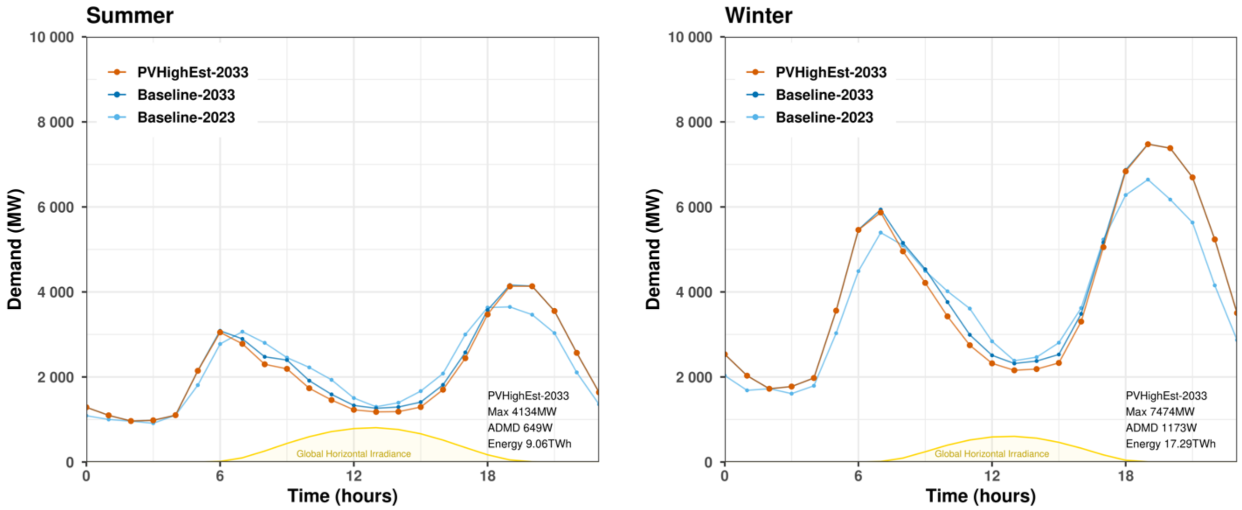
(b) Scenario PVTOU: 30% PV penetration augmented with elements off between 06:00-09:00 and 17:00-21:00 (Winter).



(c) Scenario PVDay: 30% PV penetration augmented with elements off between 15:00-10:00 (Summer).

(d) Scenario PVDay: 30% PV penetration augmented with elements off between 15:00-10:00 (Winter).

Figure 23: Simulated results for PV intervention scenario PVHighEst, summer and winter hot water usage profiles for increase to 35% PV penetration in 2033.

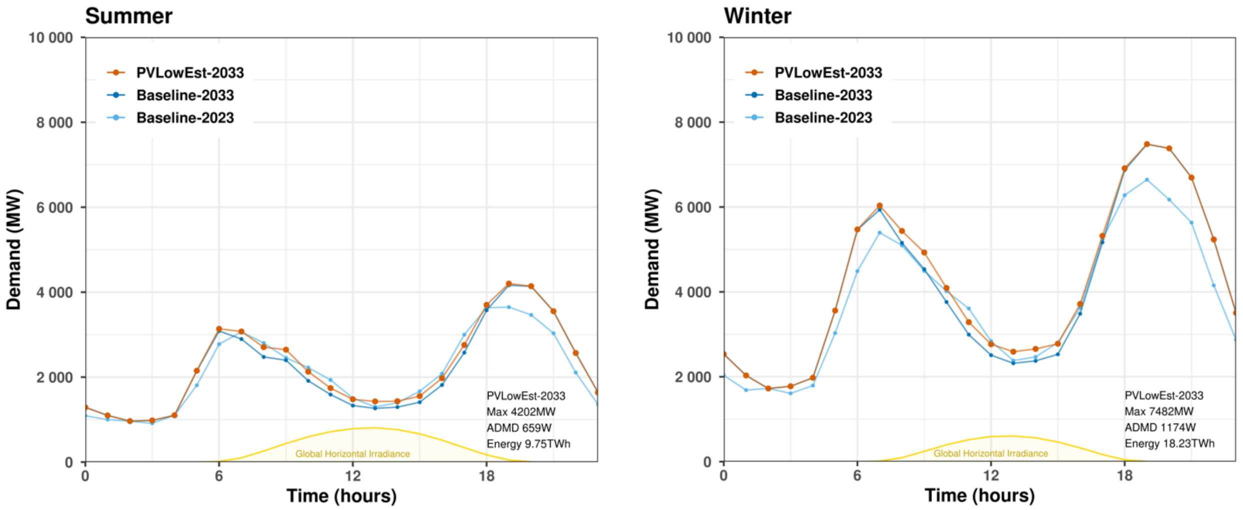


(a) Scenario PVHighEst: Increase PV penetration to 35% (Summer).

(b) Scenario PVHighEst: Increase PV penetration to 35% (Winter).

The first PV intervention scenario (PVHighEst) demonstrates a change from 14% PV penetration from 2023 baseline to an increase to 35% PV penetration in 2033. The results of the simulation in Figure 23 (a) and (b) show the total impact of water heating load removed from the grid during the day due to rooftop PV supply. The load profiles for summer and winter show that there is a potential to reduce day-time water heating load to approximate 2023 demand levels. The night-time water heating load remains the same as the 2033 baseline. The energy required for heating the geysers during the day is supplied by an external source and therefore, in this scenario, consumers could expect to have the same access to hot water service as the baseline for a sunny day.

Figure 24: Simulated results for intervention scenario PVLowEst, summer and winter hot water usage profiles for increase to 25% PV penetration in 2033.



(a) Scenario PVLowEst: Increase PV penetration to 25% (Summer).

(b) Scenario PVLowESt: Increase PV penetration to 25% (Winter).

The final simulated PV scenario (scenario PVLowEst) provides the less optimistic PV penetration of 25%. There is an observable increase in day-time load in comparison to the 2033 baseline because of this reduced penetration in PV. If the IEP plan is unsuccessfully implemented, or residential PV growth is disrupted, a lower day-time impact is expected.

The overall summary of results for the PV interventions (scenarios PVTOU, PVDay, PVHighEst and PVLowEst) are presented in

Table 26 detailing the user comfort, maximum demand, ADMD and annual energy. For scenario PVHighEst, the user comfort is unaffected for both summer and winter months with 100% of geysers supplying water temperatures above 40°C for all draw events. For scenario PVTOU, the user comfort levels drop to 99% in summer and 93% in winter. For scenario PVDay, the overall power demand and energy consumption is greatly reduced, but at the trade-off of overall user comfort, with summer levels at 87% and winter levels at 76%. While this switching scheme has great potential to vastly reduce water heating demand from the grid, the switching will need to be customized to specific households or allow manual overrides.

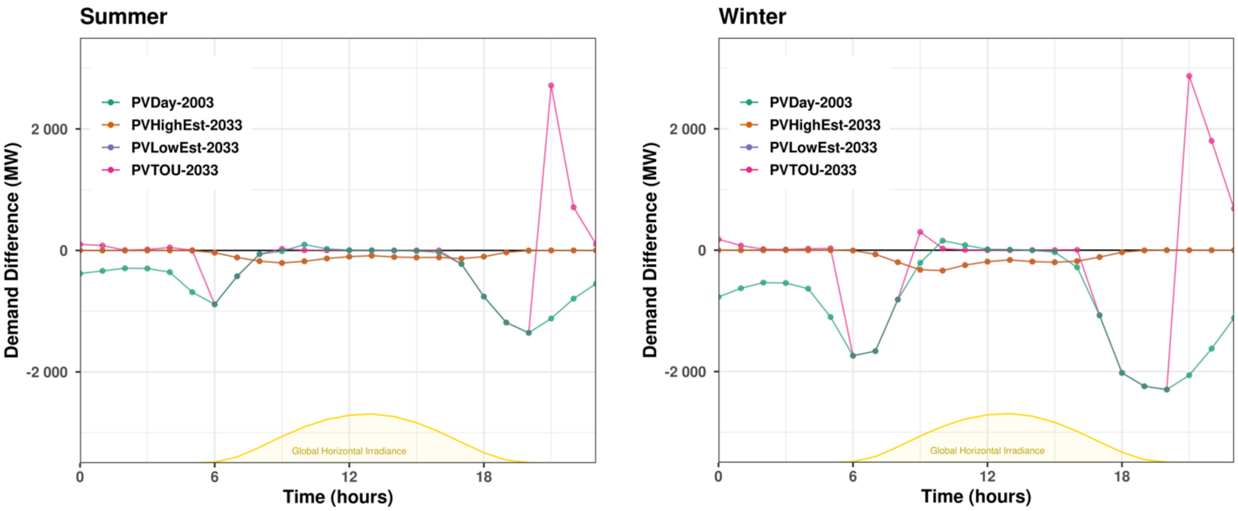
The hourly difference in demand between 2033 PV interventions and 2033 baseline is presented in

Figure 25 (a) and (b) for summer and winter. In all three scenarios, it is evident that the majority of the demand difference curves are negative, indicating that demand is reduced from the baseline. All four scenarios also demonstrate a reduction that follows the averaged GHI curve, indicating that the roof-top PV generation is supplying water heating demand before it is required from the grid.

Table 26: Summarised results for impact of PV intervention indicating the percentage user comfort, maximum demand [MW] and ADMD [W] for summer and winter and annual energy [TWh].

Simulated Scenario		User Comfort [%]	Hourly Averaged Max Demand [MW]		After Diversity Max Demand (ADMD) [W]		Energy Consumption [TWh]	
Scenario	**Description**	**S/W**	**Summer**	**Winter**	**Summer**	**Winter**	**Annual**	**Change**
Baseline-2033	No action, IEP Plan, Year 2033, 6.4M	100/100	4 163	7 478	653	1 173	27.1	-
Interventions forecasted for Year 2033								
PVTOU	30% PV, switch off at Eskom peak	99/93	6 268	9 566	983	1 501	25.8	-1.3
PVDay	30% PV, switch on during day	87/76	2 976	5 236	467	822	21.4	-5.7
PVHighEst	Increase to 35% PV penetration	100/100	4 134	7 474	649	1 173	26.3	-0.8
PVLowEst	Only 25% PV penetration reached	100/100	4 202	7 482	659	1 174	28.0	+0.9

Figure 25: Demand difference of PV interventions against 2033 baseline.



(a) Demand difference for all PV interventions (summer).

(b) Demand difference for all PV interventions (winter).

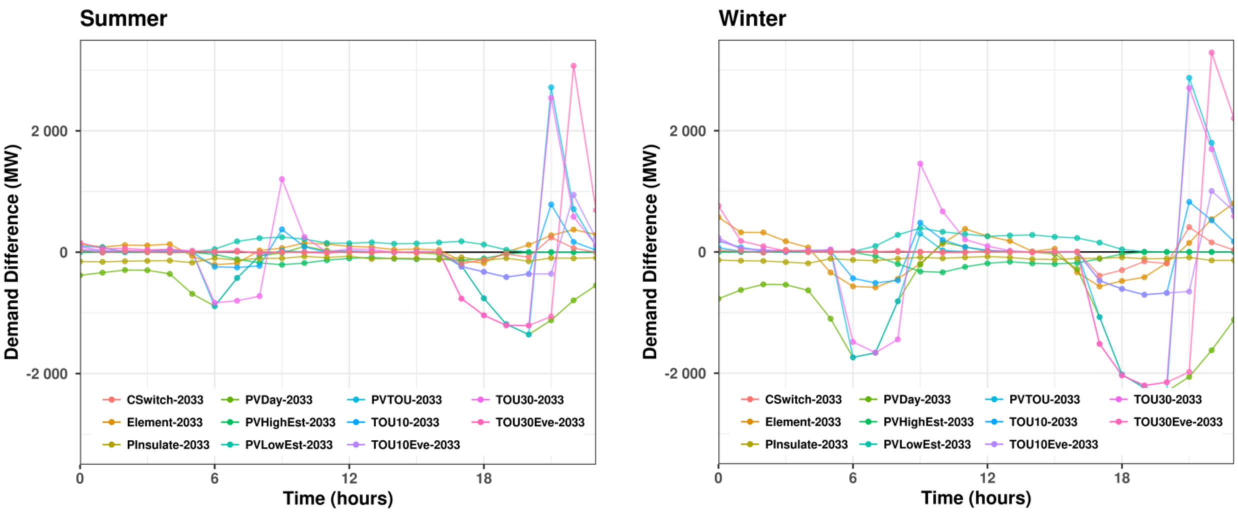
The interventions require higher demand than the baseline for scenario PVTOU after the evening peak for both summer and winter and has a similar pattern to Scenario TOU-30, with the morning restoration load offset by solar PV production. For Scenario PVDay at 10:00, the available PV supply is unable to overcome total demand due to water heating.

Two-factor PV interventions are represented for the ten-year forecast period: an increase in residential rooftop PV; and the augmentation of an external switch. In all cases, day-time demand can be vastly reduced. Switch augmentation, particularly the proactive case of keeping elements off between 15:00-10:00, has the potential to vastly reduce overall residential water heating demand to below 2023 levels. While the proactive switching approach for scenario PVDay suggests promising impacts, the important caveat to note from these switching scenarios is that user comfort is the lowest for both summer and winter. For any switching scheme to work, consumers need to have control of the switch and have access to opt-out on specific days to ensure water heating service can be met within the household.

6. DISCUSSION AND RECOMMENDATIONS

A combined demand difference profile for all interventions against the 2033 baseline is presented in Figure 26 (a) and (b) for summer and winter. All interventions except Scenario PVLowEst demonstrate a reduction in overall demand (below the zero mark). Scenario PVLowEst shows a higher overall demand as it represents a lower penetration of PV rooftop installations compared to the baseline. The interventions that have a large impact on reducing demand during peak times have the consequence of high restorative loading effects, except PVDay.

Figure 26: Combined demand differences for all interventions against 2033 baseline.



(a) Demand difference for all interventions (summer).

(b) Demand difference for all interventions (winter).

Table 27: Summary of impacts for each scenario.

Scenario	Adoption	Demand	Energy	Comment
Baseline comparisons, 10-year forecast of geyser load	-	Increase ↑ (non-daylight hours)	Increase ↑	Additional 1.2M geysers simulated to increase maximum demand by 800 MW.

Scenario	Adoption	Demand	Energy	Comment
		Decrease ↓ (daylight hours)		30% penetration of PV expected to reduce day-time load.
Piping insulation	100%	Minor decrease ↓ (all hours)	Decrease ↓	Passive overall savings can be expected.
Reducing the geyser element	100%	Decrease ↓ (peak times)	Minor increase ↑	Passive peak demand reduction.
Controlled switching (Ripple relay)	30%	Decrease ↓ (peak times)	Decrease ↓	Active control, low impact for 30% adoption rate, but could be beneficial for municipalities. Similar impact to reducing element ratings.
Electricity tariff and incentives	10-30%	Major decrease ↓ (peak times), with major consequences	Decrease ↓	Offers load shifting opportunities, but come-back load consequences.
PV, inverter and battery	30-35%	Decrease ↓ (daylight hours)	Decrease ↓	Opportunity for switch augmentation to shift load during day-time hours. Collaboration with customers required for extreme switching measures.

The results from this study indicate that several strategic approaches can be considered for demand-side management of electric water heaters to reduce overall demand and energy consumption from the electrical power grid.

6.1 REGULATION

The interventions that are enacted through regulation have the potential for widespread adoption and the possibility of 100% penetration within 10 years. The interventions are discussed as follows:

- Insulation of pipes connecting to the geyser for up to 1m length (Scenario Pipeless-1 in Section 5.1)
- Reduction of element rating (Scenario Element-1 in Section 5.2)

Scenario Pipeloss-1*:* The assumptions used for estimating standing losses through pipes of geyser installations in the field and the savings expected from pipe insulation have been derived from limited measurements. The results from this study suggest that 100 MW reduction can be achieved for all hours of the day and 1 TWh could be reduced annually by 2033. A more comprehensive study is suggested for refining the input assumptions. The regulation to insulate pipes connecting to a geyser installation exists. It is suggested to enforce the regulation through insurance replacement and incentive structure.

Scenario Element-1: The reduction in element ratings has the potential to passively reduce maximum demand during peak times. The results from this study suggest that it has a similar load profile to Scenario ControlSwitch-1 with 30% penetration. The advantage over the controlled switch scenario is its passive impact. The user comfort levels are minimally affected due to slower heating rates. This intervention can be rolled out through new manufactured geysers and implemented through replacements.

6.2 INCENTIVES

The interventions that are enacted through incentives have lower penetration forecasts but have the potential for high impact. The interventions are discussed as follows:

- Controlled switch (Scenario ControlSwitch-1 in Section 5.3)
- Time-of-Use tariffs and external switch (Scenario TOU-1 – TOU-5 in Section 5.4)
- Indirect water heating load reduction through rooftop PV augmented with external switch (Scenario PVTOU – PVLowEst in Section 5.5)

Scenario ControlSwitch-1**:** The controlled switching scenario is a coordinated switching scheme using centralised control and is designed to lower the high restorative load expected from many synchronised geysers returning to grid supply. At a 30% penetration, this study suggests that it has a similar impact to the reduction of element ratings for 100% of the population. It remains a beneficial strategy for municipalities.

Scenario TOU-1 – TOU-5**:** The results from this study suggest that deferring water heating loads with external switches is a very effective strategy to reduce maximum demand during peak times. The major challenge is the restorative load with the synchronised return of lower tariffs signalling geysers to draw from the grid. This model can allow Eskom and municipalities to communicate in relation to the EEDSM programme. Introducing diversity when power is returned can reduce the peak of the restorative load. Additionally, restorative load after 21:00 corresponds to low demand and excess generation capacity on the overall system.

Scenario PVTOU – PVLowEst: An increase of rooftop PV is forecast for the next 10 years as load shedding continues and consumers opt for electricity security. It may also be a more advantageous option for consumers in lieu of solar water heaters. The rate of increase is uncertain and the major driving factor will be load shedding as the tax incentive was terminated in March 2024. The advantage of the increase in rooftop PV is that water heating load (which can also be extended to residential loads) can be offset from the power grid during solar production hours. The results from this study suggest that 2033 forecast at 30% PV penetration has the potential to reduce day-time water heating demand to below 2023 levels.

The potential reduction in overall demand for PV and augmented switch combination has the potential for high impact. The switch augmentation will have an impact on user comfort levels, and user control for manual override may result in higher levels of consumer acceptance. The extreme switching scheme would be incentivised by higher electricity bills.

7. CONCLUSION

No single action or technology exists that can reduce load shedding by solving how water heating contributes to increased peak demand in South Africa. Instead, a comprehensive approach is needed, often referred to as a "policy package." A policy package entails combining various strategies, regulations, incentives, and enforcement mechanisms to reduce energy consumption and optimize load management. As distributed solar rooftop PV are increasingly installed in residential households, there is an opportunity to better manage load demand to optimize available resources. Regulation plays a crucial role in setting standards and guidelines for energy usage, efficiency, and sustainability. Enforcement mechanisms ensure that regulations are followed and penalties are imposed for non-compliance. Incentives are essential for encouraging desired behaviors and investments. These can take various forms, such as tax credits, subsidies, rebates, and time of use tariffs. In the context of demand-side management, incentives may encourage consumers to adopt energy-efficient technologies, such as smart thermostats or energy-efficient water heating, or to participate in demand response programmes.

In summary, addressing the challenges of sustainable energy and demand-side management requires a comprehensive policy package that combines regulations, enforcement, and incentives to promote energy efficiency and renewable energy integration, including solar PV rooftop systems. There is no one-size-fits-all solution, but rather a combination of measures tailored to the specific context and needs of each region or jurisdiction.

8. REFERENCES

(2022) Tariff & Charges Booklet 2021/2022, Eskom, www.eskom.co.za/distribution/tariffs-and-charges*.*

Brederode, W (2023) "Eskom releases statistics showing SA's solar surge, but with a slightly misleading label", News24.com, 2023/07/31.

Common domestic Solar PV package specifications (extract 2023/12/06) GoSolr, https://www.gosolr.co.za/products/residential*.*

Communities in south 55frican traditional houses, Energy vol. 21, no. 12, pp. 1101-1106, 1996.

Consumption, demand and profiles Seminar, Eskom RT&D, Nov 2014.

Covary, T. (2015). Electric Water Heaters (South Africa) . BigEE.

Cruise, M (2023), Growth of SA Residential Solar Market and impact on our load & generation future, SAIEE Load reseach Chapter 2023/09/19, https://www.saiee.org.za/displaycustomlink.aspx?name=LRCMedia

CPUT (2009) *M&V guideline for geyser insulation distribution*. Eskom M&V workshop by Cape Peninsula University of Technology.

d'Hotman D, (2023), "Fewer than 4% of SA homes have adopted solar, but it is growing fast", bizcommunity, 2023/11/27.

Dekenah M et Al, (2014), Domestic Electric Loads:

Designing incentives towards adoption of sustainable agriculture practices in South African fruit and wine sectors, Western Cape Government, www.elsenburg.com/wp-content/uploads/2022/03/2015-Market-Demand-for-Solar-PV.pdf

Domestic LR data extract (2023) (Selected sites, year 2000, Anonymised) from NRS LR database, personal communication, M Dekenah, Marcus Dekenah Consulting.

Engel W & Wagner N, (2015), Market demand for solar PV:

Eskom 2024. Demand Side - 5Y Data Request. Eskom Data Portal. *https://www.eskom.co.za/dataportal/*

Forlee C (1998), Water heating in SA: Facts and figures from 1997 notch testing, Proc DUEE pp265-270 ,1998.

Fourie Adrie, Marloes Reinink, and Sara Demartini, "In-depth Assessment of Water Efficiency Opportunities in South Africa" JANUARY 2021, https://www.clasp.ngo/wp-content/uploads/2021/01/South-Africa-Water-Efficency-Report-1.pdf

Industry interviews (2023)

IOL, 2023. "Load shedding stages are simple to reduce, claims minister" Published Jun 4, 2023 in Independent Online (IOL), South Africa's news and information website. https://www.iol.co.za/business-report/energy/load-shedding-stages-are-simple-to-reduce-claims-minister-0c98c995-b56d-4a51-9d24-7ed0bde4d090

ISO, 2019. International Organization for Standardization (ISO) 19967-1:2019: Heat pump water heaters — Testing and rating for performance — Part 1: Heat pump water heater for hot water supply. https://www.iso.org/standard/66761.html

ITS, 2024. ITS Heat Pumps and Solar (Pty) website. https://itssolar.co.za/products/heat-pumps/

J. P. Meyer JP, Tshimankinda M,(1996), Domestic hot water consumption by developing

Jacobs, S (2023), "South African solar boom", Daily investor, 2023/09/15.

LBNL, 2020 https://eta-publications.lbl.gov/sites/default/files/south_africa_appliance_energy_efficiency_sl_impacts._final_february_2020_1.pdf

McNeil, Michael A., Covary, Theo, and Vermeulen, John. Water Heater Technical Study to Improve MEPS - South Africa. 2015. https://eta.lbl.gov/publications/water-heater-technical-study-improve

McNeil. (2015). Energy and GHG Savings. LBNL. Report can be provided from authors

Meyer JP (2000), A review of domestic hot-water consumption in South Africa, R & D Journal, 16(3) pp55-61,2000.

Meyer JP, Tshimankinda M (1998), Domestic hot-water consumption in south african apartments, Energy Vol. 23, No. 1, pp. 61–66, 1998.

Meyer JP, Tshimankinda M, Domestic hot-water consumption in south african townhouses, Energy Convers. Mgmt Vol. 39, No, 7, pp. 679-684, 1998

Pandarum, A., Lekoloane, G.A. and Milazi, D.B.K. (2019). Trends and statistics of Solar PV distributed generation in South Africa. In: The Sustainability Energy Resource Handbook. South Africa Volume 9: The Essential Guide, pp. 19-25

SA Gov, 2022. "National Energy Crisis Committee of Ministers briefs media on National Energy Crisis", Media briefing by the National Energy Crisis Committee of Ministers, 01 Aug 2022, https://www.gov.za/news/media-statements/national-energy-crisis-committee-ministers-briefs-media-national-energy

SABS, 2021. South African National Standard, The application of the National Building Regulations. Part X: Environmental sustainability, Part XA: Energy usage in buildings. SANS 10400-XA:2021

Edition 2, November 2021. South African Bureau of Standards. https://www.uj.ac.za/wp-content/uploads/2023/11/sans-10400-xa-the-application-of-the-national-building-regulations-environmental-sustainability-energy-usage-in-buildings-2021.pdf

SARB, 2023, https://www.resbank.co.za/content/dam/sarb/publications/monetary-policy-review/2023/MPROCT23Internet.pdf

SAWB hourly weather AMR stations national, 2003-2005 (aggregated) (2023), personal communication, M Dekenah, Marcus Dekenah consulting.

Statistical release P0301.4, 2023, Stats SA

Stats in Brief (booklet (2011), Stats SA.

Stats in Brief (booklet (2021), Stats SA

Stats in Brief (booklet) (1996), Stats SA

Stats in Brief (booklet) (2001), Stats SA

The SA consumer in brief (BMR HH income classes defined) (2016), Standard bank, SALGA Council of Mayors, https://www.salga.org.za/SALGA%20Council%20of%20Mayors%20Web/Presentations.html

UCT, 2024 Study on Residential Load To Maximise Demand Side Management Impact. Report for SANEDI.

Van Vuuren DS, van Zyl HJD, Veck GA (2004), Payment strategies and price elasticity of Demand for water for different income Groups In three selected urban areas, WRC Report No 1296/1/04, ISBN No 1-77005-194-5.

Walsh K (2023), Review of administered prices in South Africa Water tariffs: Special OBEN 2301, SARB.

Worthmann Shaun, Ognyan Dintchev and Cedric Worthmann (2017) South African Low Pressure Solar Water Heating Mass Rollout Programme and Its Impacts on Carbon, Energy Engineering, 114:4, 47-66, DOI: 10.1080/01998595.2017.11876935

9. ANNEXES

9.1 ANNEX 1 - DEFINITIONS

The following definitions are necessary as authorities refer to demographics on different bases:

Household: A household consists either of one person living alone or a group of persons, who live together and whose expenditure on food and other household items is jointly managed (Stats SA). As such, a "household" is a largely social construct, invisible from air and untracked by local administration.

Dwelling: A dwelling is any structure intended or used for human habitation (Stats SA). Therefore, a storeroom and an abandoned house may in some circumstances be a 'dwelling'. Dwellings can usefully be identified by aerial survey & photo interpretation.

Erf (plural - Erven): A piece of land registered in a deeds registry as an erf, lot, plot or stand. The term is of Afrikaans origin. In many informal township areas, the concept of 'erf' can be troublesome to evaluate; because land is not registered, apparent borders may shift dependent upon building-on of existing structures over time. This may also be seen as ad hoc–subdivision.

Electrical supply / connection: Formal electricity supply to an erf by a legal authority.

Living Standard Measure (LSM): This is a marketing and research tool, similar to a social economic class, used in South Africa to classify standard of living and disposable income. It segments population based on their relative means, with LSM 1 being the decile with the least means and 10 with the greatest means. It does this by ranking people based on ownership of the components of a standard basket of goods (which varies over time). For instance, those people who owned a television set would rank higher in the LSM than those who did not.

Differentiation between Household, Dwelling and Erven: From the above definitions, a 'Household' is a social construct, useful for surveying and marketing. A household is not a home. A household is composed of people and determines the use of hot water. Thus, a dwelling can contain several households, or a single household can share several dwellings. One or more dwellings (and thus household/s) are situated on an erf (plot). An "erf" is normally the common point of supply coupling for electricity and water. Utility metering for the collection of revenue in SA is largely conducted at erf-level.

Typical average ratios for these measures for all HH above LSM 6 in SA are *1.78 HH/Dwelling, 1.13 Dwellings/Erf, and thus 2.02 HH/Erf.*

Such a model becomes less clear in high density informal areas (i.e., urban), as erven property boundaries are not formally registered and no title deeds exist.

These distinctions are important because answers to questions such as "What portion of population has access to electricity" vary depending on basis of reporting. SA is reported to have electrification around 90%, however at a household level, fewer households actually report the use of electricity for lighting at night. Access to electricity is linked to network extension and maintenance. Electricity use, however, is linked to appliance ownership and affordability.

In the segmentation that follows, Census 2019 data is used as the base (as circulated in Stats SA, 2021), which reports 17.16m households in SA.

9.2 ANNEX 2 - SEGMENTATION OF HOT WATER GEYSER OWNERSHIP IN SOUTH AFRICA

The objective of this segmentation study is to provide prudent assumptions as a resource to drive Geyser simulation studies, for the period 2023-2033.

Assumptions are provided in the following focus areas:

- Dwelling peak period demand and consumption
- Breakdown by housing types (Stats SA definition)
- Estimate of population, households, dwellings, and erven
- Estimate of national Geyser stock, replacements, demand for new geysers
- Estimate penetration by domestic PV systems (by size and scenario)
- Estimate of reduction in hot water use over time (i.e., price elasticity)

- All by province, climate zone, and year (2023-2033)

Base data was collated from various sources (Census, academic research, commercial research, media releases) and analysed to derive a view in a baseline year (generally in the 2019-2021) range. The view was then extrapolated (using a growth model for the SA population derived by inspection of the previous two censuses and intervening GHS surveys) and stated for years 2023 & 2033.

Data from SA Statistics (Stats SA, 2019) has been used to estimate the stock of domestic hot water geysers by location (province and city), type of house, access to water and access to electricity.

9.2.1 Domestic households by housing type and Province

Segmentation of South Africa domestic households by dwelling type and Province is shown in Table 28: SA demographics by Housing type & Province (Stats SA, 2021).

Table 28: SA demographics by Housing type & Province (Stats SA, 2021)

ID	1	2	3	4	5	6	7	8	9		
Province	EC	FS	GP	KZN	LP	MP	NW	NC	WC	SA Tot (000 HH, by type)	% (HH, by type)
House on seperate yard or farm	1113	684	2698	2039	1449	1127	909	274	1127	11420	66,8%
Traditional materials	392	12		392	19	41				856	5,0%
Flat/Apt	18	25	391	116		30	25		144	749	4,4%
Cluster/house in complex			60	14					23	97	0,6%
Townhouse		13	202	18					45	278	1,6%
Semi-detached	33		15	57					177	282	1,7%
Backyard (formal)		11	534	26	39	11	41		25	687	4,0%
Backyard (informal)	23	33	401	40	18	12	37		117	681	4,0%
Informal	70	132	549	124	40	86	193	48	244	1486	8,7%
Servant quarter/Granny flat	25	180	159	48	22	31	24		24	513	3,0%
Other			35							35	0,2%
Total (1000 HH, by Prov)	**1674**	**1090**	**5044**	**2874**	**1587**	**1338**	**1229**	**322**	**1926**	**17084**	
% (HH, by prov)	9,8%	6,4%	29,5%	16,8%	9,3%	7,8%	7,2%	1,9%	11,3%		**100**

Some cells are empty due to statistical insufficiency (as defined by Stats SA), rather than nil presence of housing. National total number of HH for this summary is about 0.5% under-reported.

The vast majority of HH (67%) live in “House on separate yard or farm” (i.e., a free-standing house on an erf), and most (2,7m) are situated in Gauteng province.

Within the given list of dwelling types, certain types can be mapped to customer class/wealth quite closely (i.e., townhouse), whilst others may be ambiguous to a wide range of customer classes.

9.2.2 Estimated Electricity & Water in domestic households

For presence of residential electric hot water geysers to be feasible, the following criteria must be fulfilled:

- Dwelling (explained below) must have piped water into house
- Electrical supply (grid) must be present
- Homeowner wealth level must be such that ownership of a HWSH is likely. This has been set at 500 electrical units or more consumed per month, where 1 unit = 1 kWh.

Response rates to availability of electricity within the home and piped water into the home are summarized in Table 29: Piped water and Grid electricity in dwellings by province below:

Table 29: Piped water and Grid electricity in dwellings by province

	Province									
Source Electricity/Water	1	2	3	4	5	6	7	8	9	**Responses**
(HH 000)	**EC**	**FS**	**GP**	**KZN**	**LP**	**MP**	**NW**	**NC**	**WC**	
Electricity from mains for lighting (000)	1510	844	3871	2577	1508	1198	1013	318	1699	14538
Electricity from mains for lighting (%)	88,7%	91,6%	76,3%	86,3%	93,0%	89,9%	81,2%	90,9%	87,9%	**84,7%**
Piped water in dwelling/house (000)	579	367	3073	1122	194	396	325	184	1467	7707
Piped water in dwelling/house (%)	34,0%	39,8%	60,6%	37,6%	12,0%	29,7%	26,0%	52,6%	75,9%	**45%**
Population (000)	1702	921	5072	2985	1621	1332	1248	350	1933	17164

Overall HH electricity access (about 85%) is less than the national population values of around 90%.

Piped water into house (at 45%[15]) is substantially lower than electrification levels, clearly one constraint to the HWSH market of SA, and a limitation on market potential.

9.2.3 Estimated electricity with piped water inside the home, by housing type

Table 30: Estimated piped water and grid electricity into SA homes, by housing type shows the estimation of electricity and water inside homes.

This is a mapping of penetration by housing type, mapped similarly to that encountered at the provincial level. In setting up this mapping, consideration was given to the urban/rural (U/R) nature of the housing type. As example, housing built with traditional materials are rural. Similarly, Cluster housing and flats are predominantly urban.

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[15] Whilst ‘access’ to water in SA households is higher than 86%, access to piped water into homes is substantially lower (around 45%). Stats SA additionally records water from tap/borehole/rain-tank in yard, neighbors tap, communal tap/borehole, river/well/dam as categories of ‘access to water’.

Table 30: Estimated piped water and grid electricity into SA homes, by housing type

Dwelling type	HH, by Dwelling type	Est Electrified	Est piped water in dwelling	Rur/Urb
	(%)	(%)	(%)	Nature
House on seperate yard or farm	67%	90%	50%	R/U
Traditional materials	5%	50%	0%	R
Flat/Apt	4%	100%	100%	U
Cluster/house in complex	1%	100%	100%	U
Townhouse	2%	100%	100%	U
Semi-detached	2%	100%	100%	U
Backyard (formal)	4%	100%	20%	U
Backyard (informal)	4%	100%	0%	R/U
Informal	9%	40%	0%	U
Servant quarter/Granny flat	3%	100%	100%	U
Other	0%	0%	0%	
HH, by prov (%)	**100**	**85%**	**45%**	

The "other" class is very small portion (0.2%), so impact may be ignored.

Domestic load research surveys have shown that backyarders to houses with electricity quickly organise access to electricity from the main dwelling.

However, the same probably does not apply for piped water into secondary dwellings. Therefore access to backyarders is estimated to be lower.

The implication of 50% penetration piped water into the stock of formal housing appears rather low, however this is explained by the fact that SA has substantial dense RDP[16] housing schemes where taps in the street/yard dominate.

This table may be updated/improved by direct query (with dependency between the services) of Census data, when available. It is unlikely, however, thatpenetration of piped water will change much for the housing types (rated very low or high) above, simply because of the nature of formalization and/or private investment involved. For example, flats and cluster complexes are assured of piped water. Informal housing is unlikely to be fitted with piped water into home.

Up to this point all demographics have been presented at the HH level and we know HH, dwelling and Erf levels are different. When State/Eskom/Municipal engineers speak of "electricity consumers", they implicitly speak of the metered load effectively at erf/property level, where one connection per erf is the over-whelming norm. Therefore, a translation between HH, dwelling and erven is essential to appreciate how many consumers are implied and the number of HWSH that involves.

9.2.4 A load-based view of SA Domestic HWSH penetration

From Domestic Load research in SA (monitored at house connection level), customer load profiles have been measured over long periods and different climates of SA. The customer sociodemographics have been mapped to LSM (Living standards measures). Therefore, an estimation of consumption can be made with associated load profiles per LSM.

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[16] Reconstruction and Development Programme scheme housing. Typically 40m^2-50m^2 brick/block walled dwellings with tin/tile roof.

The Methodology presented in “Domestic load research seminar” (2014) has been updated with Population estimate of Stats SA (2019), and is presented in Table 31: Estimated HH, Dwelling, Erven and Electricity Consumption for SA per LSM strata below.

Table 31: Estimated HH, Dwelling, Erven and Electricity Consumption for SA per LSM strata

LSM	HH (%)	N (hh)	N(Dwellings)	N (Erven)	N Electrified (Erven)	kWh/erf/ann	
	(Amps 2013B)			Potential number of connections = number erven.		DT PET 2012	
		17 160 000				Year 1	Year 15
1	2,00%	343 200	180 632	106 254	31 876,16	100	140
2	4,00%	686 400	381 333	224 314	94 211,76	121	169
3	6,00%	1 029 600	686 400	429 000	313 170,00	138	192
4	13,00%	2 230 800	2 028 000	1 267 500	1 178 775,00	176	246
5	17,00%	2 917 200	1 458 600	941 032	922 211,61	234	322
6	23,00%	3 946 800	1 315 600	877 067	868 296,00	382	498
7	12,00%	2 059 200	1 872 000	1 560 000	1 560 000,00	517	640
8	8,00%	1 372 800	915 200	915 200	915 200,00	623	727
9	9,00%	1 544 400	772 200	772 200	772 200,00	1036	1480
10	6,00%	1 029 600	343 200	343 200	343 200,00	1785	2550
	100,00%	17 160 000	9 953 165	7 435 767	6 999 141	43 224 677 869	57 379 460 258

Breakdown of HH by LSM is according to AMPS 2013B[17] survey.

Total number of HH is derived from Stats SA (2019).

Total number of dwellings is derived from HH/Dwelling and Dwelling/erf multipliers, sourced from Domestic LR field work and Spot5 Building Count and analytics, from purchased SA data by Enumerator Area (GIS).

Electricity consumption is derived from estimation model per LSM for Year 1 and Year 15 after connection.

Due to nature of the analysis, estimated N(dwellings) for flats/apartments may be under-counted (according to Stats SA, this housing type was 4 % of all HH in 2019).

Whilst distribution of customers across LSM may have shifted over time, real income in SA (ie income net of inflation) at national level (2022), is still similar to 2007.

Number of electrified erven is estimated by the application of varying electrification per LSM to obtain a national level around 93%.

Modelling of estimated consumption by LSM has provided us with estimated average consumption per month in the first year after connection and after 15 years connected.

The number of geysers involved may be estimated from the results of Domestic LR monitoring (with associated sociodemographics). The data is shown by Geyser penetration in Figure 27: Measured domestic Geyser penetration by consumption (DLR, 2014) below. Each data point is a ‘site’ of 60 or more consumers.

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[17] All Media and Product Survey dataset, result of panel surveys conducted under SA advertising research foundation (SAARF).

From this, we see the first HWSH penetration in homes arrives around 500kWh/mth. Interestingly, at this level, invariance of measured household consumption indicates that "ownership of a hot water geyser" does not mean the appliance is used regularly or even is operational. Interventions to control the estimated 1.3M geysers in households operating around this level will yield lower returns.

Therefore, only LSM 6 and above typically apply. This estimates an upper bound of roughly 58% (9,9M HH) may fall into this net on wealth-only criteria.

This implies 5,9m dwellings may be involved, across roughly 4,6m residential addresses.

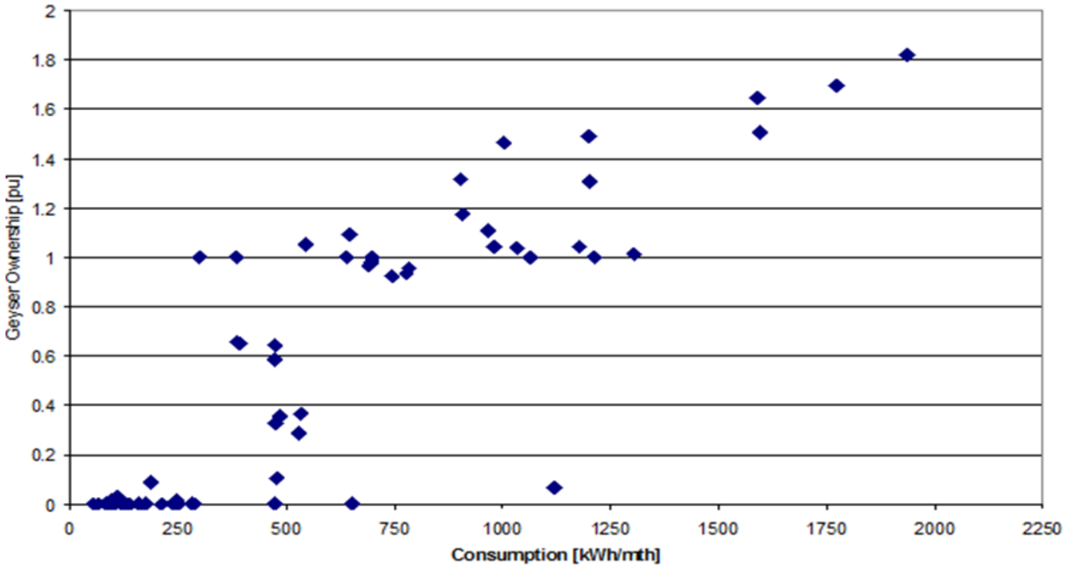


Figure 27: Measured domestic Geyser penetration by consumption (DLR, 2014)

Nominal values have been selected for intersection of the fitted line on this curve (Geyser penetration) by 15 years of LSM consumption[18], yielding the following estimates of geyser penetration by LSM (after slight offset for electrification per LSM), in Table 35.

Table 32: Estimated National Domestic Hot Water Geyser stock by LSM (2019)

LSM	**Class consumption (Avg kWh/mth, 15yrs)**	**HWSH penetration (pu, 15 years)**	**Est. dwelling with HWSH (N)**
6	498	1.0	1 302 444
7	640	1.05	1 965 600
8	727	1.1	1 006 720
9	1480	1.25	965 250

---

[18] Load modelling has shown consumption growth per LSM usefully follows gompertz curve from 70% to 100% over 15 years.

LSM	**Class consumption (Avg kWh/mth, 15yrs)**	**HWSH penetration (pu, 15 years)**	**Est. dwelling with HWSH (N)**
10	2550	2.0	686 400
		Total	**5 926 414**

Outcomes from this estimate suggest 5.2m dwellings across 4.5m different erven (i.e., metered properties) may be involved.

This total is sensitive to the following:

- Figures based upon 2019 census data.
- AMPS 2013 data (when extrapolated) estimates 45% HH (not dwellings) have hot water geysers, thus our estimated figures are an upper bound of potential.
- Possible undercounting of apartments (typically occurring within LSM 5-8).
- These dwellings include formal primary dwellings, formal backyarding and likely Granny flats.
- This is a gross estimate, based upon very little penetration of domestic solar water-heating and Rooftop PV systems. Such renewable systems would reduce the number (and load) of grid-powered hot water geysers in situ. More data is required here.

Since the Load class by LSM has been modelled, average monthly consumption and hourly winter weekday load profile of these consumers has also been modelled, and may serve as a basis of comparison (by customer class) going forward.

Using an identical technique, the latest local IDP data was used to estimate geyser stock for Johannesburg Metropolitan council in 2019, by scaling the recent IDP study (Demacon, SHSUP 2012)

The population is estimated at 5.74M persons (meaning 1.8M HH), with LSM distribution shown in Table 33.

Table 33: LSM segmentation of Johannesburg HH (2019)

LSM	**HH(%)**	**N (HH)**
1	14,73%	265 060
2	14,73%	265 060
3	14,73%	265 060
4	6,73%	121 084
5	6,73%	121 084
6	10,59%	190 663
7	10,59%	190 663
8	7,06%	127 108
9	7,06%	127 108

LSM	HH(%)	N (HH)
10	7,06%	127 108
Totals	100%	1 800 000

In this table clustered LSM data derived from the reference source has been evenly distributed among appropriate LSM classes.

Estimated Geyser Counts for Johannesburg Metro (using the same principles and technique as the national estimate) is shown in Table 34.

Table 34: Estimated Johannesburg Metro Domestic Hot Water Geyser stock by LSM (2019)

LSM	Class consumption (Avg kWh/mth, 15yrs)	HWSH penetration (pu, 15 years)	Est. dwelling with HWSH (N)
6	498	1.0	63 554
7	640	1.05	181 996
8	727	1.1	93 213
9	1480	1.25	79 443
10	2550	2.0	84 739
		Total	**502 945**

Outcomes from this estimate suggest 427 000 dwellings across 377 000 different erven (i.e., metered properties) may be involved.

Similarly to the National Estimate, these totals are sensitive to the following:

- Figures are based upon 2019 census data.
- AMPS 2013 data (when extrapolated) estimates 45% HH (not dwellings) have hot water geysers, thus our estimated figures are an upper bound of potential.
- Possible undercounting of apartments (typically occurring LSM 5-8).
- These dwellings include formal primary dwellings, formal backyarding, and likely Granny flats.
- This is a gross estimate, based upon very little penetration of domestic solar water-heating and Rooftop PV systems. Such renewable systems would reduce the number (and load) of grid-powered hot water geysers in situ. More data is required here.

9.2.5 Segmentation by domestic housing types for estimation of domestic hotwater usage by customer segment in SA

In order to estimate the combined electrical load of domestic hot water usage on the SA electrical network, we must estimate our gross domestic hot water usage shape, and then estimate the demand of electricity this would require.

In order to estimate hot water usage as a function of time, we will apply a hot water usage profile to a domestic customer segmentation that best represents that domestic customer type.

9.2.6 Characterization of Domestic hot water usage in SA

Hot water usage in South Africa has been measured and characterized by local researchers.

This section draws heavily on the work of Meyer et al., who measured hot water usage in SA, with focus on specific dwelling types. This research was conducted over the period 1998-2000.

Monthly hot water consumption was measured by meters installed at the inlet to installed hot water geysers. Thermostat temperatures were uniformly set to 65 deg C. The consumers were sampled in Johannesburg. For specified housing types, monthly hot water of several hundred households were measured for a full year.

In all cases, the number of people in each household was also measured (all ages included). Wealth was not assessed. For this study the living conditions (low/medium/high density) used by Meyer are associated with LSM 9-10, 7-9, 5-7.

Following this, a sub-sample (typically 30) was selected for each housing type according to low/medium/high density living conditions. The hourly hot water usage of this subsample was then measured for 1 year and results presented.

With sub-sampling, about 10 carefully-selected households were measured to define hourly hot water consumption of each range of customers in each housing class. Accordingly, uncertainty in the behavior of individuals in the same range at the time of peak winter hourly hot water usage was reported as 15% or more of the mean value.

The Meyer et al. work has the following shortcomings:

- Research was only conducted in the Johannesburg area. This is one of 3-5 distinct climatic zones in SA, which we know affect customer behaviours.
- Whilst the research was apparently conducted on an HH basis (possibly to align with the census), geysers only occur in a dwelling, and dwellings occur on a property where electricity is metered. Over LSM 6-10 we estimate a national average of 1.78HH/Dwelling is typical. Over LSM 6-10 we further estimate a national average of 1.13 Dwellings/Erf is typical.
- We know upper-class customers tend to have multiple geysers, but no mention of this is made in Meyer et al.'s work.
- The work did not investigate multiple dwellings per stand, such as Backyarding and/or Granny flats.
- The impact of water saving technologies (e.g., low-flow tap and shower) was not considered.

Meyer et al.'s research remains the best documented work on domestic hot water end-use behavior in SA.

Meyer hot water usage profiles are published per-capita (ie average people/HH), for an average winter weekday, for Formal dwellings, Townhouses and Apartments. Inquiries among suppliers has revealed that certain geyser types are more common in particular types of housing. As an example, apartments/flats and similar "compact" homes tend to favor vertical geysers, due to absence of a ceiling and space-saving requirements.

Given the introduction above, a segmentation of SA domestic households is obviously required to estimate total hot water consumption-shape by housing type.

9.2.7 Rationalisation of Meyer domestic hot water classes to Stats SA housing types

By comparing per capita Meyer hourly weekday consumption profiles for different housing types and densities, the following observations can be made:

- Townhouse (low density) shape is indistinguishable from formal house and apartment of low density.
- Townhouse at medium density is also nearly indistinguishable from the others at similar levels.
- Habit differences (L/M/H) in townhouses have less variance/range than those of houses or apartments.
- Inspection of the profile features shows morning peaks at 6AM, 7AM and 8AM:
    - 6AM is a 'Blue collar' start, characteristic of folk in lower LSM's (5-7), who rely on public transport to get to work. There is little hot water usage during day, and an early-to bed night time pattern.
    - 7AM is 'White collar' (LSM7-9) start, with limited hot water usage during day.
    - 8AM are dwellings with largest hot water usage during the day, indicating permanent occupancy, domestic servants, food-prep, and/or laundry active during daylight hrs. These are all characteristics of higher wealth, i.e. LSM9-10 levels.

As implied by Meyer's developed/developing description, per capita hourly hot water consumption shapes are primarily a function of wealth. The profile features described above are similarly present in measured domestic electrical load models for similar LSM customers.

These rationalisations and attributions are summarized in Table 35.

Table 35: Summary Meyer' hot water profile class attributes

	Meyer domestic HW class								
	Formal house			**Apartment**			**Townhouse**		
Dwelling density	Low	Med	High	Low	Med	High	Low	Med	High
Dwellings/Ha	8,45	20,29	38,57	49,6	87,34	268,74	38,1	81,16	251,95
People/HH (Meyer)	3,1	3,8	6,2	2,2	3,3	3,8	2,1	3,5	

Estimated LSM range	9-10	7-9	5-7	9-10	7-9	5-7	9-10	6-8	
Estimated People/HH (Domestic LR)	3,1	3,73	3,83	3,1	3,73	3,83	3,1	3,83	3,1
Apportionment by range (%)	16%	30%	54%	17%	30%	53%	26%	74%	NA

The 2nd to last row in Table 35 was extracted from the average at Domestic LR sites over the similar LSM levels around SA. Whilst these figures were not differentiated by housing type, the figures correspond, implying that the L/M/H ranges have been usefully interpreted.

The last row in Table 35 was derived by apportioning HH population within housing type according to the National HH population density over the assigned LSM ranges.

In order to assign all types of housing which could feasibly contain geysers to Meyer hot water usage classes, some special assignment had to be made, based upon "closest match". These assignments are summarized in Table 36 below.

Table 36: Assignment of Stats SA Domestic housing types to Meyer Domestic hot water classes

Stats SA housing type	**Meyer domestic HW class**		
	House	**Apartment**	**Townhouse**
House on separate erf	X		
Flat/Apartment		X	
Cluster/house in complex		X	
Townhouse			X
Semi-detached		X	
Backyard (formal)	X		
Servant quarter/Granny flat	X		

In this assignment, **Cluster-homes** are multi-story, lower cost, of limited space and share common walls. They have accordingly been classed (like Semi-detached), as Flats/Apartments.

Backyard formal and Granny flats are considered similar in nature to free-standing small houses.

Research has shown (irrespective of informality) they are overwhelmingly electrified from main dwelling within a year of establishment. If they are formal, then piped water is installed. If they are informal, we assume no piped water is installed. Backyard formal and Granny flats could arguably be called "small formal housing".

9.2.8 Scenarios for segmentation of domestic HW Geyser Stock in SA

The application of the preceding data was used to segment and estimate the number of HW geysers both nationally, and for Johannesburg Metro.

National segmentation is presented in Table 37 below.

Table 37: Segmentation of SA Domestic HH by dwelling type (Stats SA 2019), with HW Geyser

Stats SA housing type	HH, by type (000)	HH, by type (%)	Est HH with Geyser (%)
House on separate yard or farm	11420	66,8%	30,1%
Traditional materials	856	5,0%	0,0%
Flat/Apt	749	4,4%	4,4%
Cluster/house in complex	97	0,6%	0,6%
Townhouse	278	1,6%	1,6%
Semi-detached	282	1,7%	1,7%
Backyard (formal)	687	4,0%	4,0%
Backyard (informal)	681	4,0%	0,0%
Informal	1486	8,7%	0,0%
Servant quarter/Granny flat	513	3,0%	3,0%
Other	35	0,2%	0%
Total HH	**17084**	**100%**	**45,3%**

Whilst penetration of 'House on separate yard/farm' may seem low, it should be noted this covers the full scale of formal housing in SA, of which only a portion is LSM 6 and above. This excludes back-yarding, implication of which is treated separately.

The implications of this SA domestic HH Geyser segmentation are:

1. 8.1m domestic HH (45%) have access to hot water. This agrees with AMPS 2013, escalated for growth at existing rate to 2021/2.
2. 5.0m dwellings have a geyser.
3. In 2022 terms, 29.9M persons in domestic homes has access to hot water. This constitutes roughly 49.9% access by capita at national level.

A similar segmentation was completed for the Johannesburg Metropole, according to figures prepared for IDP.

Table 38: Segmentation of Johannesburg Domestic HH by dwelling type (IDP 2012), with HW Geyser

Stats SA housing type	HH, by type (000)	HH, by type (%)	Est HH with Geyser (%)
House on separate yard or farm	914,4	50,8%	20,3%
Traditional materials	98,9	5,5%	0,0%
Flat/Apartment	181,8	10,1%	10,1%
Cluster/house in complex	11,2	0,6%	0,6%
Townhouse	32,1	1,8%	1,8%
Semi-detached	32,6	1,8%	1,8%
Backyard (formal)	74,7	4,2%	4,2%
Backyard (informal)	140,4	7,8%	0,0%
Informal	239,4	13,3%	0,0%
Servant quarter/Granny flat	74,7	4,2%	4,2%
Other			
Total HH	**1 800**	**100%**	**43%**

Whilst penetration of ‘House on separate yard/farm’ may seem low, it should be noted this covers the full scale of formal housing for Johannesburg, which has a higher than national portion (i.e., a ‘hump’) of poor HH, according to IDP.

The implications of Johannesburg domestic HH Geyser segmentation are:

1. 772 000 domestic HH (43%) have access to hot water.
2. 471 000 dwellings have a geyser.
3. In 2021 terms, Johannesburg’s population of 5.74m persons, roughly 2.85m have access to hot water in the home. This constitutes roughly 49.6% access by capita at local level.

Whilst estimated geyser stock in Table 32 and Table 33 is probably an upper bound, it should be noted the segmentations in Table 37 and Table 38 are curtailed, to be consistent with auxiliary data sources (ie AMPS and IDP).

9.2.9 Segmentation by domestic housing types for estimation of domestic hot water usage by customer type and climatic region in SA

The national segmentation was broken down into Regions within SA, by climate zone.

Domestic load research in SA has determined three or more distinct types of load behavior (reflecting time of local peak).

The main climate zones are Internal, Cold and Wet, and Humid Subtropical. Over this range, the peak load of customers in the same living circumstances varies by from -12% to +12%; the variance is chiefly a result of uncertainty around the time of peak. The climate effect is graded from -1 to +1, and some regions of SA have factors in-between. Similarly, these factors are usefully a geo-interpolation between extreme sites.

After consideration of this behavior, and the location of the most populated areas in the country, the following rationalization was made:

- Round off the climatic scale to nearest digit.
- Group provinces with similar major climatic zone together (given weight of population)

Table 39: Aggregation of SA provinces by domestic climatic zone weighting

South African Province	Climatic Zone weighting
WC	1
NC	0
FS	0
GP	0
NW	0
LP	0
MP	0
KZN	-1
EC	1

Therefore, Western cape (WC) and Eastern cape (EC) were assigned the same weighting, chiefly the result of "cold and wet" winters. Kwazulu Natal (KZN) was considered a sole example of humid subtropical climate.

The remaining provinces, being inland "cold and dry" winter, were grouped together.

SA Weather data was thus aggregated on same basis, with weather station data aggregated according to Table 40.

Table 40: Key to Aggregation of SAWB climatic data by domestic climatic zone

Province	SAWB Station name	Latitude	Long	Altitude	Climatic zone weighting
EC	EAST LONDON WO	27,83	-33,03	116	1
EC	PORT ELIZABETH WO	25,62	-33,98	59	1
FS	BLOEMFONTEIN W.O	26,3	-29,1	1359	0
FS	WELKOM	26,67	-28	1343	0
GP	IRENE WO	28,22	-25,92	1524	0
GP	JHB BOT GARDENS	28	-26,15	1622	0
GP	JOHANNESBURG INT WO	28,23	-26,15	1695	0
GP	PRETORIA WO/EENDRACHT	28,18	-25,73	1310	0
GP	SPRINGS	28,43	-26,2	1592	0

Province	SAWB Station name	Latitude	Long	Altitude	Climatic zone weighting
GP	VEREENIGING	27,95	-26,57	1481	0
KZN	DURBAN WO	30,95	-29,97	8	-1
KZN	NEWCASTLE	29,98	-27,77	1238	-1
KZN	RICHARDS BAY	32,02	-28,78	7	-1
LP	GRENSHOEK TZANEEN	30,07	-23,77	893	0
LP	PHALABORWA	31,15	-23,93	407	0
MP	WITBANK	29,18	-25,83	1550	0
NC	KATHU	23	-27,67	1187	0
NC	KIMBERLEY WO	24,77	-28,8	1197	0
NW	KLERKSDORP	26,62	-26,9	1324	0
NW	POTCHEFSTROOM	27,07	-26,73	1351	0
NW	RUSTENBURG	27,23	-25,65	1151	0
WC	CAPE TOWN WO	18,6	-33,97	46	1
WC	GEORGE WO	22,38	-34,02	191	1
WC	LANGEBAANWEG WO	18,17	-32,97	31	1

In Table 40 it can be seen that most inland areas (Climatic zone weighting 0) have altitude greater than 1100m or more, typical of this territory.

The following section details regional segmentations in SA by climatic zone.

9.2.10 Summary of segmentation of SA housing type by climatic region

Under an aggregation basis detailed in Table 39, a national split was derived by housing type and climatic zone, using methods detailed in section 9.2.9, with the same qualifiers.

A summary of the National spilt is presented in Table 41.

Table 41: Summary estimated demographics and Geysers by climatic zone

	Climatic Zone			
	Cold & Wet	**Interior**	**Subtropic**	**Totals**
Climatic Zone Weight	1	0	-1	
HH (2021, Type)	3 781 854	11 145 965	3 019 180	17 947 000
HH pop pu	21,1%	62,1%	16,8%	100,0%
HH with geysers	2 149 287	4 768 369	1 178 811	8 096 466
Est Geyser pu	56,8%	42,8%	39,0%	45,1%
Dwelling-Geyser	1 325 740	2 962 740	729 311	5 017 791

Under the climatic zone criteria, the majority of SA domestic HH (62%) can be found in the interior, so load (and geyser) behaviour of these households would tend to dominate the picture, followed by Cold & Wet regions. The least is Humid Subtropical.

A breakdown of housing per Climatic Zone and Estimated Geyser holdings is detailed inTable 42, Table 43, and Table 44.

Table 42: Segmentation by housing type for Cold & Wet regions (CZW=1)

Stats SA Housing type	Housing by type (%)	Est HH with Geyser by type
House on separate yard or farm	62,2%	42,6%
Traditional materials	10,9%	0,0%
Flat/Apartment	4,5%	4,5%
Cluster/house in complex	0,6%	0,6%
Townhouse	1,3%	1,3%
Semi-detached	5,8%	5,8%
Backyard (formal)	0,7%	0,7%
Backyard (informal)	3,9%	0,0%
Informal	8,7%	0,0%
Servant quarter/Granny flat	1,4%	1,4%
Other	0,0%	0,0%
Totals	100,0%	56,8%

The region CZW1 covers a total of 3 781 854 HH

Table 43: Segmentation by housing type for Cold & Dry regions (CZW=0)

Stats SA Housing type	Housing by type (%)	Est HH with Geyser by type
House on separate yard or farm	67,3%	25,7%
Traditional materials	0,7%	0,00%
Flat/Apartment	4,4%	4,4%
Cluster/house in complex	0,6%	0,6%
Townhouse	2,0%	2,0%
Semi-detached	0,1%	0,1%
Backyard (formal)	6,0%	6,0%
Backyard (informal)	4,7%	0,0%
Informal	9,9%	0,0%
Servant quarter/Granny flat	3,9%	3,9%
Other	0,3%	0,0%
Totals	100,0%	42,8%

The region CZW0 covers a total of 11 145 965 HH.

Table 44: Segmentation by housing type for Humid Subtropical regions (CZW=-1)

Stats SA Housing type	Housing by type (%)	Est HH with Geyser by type
House on separate yard or farm	70,9%	29,3%
Traditional materials	13,6%	0,0%
Flat/Apartment	4,0%	4,0%
Cluster/house in complex	0,5%	0,5%
Townhouse	0,6%	0,6%
Semi-detached	2,0%	2,0%
Backyard (formal)	0,9%	0,9%
Backyard (informal)	1,4%	0,0%
Informal	4,3%	0,0%
Servant quarter/Granny flat	1,7%	1,7%
Other	0,0%	0,0%
Totals	100,0%	39,0%

The region CZW-1 covers a total of 3 019 180 HH.

9.2.11 Estimated penetration of Domestic Solar PV in SA

SA citizens heat water primarily from hot water geysers, from solar thermal systems, or with aid of solar PV systems.

Solar thermal systems may tend to rely on grid electricity during periods of poor weather. It is estimated there are at least 400 000 solar thermal installations in SA, largely as result of the Eskom DSM programme and subsidy around 2008 and period following.

Solar PV systems will tend to supplement the energy required for water heating, during the period if/when solar energy exceeds the need for battery recharging and other household demand during the day.

Solar PV systems may therefore act to suppress hot water geyser demand conditionally. The amount of suppression depends upon system sizing.

For baseline and other projections, it is therefore important to have an estimate of the number and type of domestic solar PV systems in SA (by size), and a projection of their impact.

With advent of deeper load shedding in the past few years, the size of the total solar market has grown substantially. Scenarios are presented for this growth based upon past research, estimated SA market potential, and market forecasts.

Eskom and other sources agree that total rooftop solar installed by the end of 2023 was 4400MW. This number was estimated per province by load correlated with solar insolation and includes all solar, not only contracted to Eskom. Contracted IPP's contributed about 2370MW additional (Mordor, 2023)).

It is estimated about half the installed uncontracted solar capacity is domestic rooftop installations.

Pandarum (2018), and Author's own analysis of Hohm Solar market potential for SA urban areas (2023) indicate total fitted panel current capacity of about 2200MW (2023). Existing estimates are that PV penetration in domestic homes is in range 5-8%, meaning about 392 000 dwellings in urban areas may now have solar PV systems.

It should be noted not all dwellings are suited to domestic PV, due to orientation and living arrangements. Townhouses, flats and cluster living tend to be less appropriate to Solar PV. Thus an estimated 68.7% of all residential solar systems in South Africa are located in full title homes.

Typical domestic system packages are being marketed nationally by suppliers in SA with specifications as follows:

Table 45: Common domestic PV system packages marketed in SA.

System ID	Invertor size (Kw)	Panel rating (kW)	Battery rating (Kwh)	Indicative energy generation (kWh/mth)
Small	3	2.7	5	628
Medium	5	3.6	5	837
Large	8	6.3	10	1465
X-Large	12	8.1	16.5	1884

Energy generation capacity was interpreted from monthly electricity expenditures published by manufacturers to guide buyers in selecting appropriately-sized systems. Panel capacity, when checked against quoted consumption, appeared to be appropriate.

9.2.11.1 Reported domestic PV fitment adoption mix by province in SA

Pandarum (CSIR, 2018) assessed domestic PV installs in SA by province. In 2023, the rate of new installs in SA was estimated by province and is presented in Table 20: Element rating changes and distribution for 2023 and ten-year forecast for 2033. below.

Table 46: Installed domestic PV mix and expected install rate mix in SA, by province.

Province	**Installed base (CSIR survey, 2018)**	**Installation rates (Ooba, 2023)**
WC	2.84%	24%
EC	16.10%	4%
NC	1.01%	1%
FS	1.30%	4%
KZN	26.98%	13%
NW	0.03%	3%
GP	39.91%	46%
MP	0.07%	4%
LP	11.77%	2%
	100%	**100%**

The market is clearly developing. It is expected that the current installation mix will prevail.

9.2.11.2 Expected Domestic PV growth rates

Research by the author has shown that price elasticity of demand in SA is rather inelastic for upper LSM groups. Therefore the driver for domestic PV systems is primarily avoidance of load shedding, and secondarily electricity cost reduction. Grid independence is considered less affordable, therefore PV-equipped homes may use the grid for limited peaking.

A number of PV market growth estimation sources were considered. We adopted an expected compound growth rate of 22.75% for all uncontracted PV, and a growth rate of 18.70% for domestic PV. This implies installed uncontracted PV capacity may increase by a factor of four (i.e., from 4 400MW to 18 476MW) by 2030.

Since load shedding is the main driver of domestic PV, its growth is highly dependent on continuation of load shedding. If load shedding curtails, then we expect growth of domestic PV to increase at 5.42% compounded (roughly rate of CPI).

Domestic PV growth scenarios are therefore dependent on the year load shedding terminates.

9.2.11.3 Scenarios for Domestic PV growth

Three domestic PV growth scenarios were modelled, based upon year of termination of load shedding:

- Projection 0 – No termination of load shedding by 2033.
- Projection 1 – Termination of load shedding, end of 2025.
- Projection 2 – Termination of load shedding, end of 2028.

The final result of these projections is displayed in the following table:

Table 47: Summary projections for domestic PV penetration (per-dwelling basis, 2023-2033)

	Year										
	2023	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**
Est. dwellings (M)	10.47	10.60	10.74	10.88	11.01	11.15	11.29	11.43	11.58	11.72	11.87
Projection 0	5.7%	6.6%	7.8%	9.1%	10.7%	12.6%	14.7%	17.2%	20.2%	23.7%	27.8%
Projection 1	5.7%	6.6%	7.8%	8.1%	8.4%	8.8%	9.2%	9.5%	9.9%	10.3%	10.7%
Projection 2	5.7%	6.6%	7.8%	9.1%	10.7%	12.6%	13.1%	13.6%	14.2%	14.7%	15.3%

The upper bound of domestic PV penetration is SA is limited by socioeconomic factors.

While residential solar installation rates have increased at a near exponential rate since 2021, research indicates an estimated 45% of the country's households would likely remain unserved by roof-top solar solutions because the cost of these systems would remain out of reach with private financing options.

In the base case simulations that follow, these penetration scenarios were reduced to geyser dwelling impacted per Climatic load region, and impact of solar on geyser load was simulated accordingly.

Comparison of SA domestic PV penetration projections with international experience

It is useful to compare our scenarios of penetration to the rest of the world. However, the levels witnessed in other countries are very much a product of local conditions, needs, drivers, incentives, and constraints.

Table 48: Illustrative domestic PV penetration rates in other countries

Country	Domestic PV Adoption rate
Australia	31% (14% in 2018)
Italy	23%
Netherlands	16%
Germany	11%
United Kingdom	4%
USA	3%
Brazil	1%

Australia has the highest penetration encountered; their market is deregulated, with trading well-established and a long tradition of incentives. High levels of PV penetration can obviously impact system stability.

9.2.12 Estimated price elasticity of demand for water consumption in SA

For this project, we were able to leverage water-use curves (Meyer 1999) from research conducted in in Johannesburg, South Africa.

Two adjustments were necessary of the Meyer curves:

- Adjustment for different water price in different parts of SA.
- Adjustment for different average air temperature in other parts of SA.

This section presents estimated adjustment coefficients due to water price only.

The relationship between the differential amount of water used and the relative price of water is encapsulated in the price elasticity of demand, normally expressed by the formula:

$$e(P) = \frac{(dQ/Q)}{(dP/P)}$$

Where:

e(P) = Price elasticity of demand

dQ = Change in quantity demanded

Q= Quantity demanded

dP= Change in price (real)

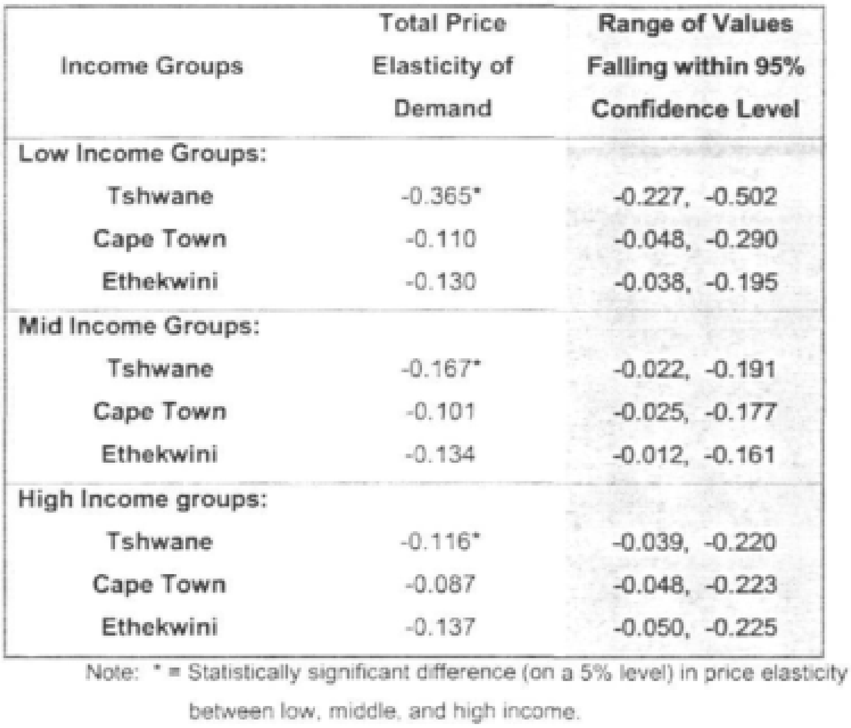
P = Price

In summary, elasticity is the relationship between per unit change in quantity and per unit change in Price.

A study was undertaken in SA (Van Vuuren et al, 2004), where water consumption and price data was gathered for a representative sample of domestic homes in known (Low, Middle, High) income bands.

This study produced Price elasticity of demand for water, as given in Figure 28 below.

The study also presented overall household, indoor and outdoor usage and price elasticities.

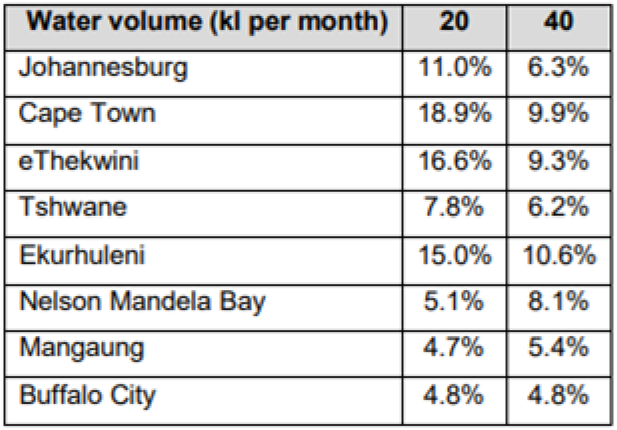


Income Groups	Total Price Elasticity of Demand	Range of Values Falling within 95% Confidence Level
Low Income Groups:		
Tshwane	-0.365*	-0.227, -0.502
Cape Town	-0.110	-0.048, -0.290
Ethekwini	-0.130	-0.038, -0.195
Mid Income Groups:		
Tshwane	-0.167*	-0.022, -0.191
Cape Town	-0.101	-0.025, -0.177
Ethekwini	-0.134	-0.012, -0.161
High Income groups:		
Tshwane	-0.116*	-0.039, -0.220
Cape Town	-0.087	-0.048, -0.223
Ethekwini	-0.137	-0.050, -0.225

Note: * = Statistically significant difference (on a 5% level) in price elasticity between low, middle, and high income.

Figure 28: Price elasticity of demand for 3 metropoles (Van Vuuren et al 2004)

Real water price changes have been estimated by SARB (OBEN 13/01, Aug 2023) during a review of administered water prices in SA (Walsh, 2023), over the period 2016-2021, which measured real average annual price increases for customers using 20-40kl water by major metropole, as shown in Figure 29.



Water volume (kl per month)	20	40
Johannesburg	11.0%	6.3%
Cape Town	18.9%	9.9%
eThekwini	16.6%	9.3%
Tshwane	7.8%	6.2%
Ekurhuleni	15.0%	10.6%
Nelson Mandela Bay	5.1%	8.1%
Mangaung	4.7%	5.4%
Buffalo City	4.8%	4.8%

Figure 29: Average real annual increases in price of water by Metro 2016-2012 (Source: Walsh, SARB 2023)

The indicative pricing growth trends were used to estimate price change by income class (low, middle, high), from year 2000 to 2023 and 2033 respectively.

Comparison between similar classes of Van Vuuren et al. (2004) and Meyer were used to estimate HH water consumption by class, by metropole. This showed 19%-35% of total HH water is hot water (depending upon wealth class).

We recognized that overall HH water elasticity is a weighted average of hot water elasticity and “other” cold HH water elasticity (largely discretionary). Outdoor water elasticity (by class and Metro) was adopted as a proxy for discretionary “other” cold HH water elasticity. The relationship was then solved, to estimate HH hot water elasticity (by class and Metro).

The results indicated the hot water portion of total HH water consumption was uniformly less elastic than overall HH water consumption (by class and Metro).

Real price changes since 2000 were then applied to HW elasticity (by class and Metro), to estimate change in hot water use.

Table 49 gives estimate of price elasticity for hot water over the period 2000-2033.

Table 49: Estimated Hot water elasticity (2000-2033)

Metropole	Income band		
	Low (LSM1-6)	Mid (LSM6-8)	High (LSM8-10)
Cape Town	-0.12	-0.06	-0.015
Durban	-0.13	-0.13	-0.1
Pretoria	-0.32	-0.16	-0.06

Table 50 and Table 51 show estimated real price change and consequent reduction in hot water demand for the three metropoles for 2000-2023 and 2000-2033, respectively.

Table 50: Estimated change in real price and quantity of hot water used (2000-2023)

Metropole	Est. real price increase (%)	Est. reduction water demand (%)

	2000-2023					
	Low	Mid	High	Low	Mid	High
Cape Town	435.7	484.4	383.0	-52.29	-29.06	-5.74
Durban	376.8	328.1	198.8	-48.98	-42.65	-19.88
Pretoria	181.4	179.0	161.2	-58.06	-28.65	-9.67

Table 51: Estimated change in real price and quantity of hot water used (2000-2033)

Metropole	Est real price increase (%) 2000-2033			Est reduction water demand (%)		
	Low	Mid	High	Low	Mid	High
Cape Town	625.2	695.0	549.5	-75.02	-41.70	-8.24
Durban	540.6	470.7	285.2	-70.27	-61.19	-28.52
Pretoria	260.3	256.9	231.3	-83.30	-41.10	-13.88

Since elasticity describes the relationship between changing consumption and changing price, the contents of Table 49 links the left and right side of Table 50 and Table 51, respectively.

In review of these results, it should be appreciated there are probably different types of elasticity for different kinds of water use, including hot water, in households. Discretionary water uses are more elastic than use of water for hygiene. Similarly, hot water use has discretionary (e.g., washing hands) and non-discretionary (e.g., showering) character, the latter being very inelastic.

In general, SA household water use has been demonstrated as rather elastic under crisis. During the City of Cape town drought (also called “Day Zero”), the city reduced total consumption from 1.2bn l/day in (2015) to 516m l/day (2018). Only 155m l/day of the loss was by leak reduction, indicating underlying reduction in whole city consumption of 49%.

9.3 ANNEX 3 - POPULATION AND CLIMATE OF MAJOR SA CITIES

SA is about 70% urbanized. Urban areas tend to be better-serviced and offer lower cost logistics.

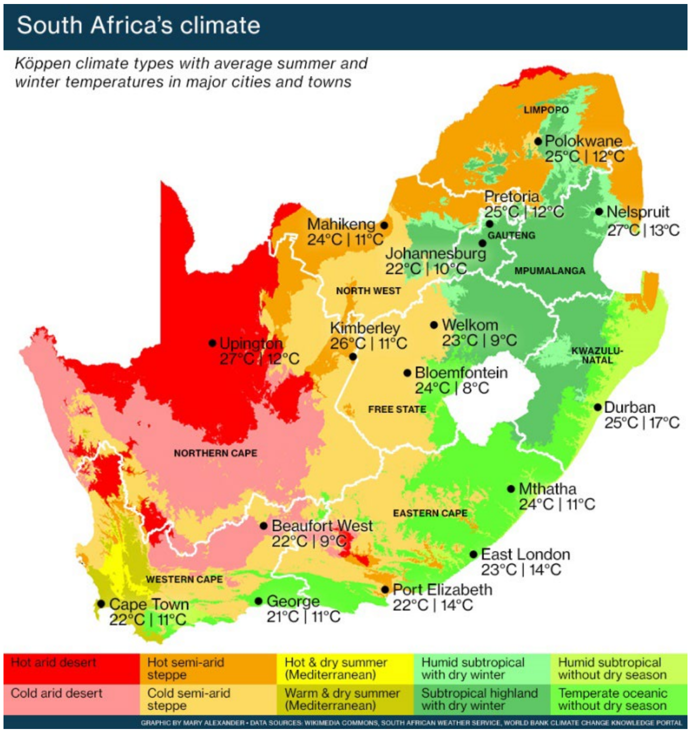
Table shows demographics for top 8 SA Metros (Stats SA 2016). At this year, these cities housed 40% of SA’s population.

Table 52: Population by top 8 Metro's in SA (2016)

ID	Name	Province	Seat	Population
1	City of Johannesburg Metropolitan Municipality	Gauteng	Johannesburg	4949347
2	City of Cape Town Metropolitan Municipality	Western Cape	Cape Town	4005016
3	eThekwini Metropolitan Municipality	KwaZulu-Natal	Durban	3702231
4	City of Ekurhuleni Metropolitan Municipality	Gauteng	Germiston	3379104
5	City of Tshwane Metropolitan Municipality	Gauteng	Pretoria	3275152
6	Nelson Mandela Bay Metropolitan Municipality	Eastern Cape	Port Elizabeth	1263051
7	Buffalo City Metropolitan Municipality	Eastern Cape	East London	834997
8	Mangaung Metropolitan Municipality	Free State	Bloemfontein	787803
			Sub tot (Pop)	22196701
			SA pop tot	55910000
			SA pop %	40%

Average hourly air temperature dictates the inlet water temperature and estimation of losses of a water heating system.

Using the Koppen climate zones in SA, Winter/Summer hourly air temperature per province may be estimated.



GRAPHIC BY MARY ALEXANDER • DATA SOURCES: WIKIMEDIA COMMONS, SOUTH AFRICAN WEATHER SERVICE, WORLD BANK CLIMATE CHANGE KNOWLEDGE PORTAL

Figure 30: Koppen climate zones for SA

Simple aggregate hourly air temperatures (mean station) have been estimated from these zones per province and are shown in Table 53: Average hourly air temperature by Province & Season below:

Table 53: Average hourly air temperature by Province & Season

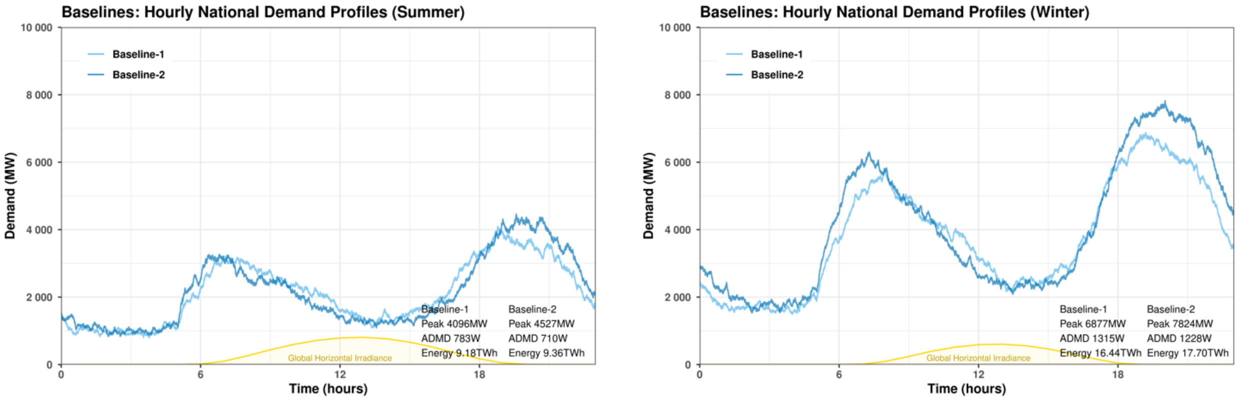
Measurand	**EC**	**FS**	**GP**	**KZN**	**LP**	**MP**	**NW**	**NC**	**WC**
Hrly avg temp (summer, Deg C)	23	24	23	25	25	27	24	27	22
Hrly avg Temp (winter, Deg C)	14	8	11	17	12	13	11	12	11
Climatic severity index	0,5	0	0	-1	0	-0,5	0	0	1

The last measurand, "climatic severity index" (CSI), is the marginal contribution to short-term regional household load (typically 12% central inland demand) for the same customer classes in different climatic zones.

9.4 ANNEX 4 - LOAD PROFILES AT MINUTE-RESOLUTION

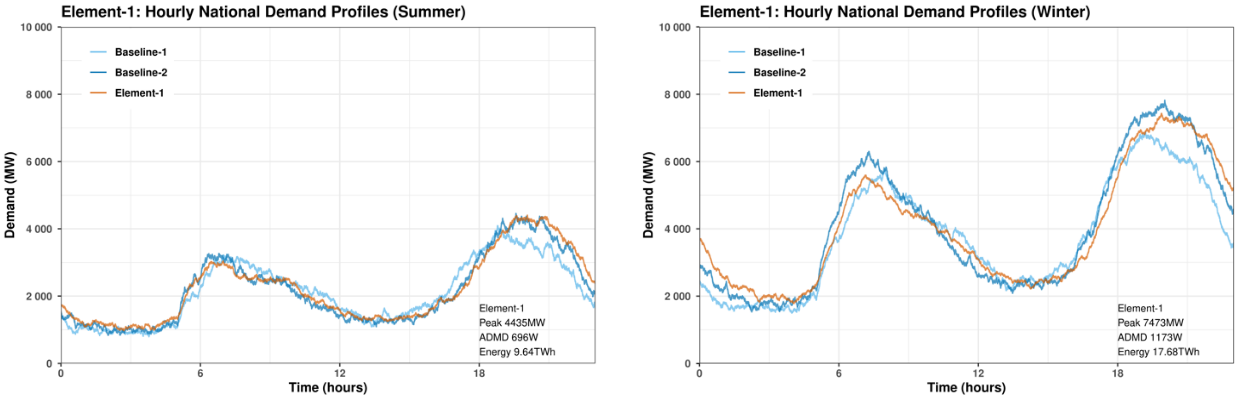
The load profiles in this study are presented in hourly averaged power demand values. The time resolutions for the simulations are performed at per minute intervals and make higher time-resolutions available for further discussions. In some instances, the hourly averaged power demand values do not show the full impact of some interventions, and therefore the minute-resolution load profile results are presented in this annex.

Figure 31: Load profiles at minute-resolution for estimated 5.2M (2023) and 6.4M (2033) geyser units nationally with set points at 65C for (a) summer and (b) winter.



(a) Baseline (summer) (b) Baseline (winter)

Figure 32: Simulated results for element reduction intervention in national geyser population against baseline for 2023 and 2033 at minute time resolution (a) summer forecast (b) winter forecast.



(a) Scenario Element-1 (summer) (b) Scenario Element-1 (winter)

Figure 33: Simulated results for Time-of-Use intervention with elements kept off during Eskom peak times in national geyser population against baseline for 2023 and 2033 at minute time resolution (a) summer forecast (b) winter forecast.

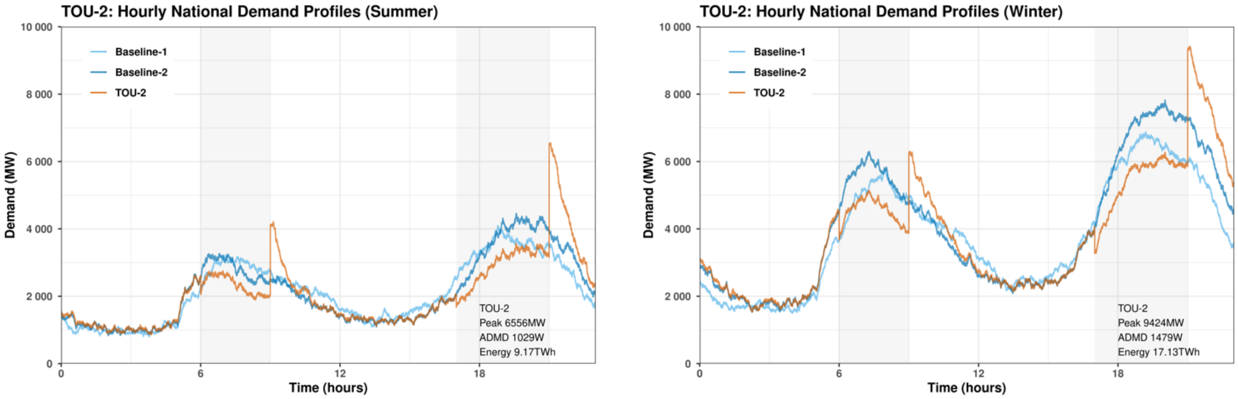
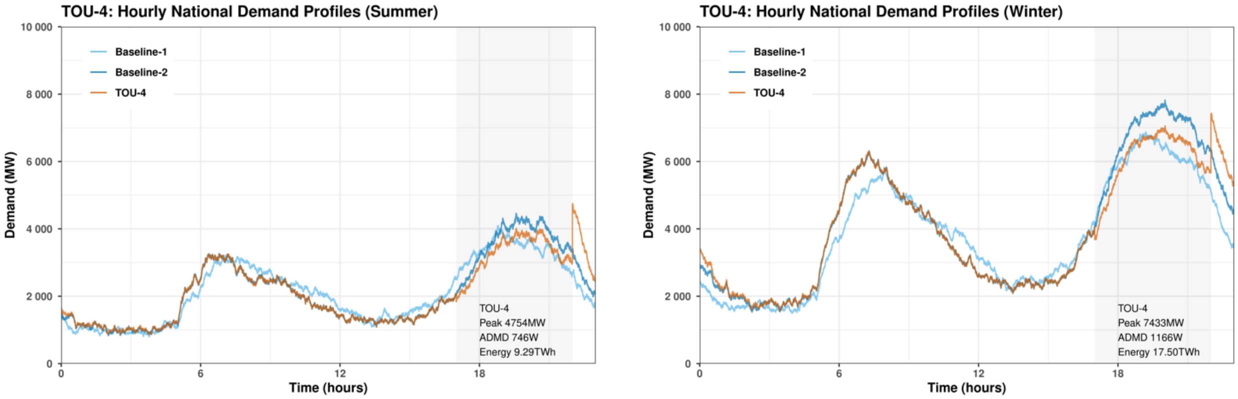


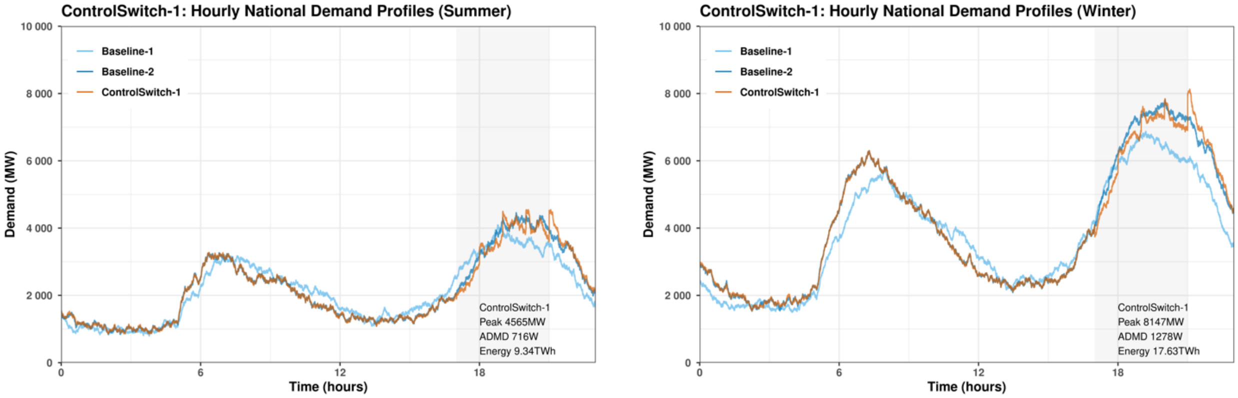
Figure 34: Simulated results for pipe insulation intervention in national geyser population against baseline for 2023 and 2033 at minute time resolution (a) summer forecast (b) winter forecast.



(a) summer

(b) winter

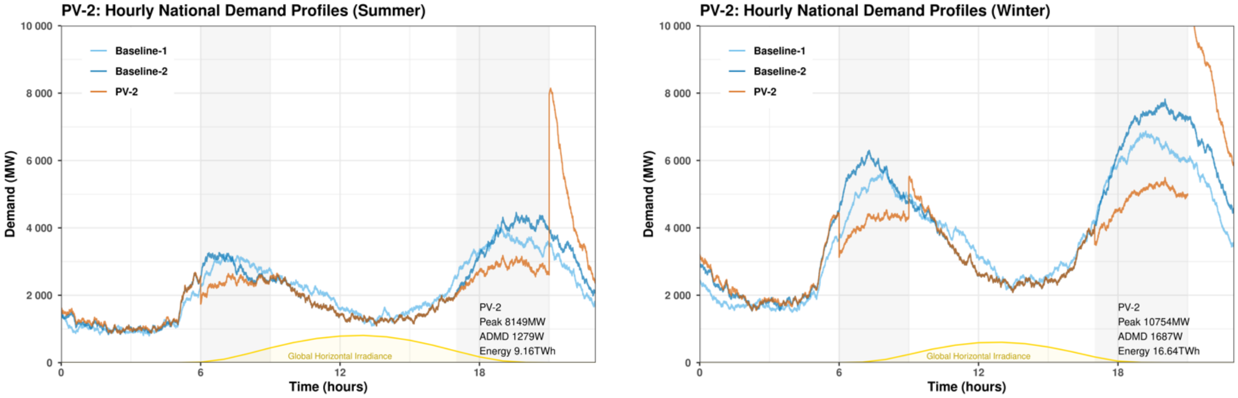
Figure 35: Simulated results for pipe insulation intervention in national geyser population against baseline for 2023 and 2033 at minute time resolution (a) summer forecast (b) winter forecast.



(a) summer

(b) winter

Figure 36: Simulated results for pipe insulation intervention in national geyser population against baseline for 2023 and 2033 at minute time resolution (a) summer forecast (b) winter forecast.



(a) summer

(b) winter