# University of Cape Town

# RESIDENTIAL ELECTRICITY CONSUMPTION IN SOUTH AFRICA

## Research Project Report

## 14 April 2021

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LIMITED DISTRIBUTION

## Contents

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## List of figures

# List of tables

## Nomenclature

| | |
|---|---|
| AMPS | All media products survey |
| AREP | Association for Renewable Energy Practitioners |
| BAT | Best available technology |
| BBBEE | Broad-based black economic empowerment |
| BUENAS | Bottom-Up Energy Analysis System |
| °C | Degrees Celsius |
| CFL | Compact fluorescent |
| COVID-19 | Severe Acute Respiratory Syndrome Coronavirus 2 |
| DEL | Domestic electricity load |
| DLR | Domestic load research |
| DMRE | Department of Mineral Resources & Energy |
| DOE | Department of Energy |
| DSM | Demand side management |
| DTI | Department of Trade & Industry |
| DVD | Digital video disc |
| ECO | Eco-friendly appliance cycle option |
| EDR | Energy demand resource |
| EE | Energy efficiency |
| EEDSM | Energy efficiency & demand side management |
| EETMS | Energy efficiency target monitoring system |
| e-SAGE | General equilibrium model |
| EU | European Union |
| FBE | Free basic electricity |
| GDP | Gross domestic product |
| GEF | Global Environment Facility |
| GHS | General household survey |
| GJ | Gigajoule |
| h | hour |
| HP | Heat pump |
| HP | High pressure |
| IEC | International Electrotechnical Commission |
| IQR | Inter-quartile range |
| INEP | Integrated national electrification programme |
| kg | Kilogram |
| kW | Kilowatt |
| kWh | Kilowatt-hour |
| KZN | Kwazulu-Natal |
| l | litre |
| LBL | Lawrence Berkeley National Laboratory (Berkeley Lab) |
| LCS | Living conditions survey |
| LEAP | Low Emissions Analysis Platform |
| LED | Light emitting diode |

| | |
|---|---|
| LP | Low pressure |
| LSM | Living Standards Measure |
| M&V | Measurement & Verification |
| min | Minute |
| MEPS | Minimum energy performance standards |
| NES | National Energy Savings |
| NEES | National energy efficiency strategy |
| POD | Point of delivery |
| PSC | Project steering committee |
| PV | Photovoltaic |
| PVR | Personal video recorder |
| R | South African Rands |
| REC 2020 | Residential Energy Consumption Online Survey 2020 |
| s | Second |
| S&L | Standards & labelling |
| SA | South Africa |
| SABS | South African Bureau of Standards |
| SANEDI | South African National Energy Development Institute |
| SANS | South African National Standard |
| SATIM | South African TIMES energy model |
| SD | Standard deviation |
| SEI | Stockholm Environment Institute |
| SESSA | Sustainable Energy Society of Southern Africa |
| SSEG | Small-scale embedded generation |
| Stats SA | Statistics South Africa |
| SWH | Solar water heater |
| t | time |
| TV | Television |
| UBPL | Upper bound poverty line |
| UCT | University of Cape Town |
| U.S. | United States of America |

# 1. Introduction

On a global basis, the residential sector consumes one fifth of the world's energy (International Energy Agency 2018: 2) and has a large untapped potential to benefit from the multiple positive economic and social impacts of energy efficiency. These benefits include increased disposable income, poverty alleviation, improved health & well-being, improved energy security and macro-economic benefits (IEA 2015: 31–37). Improved energy efficiency means that less energy is used while maintaining the same level of service, or increasing service levels while maintaining energy use. In the residential context this is achieved by utilizing more efficient appliances and by utilizing appliances more efficiently, meaning that efficiency improvements may be affected both by investments in technical interventions and by changes in behaviour.

The residential sector in South Africa was comprised of approximately 16.9 million households in 2016, of which about 86% were electrified (Stats SA 2016: 96; DOE 2018: 24). Electrified households consume roughly 17% of the country's total grid electrical energy to provide energy services (DOE 2018: 47), the most significant of which is resistive water heating. During peak periods, the residential sector can account for up to 35% of national electricity demand and energy efficiency in the residential sector can therefore contribute to reducing peak demand (McNeil, Covary & Vermeulen, 2015: 2).

Households in South Africa are heterogeneous, and electricity use by households is not well characterized by averages. Appliance ownership, age, utilization patterns and monthly spend on electricity all vary with household income which is very diverse. Poverty remains high and limits household electricity and appliance purchases. For example, a Stats SA study (2017a: 14) found that in 2015 55.5% of the population were living below the Upper-Bound Poverty Line (UBPL). Energy poverty is equally prevalent in South Africa, particularly in lower income households where electricity is often used in combination with solid fuels. Studies have shown that up to half of South Africa's households may be in energy poverty (DOE 2013: 65,67,76; Ye, Y;Koch, 2020: 24). The cost of purchasing electricity can contribute significantly to energy poverty and therefore energy efficiency interventions can also realise important social benefits in South Africa's lower income households.

To promote energy efficiency in South Africa, the first National Energy Efficiency Strategy (NEES) was released in 2005. The NEES derived its mandate from the White Paper on Energy Policy (Department of Minerals & Energy, 1998) and included a target to improve residential energy intensity by 10% in 2015 compared to a year 2000 baseline (DMRE 2005: 15). The mechanisms envisaged for achieving this target were Standards and Labelling (S&L) of household appliances, improved building efficiency, awareness campaigns and efficient lighting and energy audits. The NEES targets were based on estimates of potential savings that could be achieved by each of these programmes.

In support of the strategy, an S&L programme was introduced in 2005 which was voluntary, applied only to refrigerators, and achieved limited impact. In 2008, the SABS began the adoption of the IEC 941 standard as SANS 941 for the energy efficiency of electrical and electronic apparatus. In November 2014, government gazetted compulsory specifications for minimum energy efficiency performance standards (MEPS) and labelling (S&L) covering ten categories of appliances (VC9008) (Government Gazette 38323 2014: 31,32).

From 2011 onwards the United Nations Development Programme (UNDP) ran the Global Environment Facility (GEF) funded S&L support programme with the aim of reducing national residential electricity consumption through widespread uptake of energy efficient appliances. Under the programme, market studies have been undertaken to inform revisions of the South African S&L label format as well as to launch a household lighting information guide. In 2019 and 2020, the programme facilitated stakeholder workshops to revise the current MEPS and an amendment to the VC9008 specification is expected to be fully implemented in late 2021 (NRCS 2021: 5)[1].

In order to monitor the progress made towards meeting the original targets (measured against a year 2000 baseline), the Energy Efficiency Target Monitoring System (EETMS) was established in 2014. The EETMS reported that in 2012 the energy intensity of the residential sector had improved by 28.2% against a year 2000 baseline (DOE 2016: 1/431). The estimate was based on a decomposition analysis at the sector level.

In December 2016, the Draft Post-2015 NEES was published in Government Gazette 40515 for comment. The new strategy targeted a 33% reduction in the average specific energy consumption of new household appliances purchased and a 20% improvement in average energy performance of residential building stock, both by 2030 with respect to the 2015 baseline (DOE 2016: 19).

A significant step towards assessing the likely savings of the proposed revision of the S&L and MEPS programmes was made in 2018 when Lawrence Berkeley National Laboratory (Berkeley Lab) developed the South Africa Energy Demand Resource (EDR) model in The Low Emissions Analysis Platform (LEAP), in collaboration with the Department of Mineral Resources and Energy, SANEDI and UNDP. The model was used to project the electrical energy and greenhouse gas emissions associated with the use of various appliances and equipment (de la Rue du Can et al., 2020). By taking into account the changes in energy consumption resulting from efficiency improvements to different appliances, EDR provided a comprehensive forecast of the energy savings and emissions reductions that result from the implementation of minimum energy performance standards (MEPS). The LEAP model used the Bottom-Up Energy Analysis System (BUENAS) methodology, which emerged from the example of the National Energy Savings (NES) (McNeil et al., 2013). NES is a component of analyses supporting U.S.A federal rulemakings on MEPS for residential and commercial equipment. The South Africa EDR model was specifically developed for South Africa to run independently of any other models and to be used by the DMRE and its partners.

Three scenarios were explored, in the EDR model, to estimate energy consumption. These were a baseline scenario, the energy savings impacts of the proposed revision of the S&L program and the impacts of achieving international best practice. However the EDR model used an average penetration level across South African households and therefore does not account for shifts in income as they occur across income levels.

This study draws on the BEUNAS methodology and EDR model. In this study the electrical energy consumption of low, middle & high income households is characterized within a South African Residential Sector LEAP model. Within each of these income groups, appliance penetration rates together with appliance average annual energy consumption estimates are used to approximate the national annual electricity consumption of the sector. The disaggregation of energy services and appliances within the model, expands upon those of the EDR model, and includes lighting, cooking (oven, stove, microwave, kettle and other), refrigeration (fridges and freezers), dishwashers, washing machines, tumble dryers, water heating (electric geysers, solar water heaters and kettles), space heating (all electrical heaters), televisions, pool pumps, air conditioning and other plug loads (Listed in Table 5-1 on p27).

[1] In early 2021, the DMRE announced that, moving forward, formal support for the S&L programme would be wholly transferred to SANEDI (DMRE S&L Newsletter 2021). More information, including research reports, can be found on the programme website www.savingenergy.org.za.

A range of scenarios are developed to allow the likely impacts of energy efficiency programmes to be estimated against energy service consumption levels in each income group. The LEAP model has been used to estimate the energy efficiency impacts of the South African appliance Standards & Labelling (S&L) programme over the period 2015 – 2020. The potential for further energy savings of various technical and behavioural scenarios to 2040 have also been explored. It is understood that energy efficiency interventions may trigger various rebound effects, however these cannot be easily anticipated and have not been considered.

The report is structured as follows. Chapter 2 provides an overview of this study with a high level description of the household survey, and the LEAP model. Chapter 3 describes the household survey methodology in detail and Chapter 4 provides an overview of the survey results. Chapter 5 describes the structure of the LEAP model, calibration of electricity consumption, key drivers, demand assumptions and scenario development. Chapter 6 presents the LEAP model results: reference case consumption demand and stock growth, results of the savings achieved by the S&L programme from 2015 – 2020, the savings under various scenarios to 2040 and discusses the model boundary. Chapter 7 provides a discussion and key recommendations, an assessment of the Post-2015 NEES targets for residential appliances, further comments on selected appliances and project lessons learned. Chapter 8 is the report conclusion and this is followed by references and appendices.

# 2. Overview

The study presented in this report has three primary components, which contribute to the S&L impact assessment and review of the Post-2015 NEES as it relates to residential appliances. The first component of the study was the development and rollout of the REC 2020 household survey (covered in detail in Chapters 3 and 4). The second component was the development of a calibrated bottom-up South African residential sector LEAP model representing household appliance ownership and electricity consumption (covered in detail in Chapters 5 & 6). The third component was the development of scenarios, applied in the LEAP model, to assess the impact of the S&L programme and the potential for enhancing energy efficiency through extended MEPS and awareness campaigns aimed at behavioural change (covered in detail in Section 5.5). Figure 2-1 provides an overview of the project stages followed to: develop and administer the REC 2020 household survey; calibrate the residential sector LEAP model and; perform the LEAP impact assessment.

## 2.1. REC 2020 Online household survey

The household survey was designed to provide data that could be used to estimate electricity used to supply energy services in South African households. The questionnaire was developed after an extensive literature review which included a review of surveys implemented in South Africa and abroad. The data gathered includes household demographic data, appliance technology ownership and utilisation data, and electricity purchases. Throughout this report, the survey is referred to as the "Residential Energy Consumption Online survey 2020", or simply "REC 2020".

## 2.2. SA Residential Sector Calibrated LEAP model

The processed survey results, together with a broad literature review contributed to the calibrated appliance ownership levels and annual kWh estimates for each appliance type in the LEAP model. The REC 2020 survey was used primarily to determine appliance age and usage patterns across the income groups, while appliance penetration levels at the national level were informed by nationally representative surveys, such as the Stats SA General Household Survey (GHS) and Community Survey (CS). In this report, the annual kWh estimates for appliances are referred to as the "calibrated appliance intensities" or the "appliance intensities".

The reference scenario includes assumptions about household growth, income growth, electrification, appliance stock and sales and the electrical intensity of appliances between 2015 and 2040. The assumptions that inform these scenarios are discussed in Chapter 5.

The energy consumption and savings reported in this study occur within a measurement boundary. At the single household level a measurement boundary is drawn around the dwelling to isolate the electricity use to the homeowner side of the electricity meter. At a project level, the measurement boundary consists of the sum of all the individual households.

Given this boundary, the impacts do not include the savings associated with transmission and distribution losses. It is also important to note that embodied appliance energy has been ignored which includes all the energy associated with product manufacture, transport and eventual scrapping or disposal. To quantify this energy would require a life-cycle product assessment. The study thus only considers energy consumption and savings at the point of use – the demand side.

## 2.3. S&L impact assessments and Post 2015 NEES target review

The S&L impact assessment and Post 2015 NEES target review were conducted using scenarios modelled in the LEAP.

### 2.3.1. Past impacts of the S&L programme

The assessment of S&L programme impacts, utilised the LEAP model to estimate the electrical energy savings that occurred between 2015 and 2020 as a result of the S&L programme. The assessment relies on two scenarios, in the first the electrical intensity of appliances remains the same as that of new appliances in 2015, in the second the electrical intensity of appliances purchased in the years following the introduction of MEPS and S&L is reduced. The second scenario is the Reference scenario.

### 2.3.2. Future potential S&L impacts

The assessment of potential S&L impacts between 2020 and 2040, utilised the LEAP model to determine the savings potential of two different future S&L programme scenarios. These scenarios both assume a revision and tightening of existing MEPS and are named "Moderate MEPS Scenario" and "Extensive MEPS Scenario". In these scenarios savings are measured using 2020 as a base year and 2020 appliance performance levels for new products as a reference case.

### 2.3.3. NEES Review

The NEES review draws on the Moderate and Extensive MEPS scenarios as well as a scenario named "Behavioural Scenario" which models the potential impacts of selected behavioural interventions and a scenario named "SWH & Heat Pump" Scenario, which models the impact of a higher adoption of Solar Water Heaters or Heat Pumps. The behavioural interventions were selected based on whether the impacts were reasonably certain and if it seemed plausible that there could be broad and sustainable uptake. The Behavioural and SWH & Heat Pump scenarios provide a useful starting point to compare the relative magnitudes of behavioural versus technical interventions and may be used as a basis for a cost benefit comparison of the two approaches. However, it is important to note that all impacts in the behavioural scenario are additive and mutually inclusive with both the Moderate and Extensive MEPS scenarios.

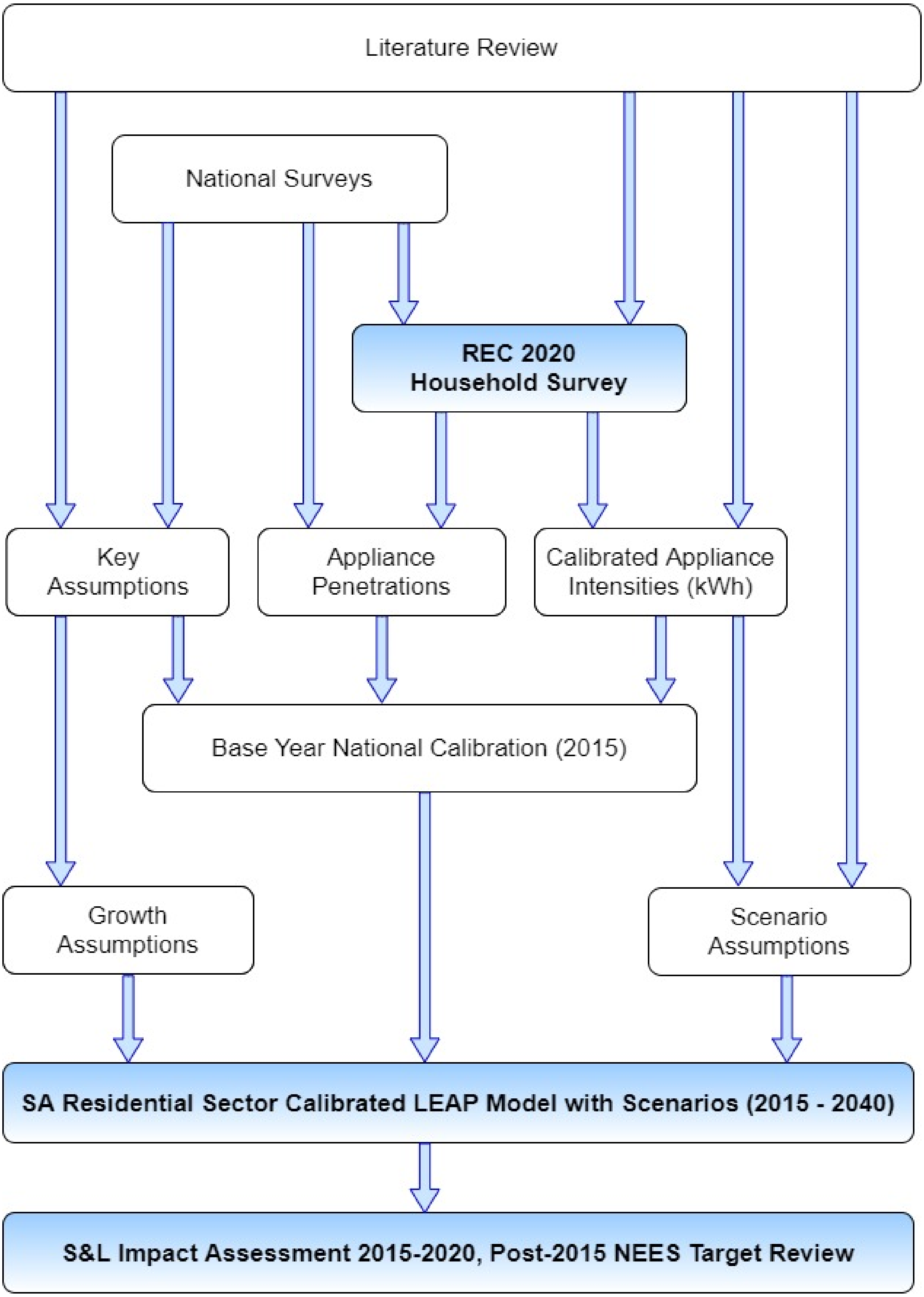


*Figure 2-1: Project overview showing interactions of key stages, data sources and deliverables.*

# 3. REC 2020 Household survey methodology

## 3.1. Survey methods considered

Three survey methods were originally suggested in the inception report namely (i) online panels (ii) e-surveys conducted in partnership with municipal metros and (iii) a small door to door survey in one municipality. Due to the COVID-19 outbreak, and the necessary restrictions on movement and interaction, only methods (i) and (ii) were implemented.

## 3.2. Online panels

An online panel is a large group of members of the public that are incentivised by a private survey company to voluntarily partake as subjects in a broad range of online consumer research. The primary means of completing online panel surveys is via a mobile platform and incentives are typically randomly drawn prizes for respondents that complete surveys. Respondents are only allowed to partake in each survey once.

An online panel was chosen as the primary survey method. There were several reasons for this but primarily this method was pursued as a way of ensuring a high response rate, across LSM groups, at a time when door to door surveys could not be completed and the response of municipalities to requests for partnership was slow and uncertain.

The service provider selected was Springvale Online CC, a Level-1 BBBEE contributor based in Rosetta, KZN. Springvale Online was established in 2005 and has built up a panel of respondents totalling in excess 40,000 with a broad demographic spread of gender, ethnicity, income, region, age and marital status.

## 3.3. Questionnaire development, testing and deployment

The questionnaire was designed to gain an overall understanding of the demographic profile, appliance ownership and usage, and electricity consumption of households within the sample. Respondents were asked to identify their geographic region, housing type and the number of rooms in the house, their household size, and household income level. The energy services and appliances investigated included those used for lighting, cooking, refrigeration, space heating & cooling and water heating and entertainment.

The review and deployment of the questionnaire included the following steps.

- A draft *Word* version of the questionnaire was developed and distributed to the PSC for the first round of comment. Valuable feedback was received and incorporated.
- An electronic version of the updated questionnaire was developed on Googleforms and distributed to colleagues, friends and family for comment. The electronic medium gave reviewers a real sense of what could be expected in the final survey and also allowed for a real estimate of completion time. Pictures were added to assist respondents to identify specific technologies.
- The survey was also forwarded to Springvale Online for comment. Once again, valuable feedback was received and incorporated. In particular, the length of the survey was reduced by about 15% (in terms of number of questions).
- An updated *Word* version was submitted to Springvale Online for trial upload to their preferred survey platform and this was made available to UCT electronically for internal review. Final changes were made to ensure that consistent language was used throughout.
- On 30/07/2020, the survey was launched to the Springvale Online respondent panel by means of a "soft-launch". (Following after 100 responses were received, the company would provide UCT with feedback about potential problems with questionnaire or the response rate, providing an opportunity for correction and refinement before collecting the full target number of responses.

The soft-launch was completed on 03/08/2020 (110 completed responses). At this point, no further corrections or refinements were necessary and no problems were anticipated.

- The survey was then immediately "hard-launched" to reach the target number of 2,000 completed surveys. The final number of completed responses was 2,075.
- Prior to launch, the survey was approved by UCT's ethics clearance process for research.
- The Springvale survey ran from 30 July to 03 August 2020.

# 4. REC 2020 survey findings

This section provides an overview of the demographic profile of households that participated in the survey, as well as the appliance ownership and usage patterns reported by households. A comparison of the REC 2020 appliance ownership levels reported here with other, nationally representative, surveys is provided in Table 5-4. Although the REC 2020 survey results, for low and middle income households, do not appear to be nationally representative they were able provide a useful starting point for the characterization of appliance intensities for the SA LEAP model.

There were three households in the sample that reported a household size of greater than 20, and one household that reported spending in excess of R20 000 a month on electricity. These households were excluded from the sample in the analysis which follows.

## 4.1. Demographic profile of respondents

The mean, median, minimum and maximum household size, number of adults, number of rooms and the number of dining rooms and bedrooms is shown in Table 4-1. The mean household size for the sample was 4.6, the mean number of rooms was 6, the majority of households reported a household size of between 3 and 5 people with between 4 and 8 rooms. The mean household size in this sample is higher than the mean household size of 3.6 recorded in the 2011 Census (StatsSA 2012:56).

*Table 4-1: Selected household statistics*

| Statistic | Household size | Adults | Rooms (total) | Dining and living rooms | Bedrooms |
|---|---|---|---|---|---|
| Mean | 4.6 | 3.0 | 6.0 | 1.6 | 2.9 |
| Standard deviation | 2.1 | 1.5 | 2.7 | 0.8 | 1.4 |
| Median | 4 | 3 | 6 | 2 | 3 |
| Minimum | 1 | 0 | 0 | 0 | 0 |
| Maximum | 16 | 15 | 30 | 8 | 22 |

The share of respondents in each income group in the sample is shown in Table 4-2. As a cautionary note it is very important that the survey results on household incomes are read in conjunction with the discussion in Section 5.2.3.

*Table 4-2: Share of household respondents by gross household income*

| Less than R5,000 | R5,001 to R10,000 | R10,001 to R20,000 | R20,001 to R40,000 | R40,001 to R80,000 | More than R80,001 | Preferred not to say |
|---|---|---|---|---|---|---|
| 18.3% | 24.5% | 24.5% | 18.4% | 8.2% | 2.6% | 3.6% |

As the LEAP model (see Chapters 5 & 6) includes only low, middle and high income groups, the income groups in Table 4-2 are reduced to three groups, representing a low income group with incomes of less than R5,000 per month, a middle income group with incomes of between R5,001 and R20,000 per month and a high income group with incomes of more than R20,001 per month. This mapping is used for the analysis that follows in this chapter and in the parameterization of the LEAP model (Chapter 5). Table 4-3 provides the share of household respondents in each of these income groups. Households that did not indicate an income level are not included in the table. Of the responses, the majority of households (over 1,600 households) reported a household income of between R5,000 and R20,000 a month.

*Table 4-3: Share of household respondents in three income groups*

| Low | Middle | High |
|---|---|---|
| Less than R5,000 | R5,001 to R20,000 | More than R20,001 |
| 18.96% | 50.73% | 30.31% |

The response rate according to dwelling type, for the low, middle and high income groups is shown in Figure 4-1. The majority of households in the sample were living in a house or semi-detached house, there were very few respondents that indicated that they lived in informal dwellings.

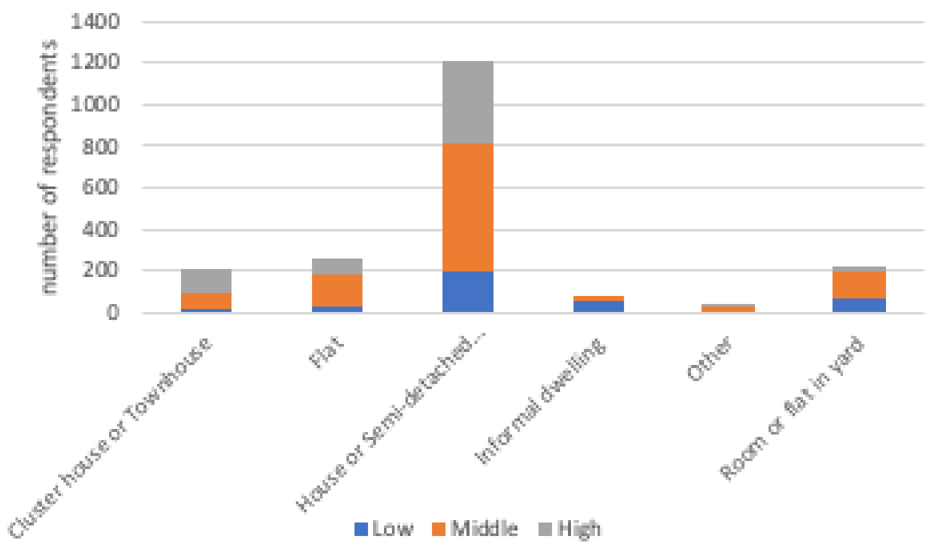


*Figure 4-1: Survey respondents according to dwelling type*

## 4.2. Geographic spread of respondents

The responses were received from residents in many of the major metros, Table 4-4 shows the number of responses that could be attributed to some of the major metros. These represent the mimimum number of households that responded to the survey in each of these Metros.

*Table 4-4: Online surveys completed from major metros*

| Major metro | Number of completed questionnaires |
|---|---|
| City of Cape Town Metropolitan Municipality | 142 |
| City of Ekurhuleni Metropolitan Municipality | 85 |
| City of Johannesburg Metropolitan Municipality | 147 |
| City of Tshwane Metropolitan Municipality | 135 |
| eThekwini Metropolitan Municipality | 120 |
| Nelson Mandela Bay Metropolitan Municipality | 43 |

## 4.3. Electricity consumption

The majority of households in the sample were on prepaid electricity meters. Reported spending on electricity varies widely, with a mean and median spending of R907 and R600 respectively (see Table 4-5). Only six households in the sample reported spending more than R6,200 per month on electricity. These households are not shown in Figure 4-2 but are included in the calculation of mean and median expenditure (Table 4-5) (with the exception of the one household that reported spending over R20,000).

*Table 4-5: Monthly spending on electricity*

| Statistic | Monthly electricity spend (R) |
|---|---|
| Mean | 907 |
| SD | 1,033 |
| Median | 600 |
| Minimum | 4 |
| Maximum | 12,200 |

Table 4-6 shows the mean and median spending on electricity and standard deviation recorded in the sample for the low, middle and high income groups. The data indicates a positive relationship between reported monthly income and spending on electricity[2] (see Figure 4-2). It also suggests that spending increases significantly between households with a monthly household income of less than R40,000 and those with an income of higher than R40,000.

*Table 4-6: Monthly spending on electricity per income group*

| Income mapping | Count | Mean | SD | Median |
|---|---|---|---|---|
| Overall | | 907 | 1,033 | 600 |
| Low | 379 | 452 | 487 | 300 |
| Middle | 1,014 | 797 | 806 | 525 |
| High | 606 | 1,338 | 1,638 | 1,000 |

[2] Pairwise comparisons between the low, middle and high income groups, using a Wikoxan rank sum significance test show a significant difference between all three groups (R<0.001).

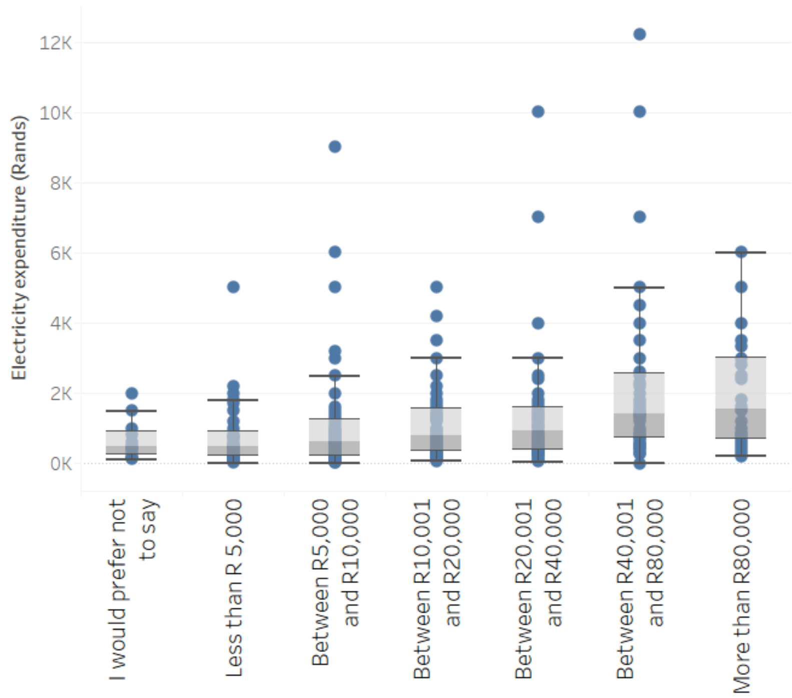


*Figure 4-2: Monthly household electricity expenditure by gross monthly household income*

## 4.4. Appliance ownership and use

An overview of household appliance ownership for larger appliances is shown in Table 4-7. This shows the percentage of households that reported owning tumble dryers, washing machines, dishwashers, pool pumps, TVs, air conditioners, fridges and deep freezers and geysers in the low, middle and high income groups and over the entire sample. Ownership of large appliances show large increases as household income increases, with the exception of fridges and televisions where the difference between low and high income groups is smaller.

It is clear that some of the reported ownership levels in the low income category are higher than expected. For example, tumble dryers (11%), dishwashers (5%), pool pumps (4%), air conditioners (6%) and geysers (33%). One possible reason for this could be that some respondents under-reported monthly household income, thus placing the household in the low income category and causing ownership levels in that category to be inflated.

*Table 4-7: Selected large appliance ownership levels*

| **Appliance** | Tumble dryer | Washing machine | Dish-washer | Pool pump | TV | Aircon | Geyser | Fridge | Deep freeze |
|---|---|---|---|---|---|---|---|---|---|
| All | 19% | 76% | 14% | 8% | 92% | 14% | 66% | 98% | 35% |
| Low | 11% | 52% | 5% | 4% | 84% | 6% | 33% | 94% | 21% |
| Middle | 18% | 76% | 10% | 5% | 93% | 11% | 65% | 99% | 35% |
| High | 27% | 91% | 26% | 17% | 95% | 23% | 87% | 100% | 45% |

Figure 4-3 provides an overview of household ownership of smaller appliances, showing the average number that households that reported owning the appliances in the three income bands. The smaller appliances included computers (laptop and desktop), tablets, Wi-Fi routers, cell phones, gaming consoles, DSTV decoders (including PVR), DVD players, home theatre systems, audio systems and hair dryers or flat irons. The ownership of smaller appliances also follow a trend in which the number of appliances per household increases with household income, although the trend is less pronounced than among the large appliances.

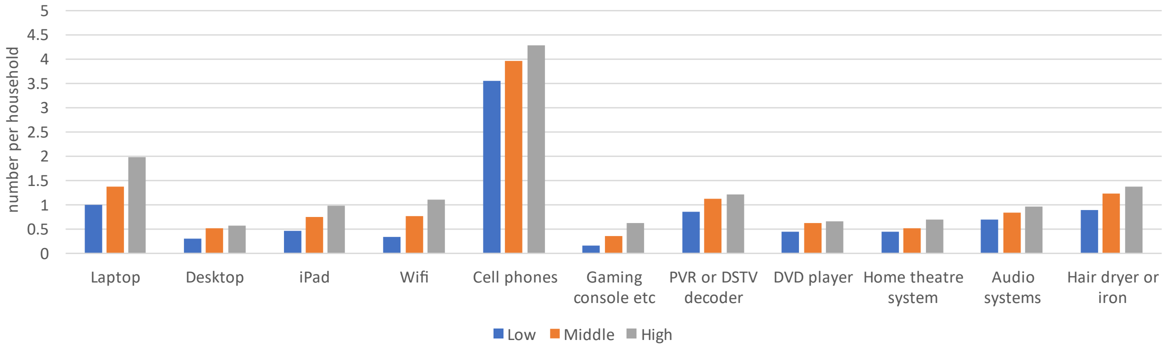


*Figure 4-3: Selected small appliance ownership levels*

## 4.4.1. Lighting

The number of lamps within the dwelling varies between income groups with an average ratio of around 2 lights per room in households across the sample (
Table 4-8). The majority of households in the low and middle income groups reported using fewer than 10 inside lights whereas those in the highest income group fell largely within the 10-19 range. Although a number of households indicated that they were not able to distinguish between the different lighting types, the data indicates that most households were using CFLs, followed by halogen lamps, and that very few households used LEDs. This indicates a large potential for improving the energy efficiency of lighting. The spread of LED, CFL and halogen use across income groups is shown in Figure 4-4. Table 4-9[3] shows the reported penetration rates of inside lighting technologies.

*Table 4-8: Number of inside lamps per income group*

| Income group | Less than 10 | 10 to 19 | 20 to 39 | 40 to 59 | 60 to 79 | More than 80 | I don't know |
|---|---|---|---|---|---|---|---|
| **Low** | 81.5% | 16.9% | 0.8% | 0.3% | 0.0% | 0.3% | 0.3% |
| **Middle** | 63.2% | 28.0% | 7.0% | 0.5% | 0.1% | 0.0% | 1.2% |
| **High** | 30.7% | 50.0% | 12.0% | 4.0% | 1.0% | 0.7% | 1.7% |

[3] The NOVA Economics CBA Report (Walsh et al., 2019: 28) quotes 2018 H1 sales as: CFL = 52%, LED = 20% and Halogen = 26%. There is expected to be a lag in shares of stock vs shares of sales due to lamp lifespan.

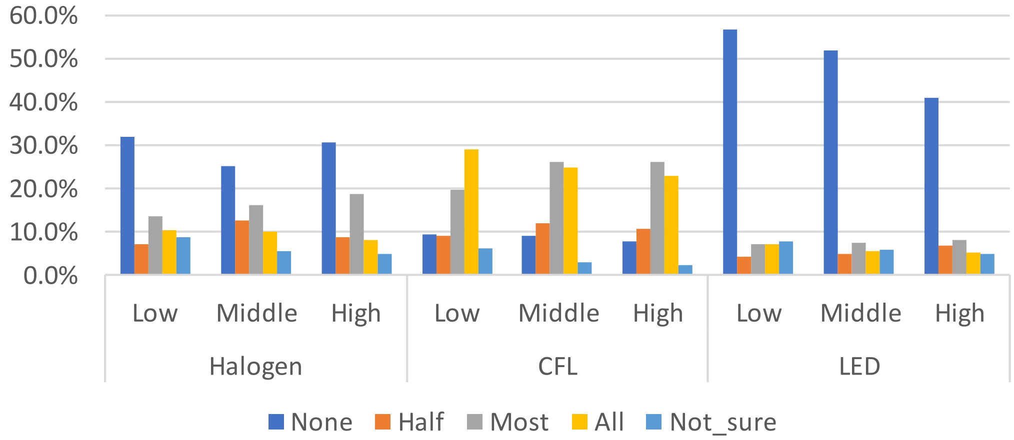


*Figure 4-4: Shares of inside lighting technologies per income group*

*Table 4-9: Inside lighting penetration rates per technology*

| Lamp Type | Penetration |
|---|---|
| **Other** | 19% |
| **CFL** | 67% |
| **LED** | 13% |

Most households had between 1 and 5 lights outside the dwelling as shown in Table 4-10 and Figure 4-5. Figure 4-6 shows that the majority of these are on for more than four hours each day. Although a number of households indicated that they were using LEDs outside, the majority of households indicated that most of their outside lights were CFLs (Figure 4-5) with some households still using incandescent lamps. This also indicates that there is potential for improving lighting energy efficiency.

*Table 4-10: Number of outside lamps per income group*

| Income group | None | 1 to 5 | 6 to 10 | More than 10 | I don't know |
|---|---|---|---|---|---|
| **Low** | 20.6% | 72.0% | 4.2% | 1.1% | 2.1% |
| **Middle** | 9.1% | 78.8% | 8.3% | 2.0% | 1.9% |
| **High** | 4.0% | 77.2% | 14.7% | 3.0% | 1.2% |

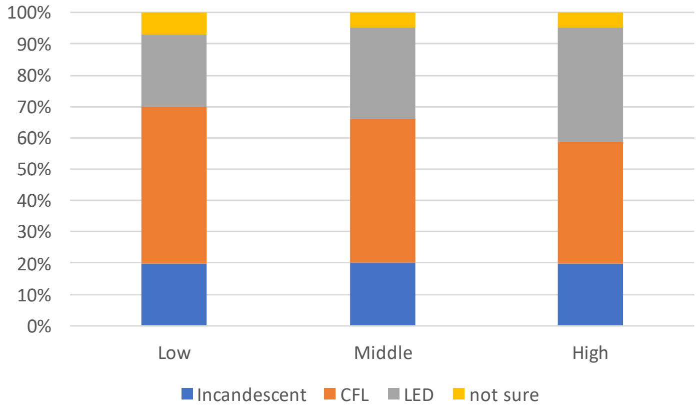


*Figure 4-5: Shares of outside lighting technologies per income group (Halogens grouped with Incandescent)*

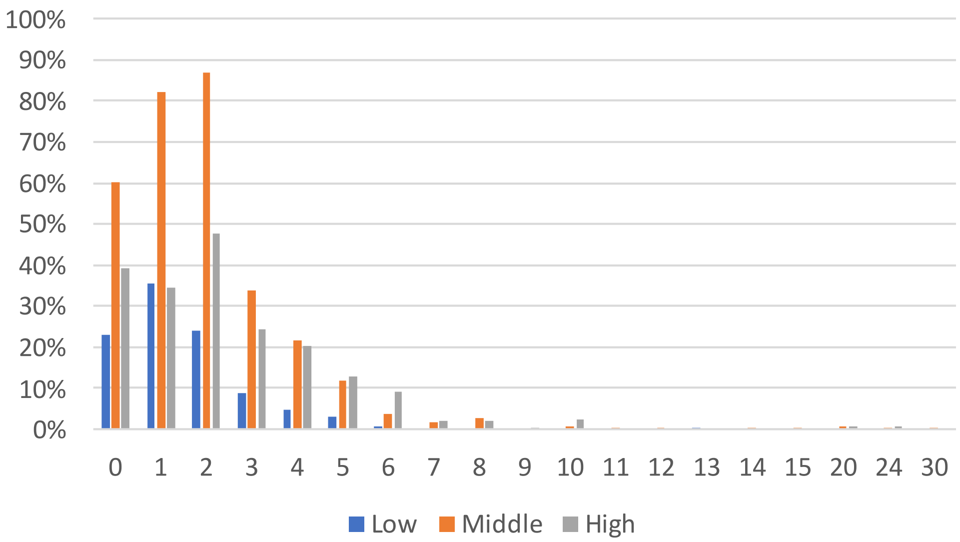


*Figure 4-6: Percentage of households that reported having none (0) or more than 1 light on for more than four hours a day*

### 4.4.2. Cooking: Oven and Stove top (hob)

The majority of households in the sample were using electricity only for cooking, with an electric stove top (hob) and an oven. The distribution of cooking appliance ownership reported by households is shown in the top left graph of Figure 4-7. In addition to questions relating to the type of cooking appliance, households were also asked how often they cooked and how many times a week they used their oven and stove top. These responses are also shown in Figure 4-7 in the top right, bottom left and bottom right graphs respectively. The majority of households in all income groups were cooking one or more meals a day on an electric stove. Oven use by comparison is infrequent with the majority of households using their oven less than three times a week, and with oven use being far less frequent in lower income households.

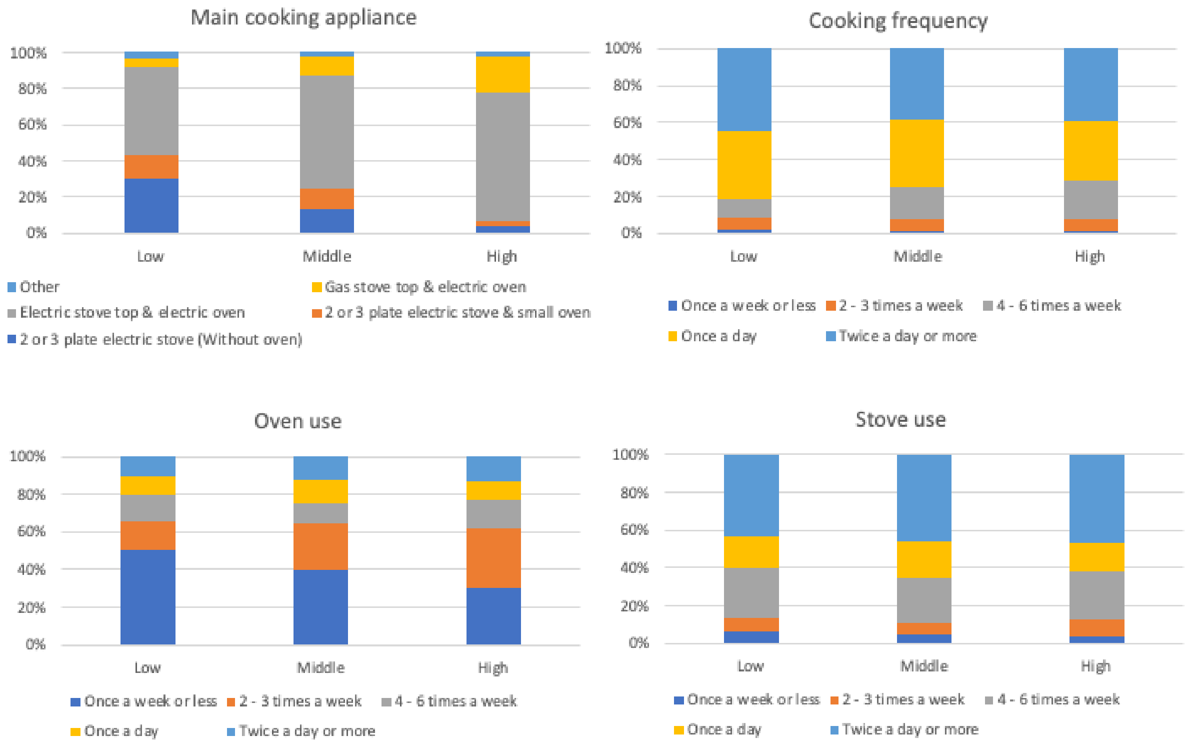


*Figure 4-7: Main household cooking appliances and frequency of use*

### 4.4.3. Cooking: Microwave oven

The percentages of low, middle and high income households that reported owning a microwave oven were 69.9%, 89.1% and 94.6% respectively. Table 4-11 shows that in all income groups microwaves were used most frequently for heating up food and re-heating food.

*Table 4-11: Microwave oven most common uses (multiple selections allowed per respondent)*

| Income group | Heating up food and re-heating food | Defrosting food | Cooking meals from raw | Heating up drinks like tea & coffee | A bit of everything |
|---|---|---|---|---|---|
| **Low** | 87.1% | 33.1% | 9.5% | 15.6% | 16.3% |
| **Middle** | 88.6% | 46.1% | 12.6% | 24.2% | 17.7% |
| **High** | 89.3% | 51.0% | 13.3% | 33.0% | 24.7% |

### 4.4.4. Cooking: Kettle

Of all households surveyed, 99% reported making use of a kettle for cooking or making hot drinks. Figure 4-8 below shows that the majority of households in all income groups reported boiling water more than four times a day. Kettles are revisited in Section 4.4.7 as kettles are also used for water heating for bathing, washing and cleaning.

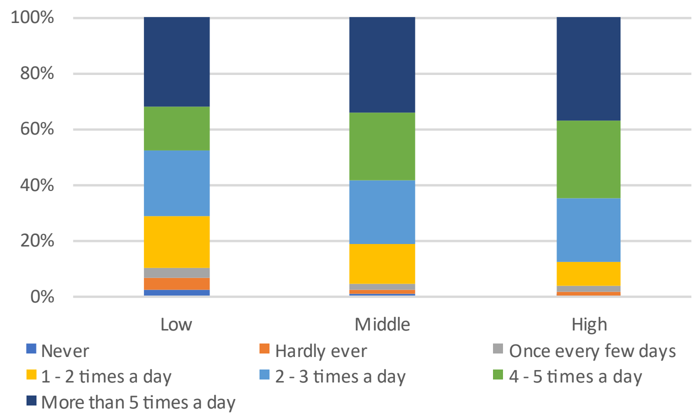


*Figure 4-8: Frequency of kettle use for cooking and hot drinks*

### 4.4.5. Cooking: Other appliances

Households indicated owning several other cooking appliances, with appliance ownership increasing with household income. Table 4-12 shows the appliance ownership of smaller kitchen appliances in the sample. Across all income groups, toaster ownership was the most prevalent small cooking appliance.

Table 4-12: Ownership of other small cooking appliances

| Income group | Toaster | Coffee maker | Slow cooker | Air fryer | Induction stove | Food processor | Blender or juicer | Coffee grinder |
|---|---|---|---|---|---|---|---|---|
| Low | 64.6% | 6.1% | 9.5% | 5.8% | 14.5% | 6.6% | 19.3% | 4.2% |
| Middle | 73.0% | 9.7% | 13.7% | 7.4% | 10.9% | 9.9% | 31.6% | 6.2% |
| High | 76.6% | 19.5% | 20.5% | 15.2% | 13.7% | 19.1% | 47.9% | 9.4% |

## 4.4.6. Refrigeration: Fridge & freezer

98.1% of households in the sample reported owning at least one fridge, and 24.0% of households reported owning more than one fridge. In comparison 64.9% of households in the sample (n=1,346) reported not owning a chest freezer (deep freeze), and 2.1% of households reported owning more than one chest freezer. The percentage of households in each income band that reported owning fridges and chest freezers is shown in Table 4-13.

Although some households in all income bands reported owning more than one fridge, as expected second fridge ownership increases with household income and in the highest income band 32.5% of the households (n=607) reported owning more than one fridge. Fridge and second ownership by type and age are shown in Figure 4-9 and Figure 4-10 respectively. The majority of fridges are double door fridge/freezer combinations, with the fridge compartment at the top and the freezer compartment below. Ownership of chest freezers by type and age is shown in Figure 4-11. The majority of freezers were in the 200-350l range, and between 3 and 5 years old.

Table 4-13: Percentage of households that own at least one, or more than one fridge and deep freeze

| Income group | Own at least one fridge | Own more than one fridge | Own at least one deep freeze | Own more than one deep freeze |
|---|---|---|---|---|
| Low | 94.2% | 15.4% | 20.3% | 0.8% |
| Middle | 98.7% | 22.4% | 32.7% | 2.0% |
| High | 99.8% | 32.5% | 41.7% | 3.0% |
| All | 98.1% | 24.0% | 33.1% | 2.1% |

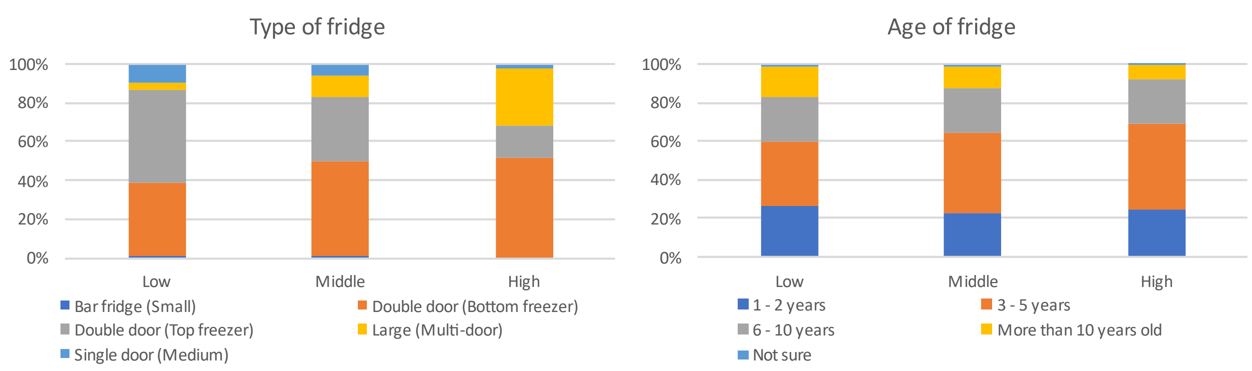


Figure 4-9: Type and age of primary fridge per income group

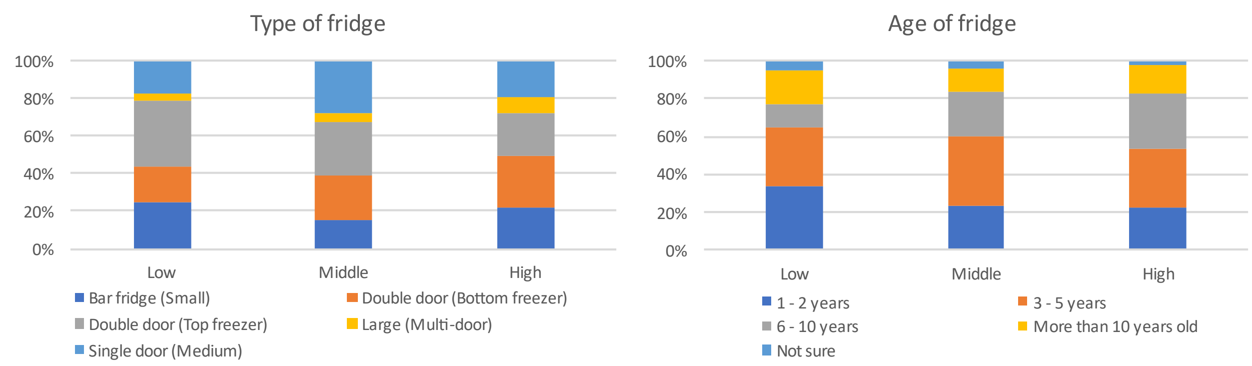


*Figure 4-10: Type and age of secondary fridge per income group*

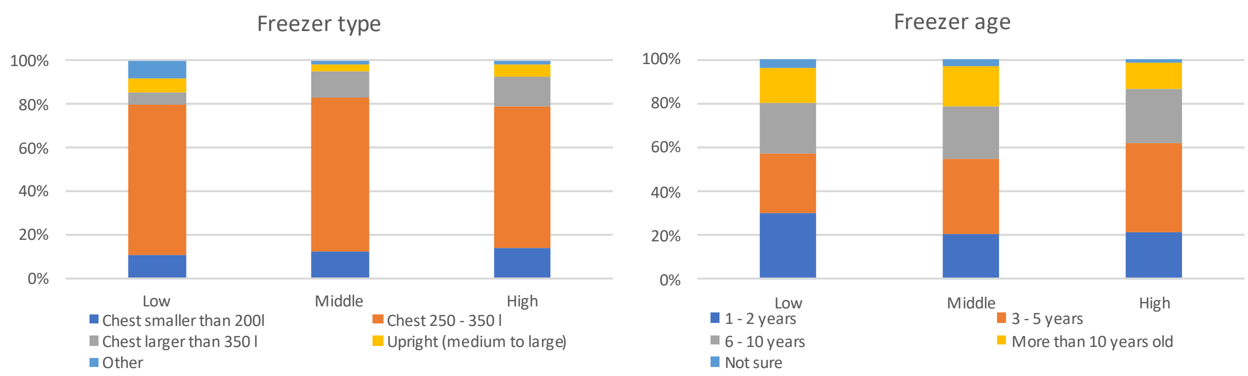


*Figure 4-11: Type and age of primary chest freezer per income group*

### 4.4.7. Water heating

13% of households reported owning a SWH and 10% of households reported owning a heat pump, however there appears to be double counting as several of these households reported owning both a SWH and a heat pump. The data seems to indicate that households may not be able to easily distinguish between these technologies even with the help of pictures and perhaps may also have difficulty distinguishing between SWHs, heat pumps and normal geysers. Ownership of these technologies requires further investigation. The distribution of geyser ownership reported by households along with the distribution of geyser size and age is shown in Figure 4-12. The majority of households reported owning only one geyser, although many households (30%, n = 419) indicated that they were not able to identify the size of the geyser. Of the households that were able to estimate their geyser size, the majority reported owning a geyser of between 100 and 250 litres. The majority of geysers owned by households were between three and five years old.

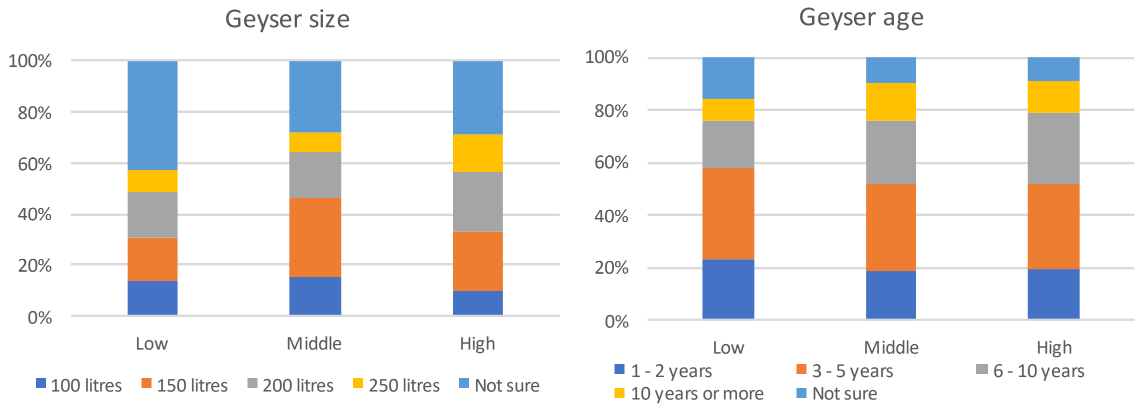


*Figure 4-12: Reported geyser ownership in terms of size, age per income group*

## 4.4.8. Washing machine

Percentage breakdown of washing machine ownership according to machine type and income group was reported as shown in Table 4-14. Machine ownership appears to be clearly correlated to household income with ownership being lower among low income households and higher among those in the high income group. It also appears that top loader washing machines are far more popular than front loading machines and this trend becomes greater as household income decreases. Figure 4-13 below shows the washing machine age profile shares for each income group. Most washing machines are reported to be less than 10 years old and almost half are reported to be between 3 and 5 years old. Figure 4-14 shows usage patterns and cycle temperatures for each machine type and income group. An important energy-related observation here is that lower cycle temperatures are more prevalent than higher temperatures, regardless of usage, machine type or income group (see Section 7.4.6 (p67) for further discussion).

*Table 4-14: Washing machine ownership according to machine type per income group*

| Income group | All types | Front loader | Top loader |
|---|---|---|---|
| **Low** | 51.7% | 7.7% | 44.1% |
| **Middle** | 75.9% | 15.3% | 60.6% |
| **High** | 90.6% | 29.2% | 61.4% |
| **All** | 75.8% | 18.0% | 57.8% |

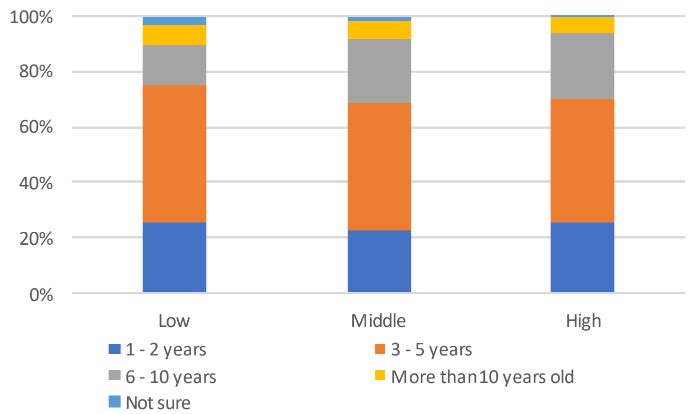


*Figure 4-13: Washing machine age shares per income group*

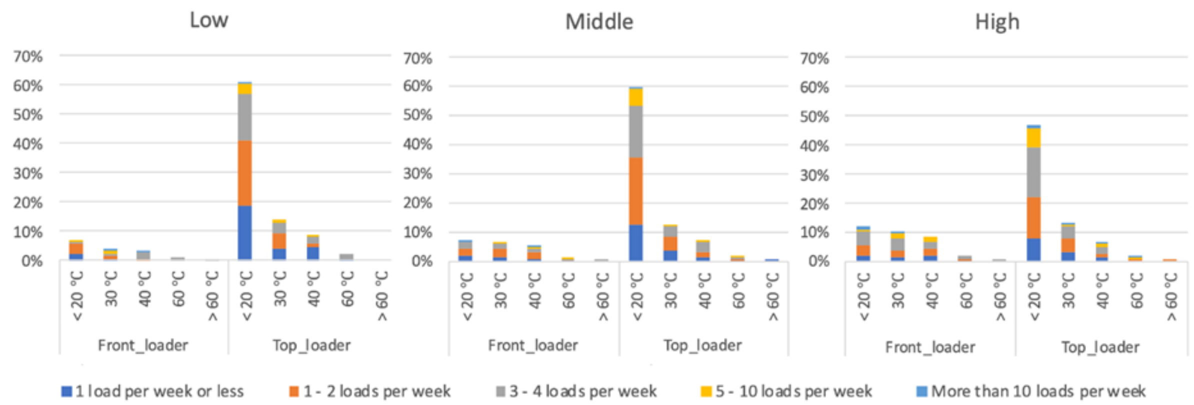


*Figure 4-14: Washing machine usage patterns and cycle temperatures for each machine type per income group*

## 4.4.9. Tumble dryer

Tumble dryer ownership is shown in
Table 4-15. Average ownership across all income groups is 19.4%, although percentage ownership in the low income group is less than half that of the high income group. Figure 4-15 shows the frequency of tumble dryer use (annual and weekly) and the age of appliances reported in each income group. A slightly larger share of households in the lower income group reported using their tumble dryers all year round, although the sample was quite small (n=40), compared to the middle and higher income groups, where the sample size n was 201 and 161 respectively.

*Table 4-15: Tumble dryer ownership per income group*

| Income group | Ownership |
|---|---|
| **Low** | 10.6% |
| **Middle** | 18.5% |
| **High** | 26.5% |
| **All** | 19.4% |

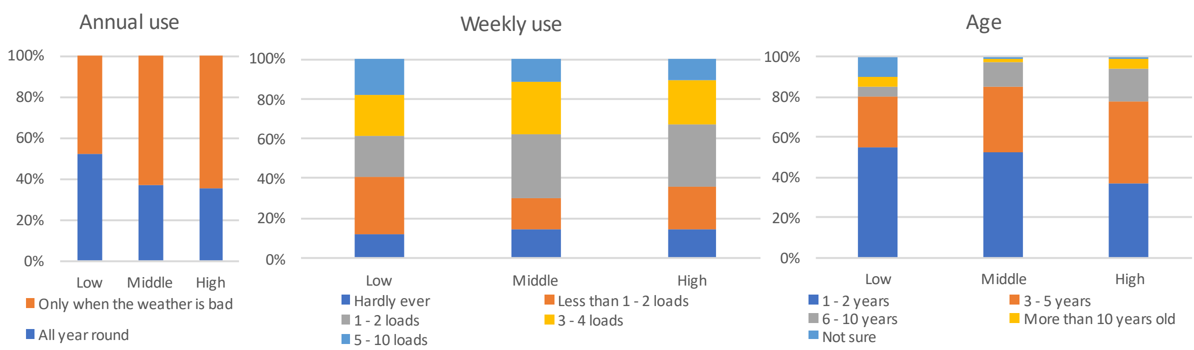


*Figure 4-15: Annual & weekly usage and age of tumble dryers per income group*

### 4.4.10. Dishwasher

Dishwasher ownership is provided in Table 4-16. Average dishwasher ownership across all income groups is 13.8%. Ownership in the low income group was just 5.3%, but was 25.5% amongst high income households.

*Table 4-16: Dishwasher ownership per income group*

| Income group | Ownership |
|---|---|
| **Low** | 5.3% |
| **Middle** | 10.3% |
| **High** | 25.5% |
| **All** | 13.8% |

Figure 4-16 shows the frequency of use for each income group as well as wash cycles selected. It would appear that short, medium length and eco-friendly cycles are the most commonly used cycles. As mentioned previously, the ownership level of dishwashers amongst low income households was higher than expected. This may have been caused by some households under-reporting monthly income and thus inflating appliance ownership levels in the low income category. To provide context, households that reported owning dishwashers for low, middle and high income groups were 20, 112 and 155 respectively.

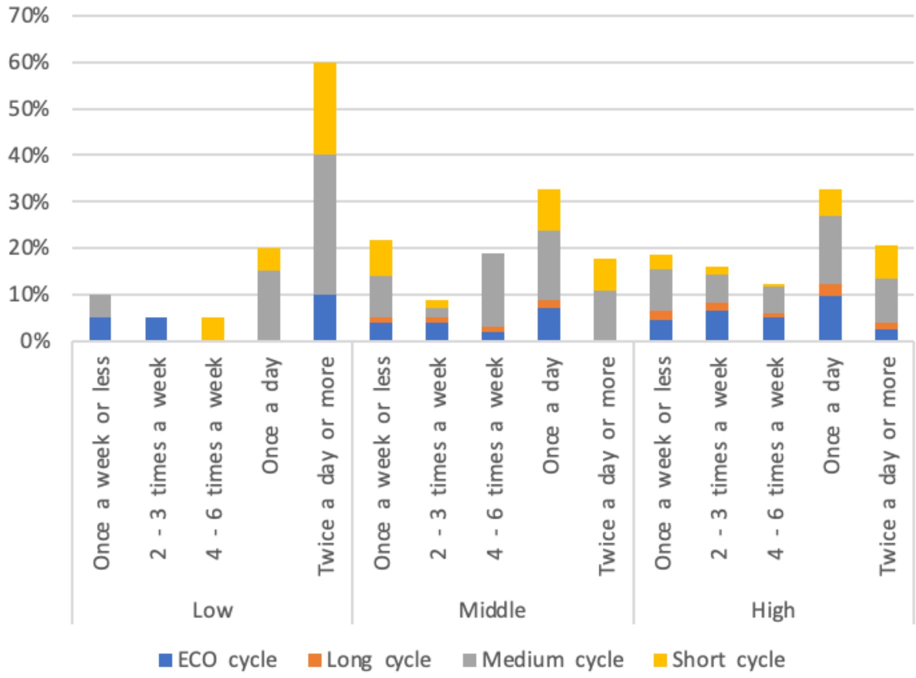


*Figure 4-16: Dishwasher use and common wash cycles selected per income group*

## 4.4.11.Space heating

Figure 4-17 shows the ownership quantities of various types of electric space heating appliances as well as usage (hours/day) in winter. The most common types were bar heaters followed by fan heaters. Ownership of multiple heaters was highest in the high income group and lowest in the low income group. Daily hours of use in winter were quite similar across all income groups. A number of households indicated that they used gas, paraffin or coal for heating. Table 4-17 shows ownership of heaters per income group.

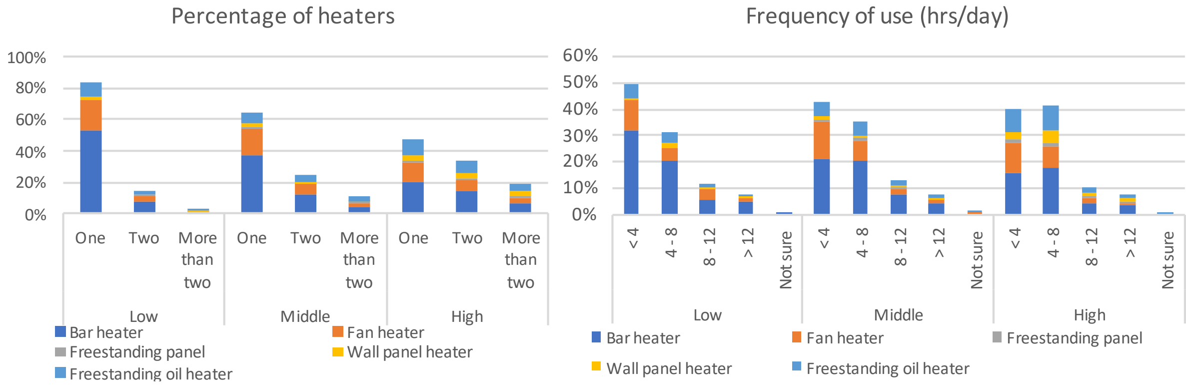


*Figure 4-17: Ownership and winter usage patterns of space heater types per income group*

*Table 4-17: Ownership levels of heaters per income group*

| | None | One | Two | More than two |
|---|---|---|---|---|
| **Low** | 52% | 42% | 6% | 1% |
| **Middle** | 37% | 44% | 14% | 5% |
| **High** | 35% | 37% | 20% | 8% |
| **All** | 39% | 41% | 14% | 5% |

## 4.4.12.Televisions

Table 4-18 shows reported television ownership was high at 92.0% across income groups (n=1,909) and ownership percentage increased with household income. Of the entire sample, 35.8% of households owned a second television and once again, ownership levels vary with income, although in a more marked way than in the case of first television ownership levels. Figure 4-18 shows that most of the newer technology large flat screen televisions reside in high income households while the smaller flat screen and older (CRT) technologies are owned by households in the low income group. It can also be seen that in all income groups the majority of televisions are on for more than 4 hours per day.

*Table 4-18: Ownership levels of first and second TV per income group*

| Income group | Own at least one TV | More than one TV |
|---|---|---|
| **Low** | 83.9% | 17.9% |
| **Middle** | 93.0% | 34.3% |
| **High** | 95.2% | 49.6% |
| **All** | 92.0% | 35.8% |

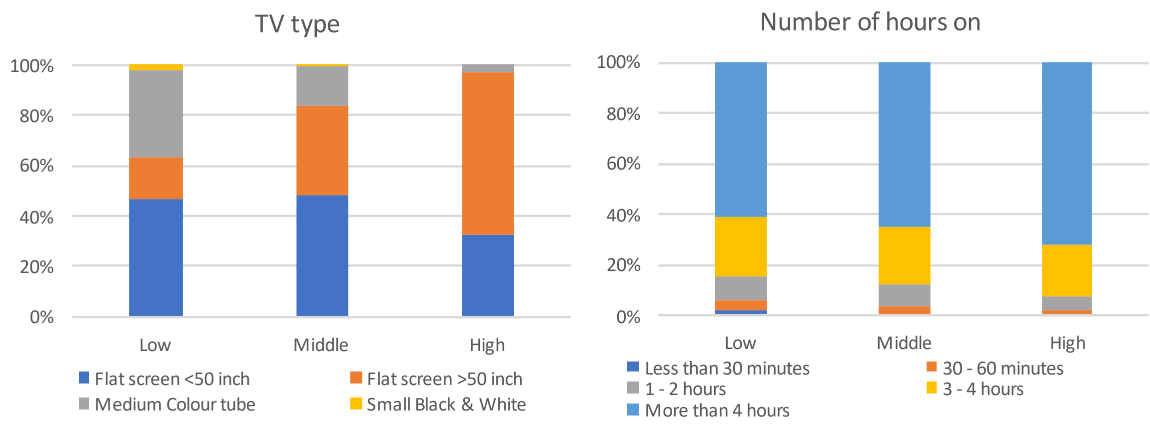


*Figure 4-18: Television types and usage per income group*

## 4.4.13. Air conditioning

Table 4-19 shows that air conditioner ownership levels were low at an average of 13.8%. As expected ownership levels increase with household income. Figure 4-19 shows that the bulk of air conditioners are split units, across all income groups.

*Table 4-19: Air conditioner ownership levels per income group*

| Income group | Ownership level |
|---|---|
| **Low** | 5.8% |
| **Middle** | 11.7% |
| **High** | 22.6% |
| **All** | 13.8% |

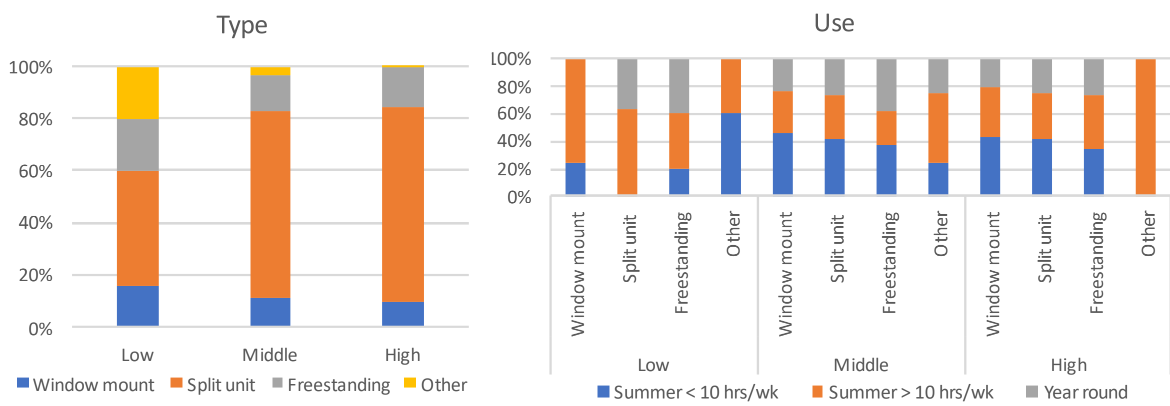


*Figure 4-19: Types of air conditioners and usage patterns per income group*

## 4.5. Appliance purchasing habits

Figure 4-20 below shows results in respect of appliance purchasing habits. The graph on the left shows there is a strong preference across all income groups to purchase appliances new, although the preference for second-hand products is slightly higher among low income households than those in the high income category. The graph on the right shows that the bulk of respondents in all income categories generally only replace appliances when they break rather than when they can be afforded. However this pattern is slightly lower among high income households.

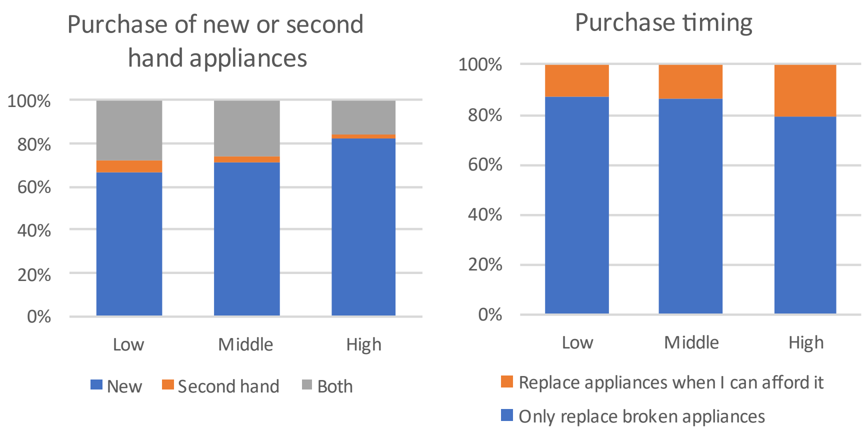


*Figure 4-20: Appliance purchasing preferences*

## 4.6. Standards & Labelling (S&L) awareness and consideration

Whilst the vast majority of households are aware of appliance labels (81 percent, n=1691) and only 9% of the sample indicated that they were not aware of appliance labels, there are many households that do not consider the appliance label when purchasing appliances. The responses of households about awareness of energy labelling and about whether these labels are considered when making purchases are shown in Figure 4-21. Of those respondents that were aware of energy labels, the figure on the right shows the extent to which those households own various appliance types with energy labels. There appears to be a small, but consistent, trend in which appliances with energy labels are more likely to be found in high income households and less likely to be found in low income households.

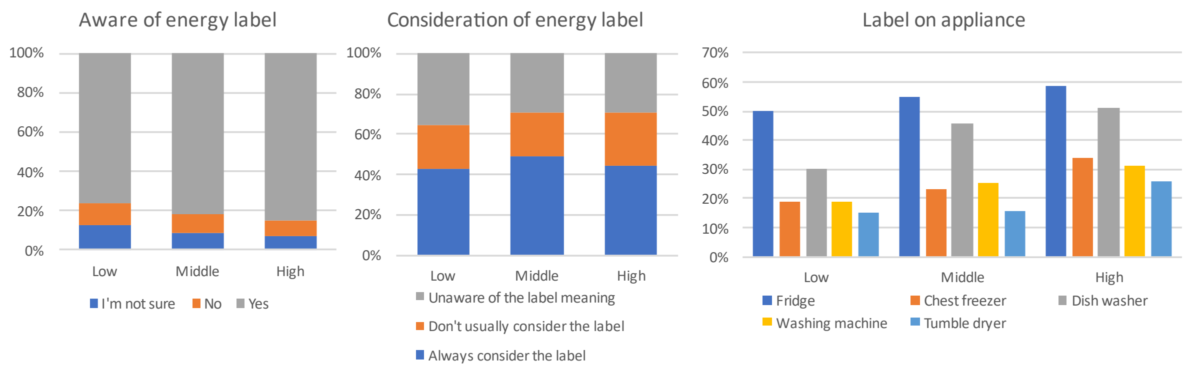


*Figure 4-21: Appliance standards & labelling awareness, consideration and ownership*

# 5. LEAP model methodology

This section provides an overview of the structure and accounting framework of the Low Emissions Analysis Platform (LEAP) model, as well as the calibration of energy consumption and appliance ownership levels in the SA LEAP model. LEAP, which is developed, maintained and distributed by the Stockholm Environmental Institute (SEI), is widely used internationally. LEAP offers a user friendly modelling platform with which to review energy and mitigation policies and targets using scenario analysis. LEAP models can be constructed at many scales and can be designed to focus on individual subsectors or on the entire energy chain, from sector needs for energy services to the supply of electricity. Complementing the demand side analysis, LEAP also allows the optimization of electricity supply, and cost and emissions analysis for scenarios.

The demand side of LEAP models allows the analysis of energy demands at the level of energy services. LEAP supports a range of demand side methodologies. These include:

- Final energy demand, where the demand for energy services is represented in terms of the level of activity (for example number of households that use a stove to cook) and the final energy intensity. Final energy intensity is the energy needed for each unit of activity. Over time energy reductions resulting from policies and technology or behaviour change cause the final energy intensity or activity levels to change, resulting in a change in energy demand.

$$energy\ consumption = activity\ level * energy\ intensity$$

- Useful energy demand, where the demand for energy services is represented in terms of activity shares, efficiency and useful energy intensity. This allows behaviour and other impacts on useful energy to be modelled explicitly (for example a household may reduce the number of meals they cook). It also allows the shares of technologies supplying an energy service and the efficiency of technologies to be considered independently in the analysis.

$$energy\ consumption = activity\ level * activity\ share * useful\ energy\ intensity/efficiency$$

- Stock-based demand, where the demand for energy services is represented in terms of the stock supplying the energy service and the energy intensity of each device. Energy consumption is calculated based on current and future stock levels, along with the current and future average annual energy intensity of all existing and new stock. This method is particularly useful where stock turnover is likely to dictate the speed at which energy consumption levels change due to changes in the energy intensity of new stock.

$$energy\ consumption = stock\ of\ devices\ x\ energy\ intensity\ per\ device$$

$$Stock_{t,y,v} = Sales_{t,v} \cdot Survival_{t,y-v}$$

$$Energy\ Consumption_{t.y} = \sum_{v=0..V} Stock_{t,y,v} \cdot Annual\ energy\ intensity_{t,y,v}$$

Where t = the technology stock type
v = the vintage year
V = the maximum number of vintage years
y = the calendar year
Sales = the number of technologies sold or added in a particular year
Stock = the total number of technologies according to each type
Survival = the fraction of technologies from each vintage year that remain unretired in the calendar year
Annual energy intensity = the average annual energy intensity of that technology type

In this study two of the demand side methodologies are applied. In all cases where appliances are part of the MEPS and S&L programmes, with the exception of air conditioners[4], a bottom-up stock-based analysis of demand is used. Where appliances have not been targeted in the programme or where there may be a wide range of appliances used to supply an energy service, a final energy demand-based analysis is applied. The stock-based analysis is therefore applied to ovens, fridges, freezers, dishwashers, washing machines, tumble dryers, televisions[5] and geysers. Final energy demand analysis is used for microwaves, kettles, space heating, pool pumps, air conditioning and "other" electricity uses.

Although it is possible to optimize the supply of electricity, this is not applied as only the residential sector is included in the SA LEAP model developed. Similarly, whilst LEAP allows technology costs and emissions to be included, these features are not used in this analysis. In future analysis, as LEAP has a flexible and adaptable model structure, it will be possible to expand the model structure to include the optimization of the power sector, a cost analysis of technologies, emissions analysis, as well as additional sectors, such as the commercial and industrial sector, and all other fuels.

[4] Air conditioners were excluded from the stock-based approach due to limited availability of local data of device lifespans for all different air conditioner types and lifespan variations between coastal and inland regions for all different types.

[5] Although televisions do not form part of the current MEPS/S&L programme, this study suggests including televisions as part of the programme under the "Extensive MEPS" scenario from 2030 onwards, hence it was characterised by means of a stock-based approach.

## 5.1. SA LEAP Model structure

The overview of the LEAP model structure is presented in two sections, firstly an overview of the structure of key drivers and key driver assumptions is provided, this is followed by an overview of the structure of the demand sector. The energy services and appliances considered in the model are listed in Table 5-1.

The structure of the LEAP model, and level of energy service and appliance disaggregation, was informed by the literature review (see the Appendices), the REC 2020 survey, national surveys and a review of the SA EDR model. The general bottom-up approach of the EDR model developed by Berkeley Lab was followed and refined to disaggregate demand according to low, middle & high income groups. Furthermore the appliance intensities were calibrated for each income group according to the REC 2020 survey responses and an extensive literature review. The model was also calibrated to the national level to fully represent the entire SA residential sector.

*Table 5-1: Energy services and appliances considered in the LEAP model*

| End use | Appliance |
|---|---|
| Lighting | All: Incandescent, Halogen, CFL, LED, etc. |
| Cooking | Oven |
| | Stove |
| | Microwave |
| | Kettle |
| | Other kitchen appliances: Toaster, Coffee machine, Coffee grinder, Slow cooker, Air Fryer, Induction stove, Food processor, Blender, Juicer |
| Refrigeration | Fridge, Fridge/Freezer (Primary and secondary) |
| | Deep Freeze (Primary and secondary) |
| Dish washing | Dishwasher |
| Clothes washing | Washing Machine |
| Clothes drying | Tumble Dryer |
| Water heating | Electric geyser (Primary and secondary) |
| | Solar water heater (with backup), Heat pump |
| | Kettle |
| Space heating | All electrical space heaters |
| Media | Televisions (Primary and secondary) |
| Pool pump | Pool pump |
| Air conditioning | Air Conditioner (Excluding Fans) |
| Other plug loads | Hair iron, Hairdryer, Clothes iron, Electric blanket, Vacuum cleaner, Laptop, Desktop, Tablet, Cellphones, Gaming console, DSTV Decoder/PVR, Home theatre, Audio system, Bluetooth speakers, Dehumidifier, Borehole, Wellpoint, all other plug loads |

### 5.1.1. Key drivers/assumptions

Key drivers in LEAP record assumptions related to demography and other time series variables. In the SA LEAP model key drivers include population estimates and growth assumptions, household size estimates, assumptions related to electrification and appliance ownership levels and assumptions related to expected future household incomes. The data underlying these is discussed further in Section 5.3.

In addition to these the assumed penetration of end use technologies is included under key drivers in the SA LEAP model. Figure 5-1 shows the structure of key drivers within the LEAP model. The expanded structure showing appliance ownership in middle income households on the right hand side of the figure is repeated for low and high income households.

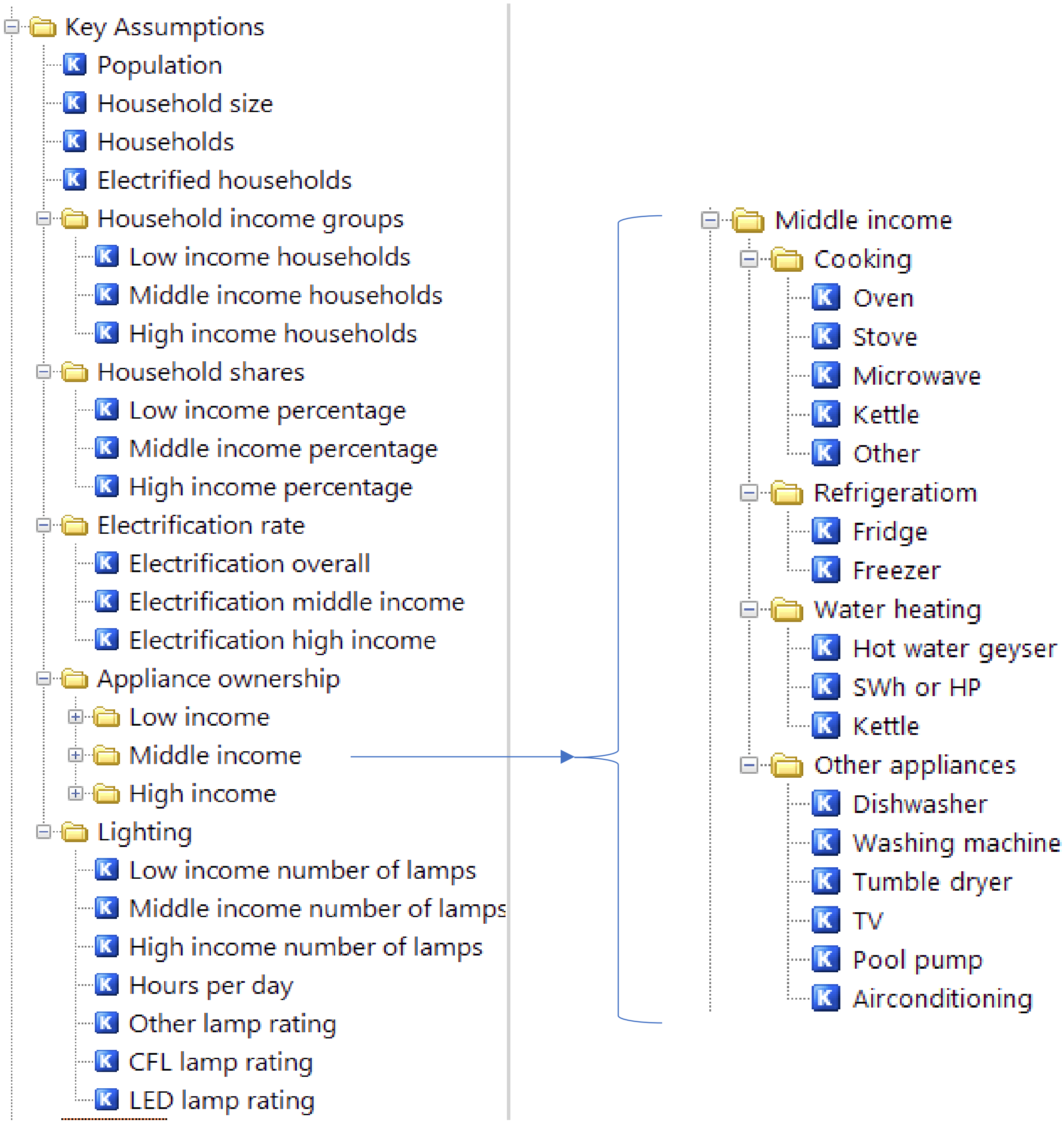


*Figure 5-1: Structure of key drivers in the LEAP model*

### 5.1.2. Demand sectors

The demand analysis within LEAP allows disaggregation by technology at the energy service level. This feature is used in the SA LEAP model. Figure 5-2 shows the structure of the household demand within the LEAP model. The expanded structure shown on the right hand side for high income households is repeated for low and middle income households. Cooking, refrigeration, water heating, space heating and lighting demands are represented within individual branches. The "other appliances" branch includes dishwashers, tumble dryers, washing machines, TVs, pool pumps, air conditioning and all "other" plug point loads listed in Table 5-1.

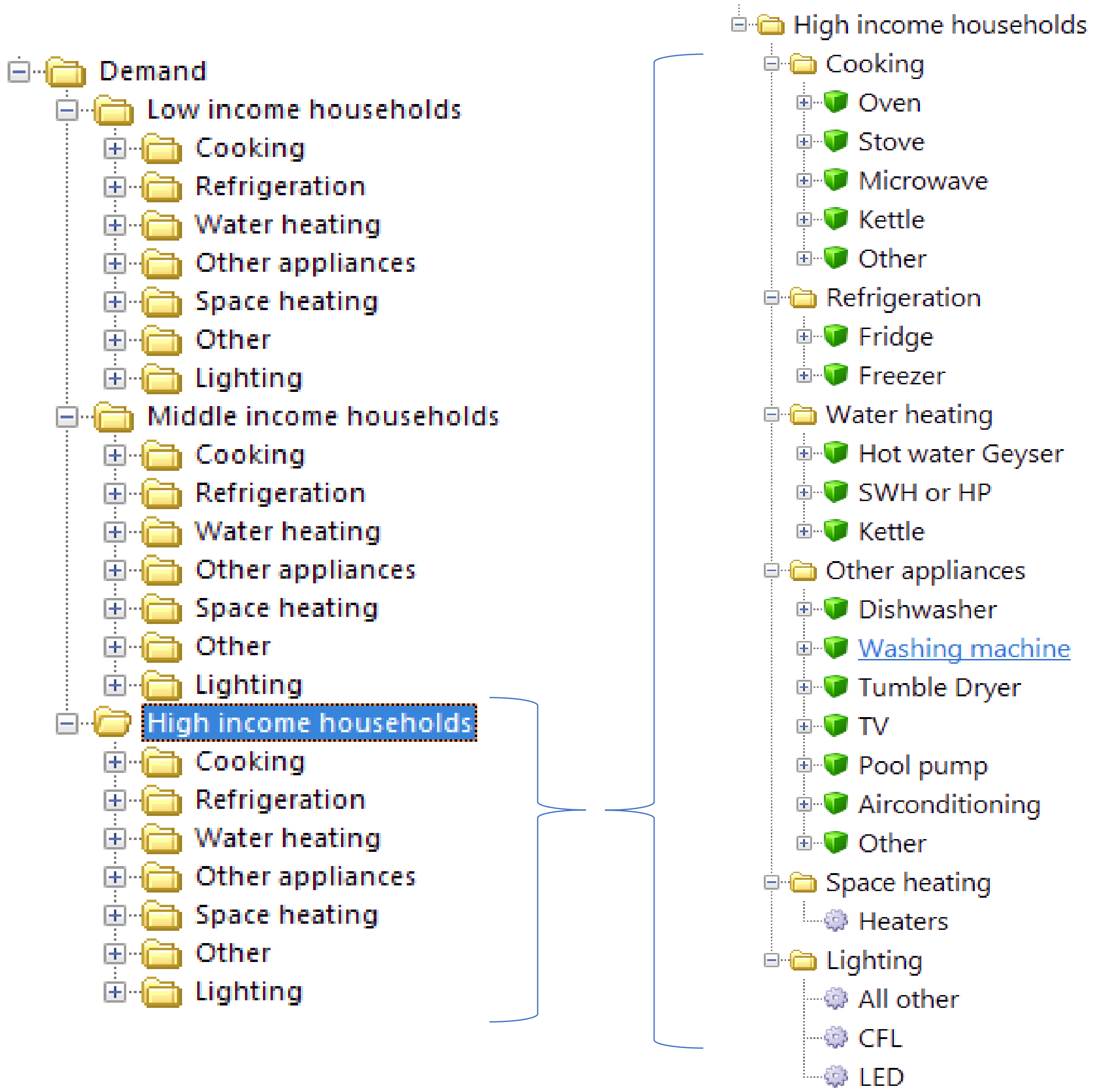


*Figure 5-2: Structure of the demand sectors in the LEAP model*

## 5.2. Calibration of electricity consumption

The calibration of electricity consumption, for the three household groups in the LEAP model, consisted of two distinct steps. Firstly the REC 2020 survey was used to estimate household consumption for each of the energy services represented in the model. Secondly these estimates were scaled up to the national level and calibrated to match a top down estimate of national electricity sales to the residential sector. Figure 5-3 provides an overview of these steps and shows how they are related. The rest of this section provides a detailed overview of the calibration process, key uncertainties in this process, and assumptions underpinning the appliance ownership and stock estimates.

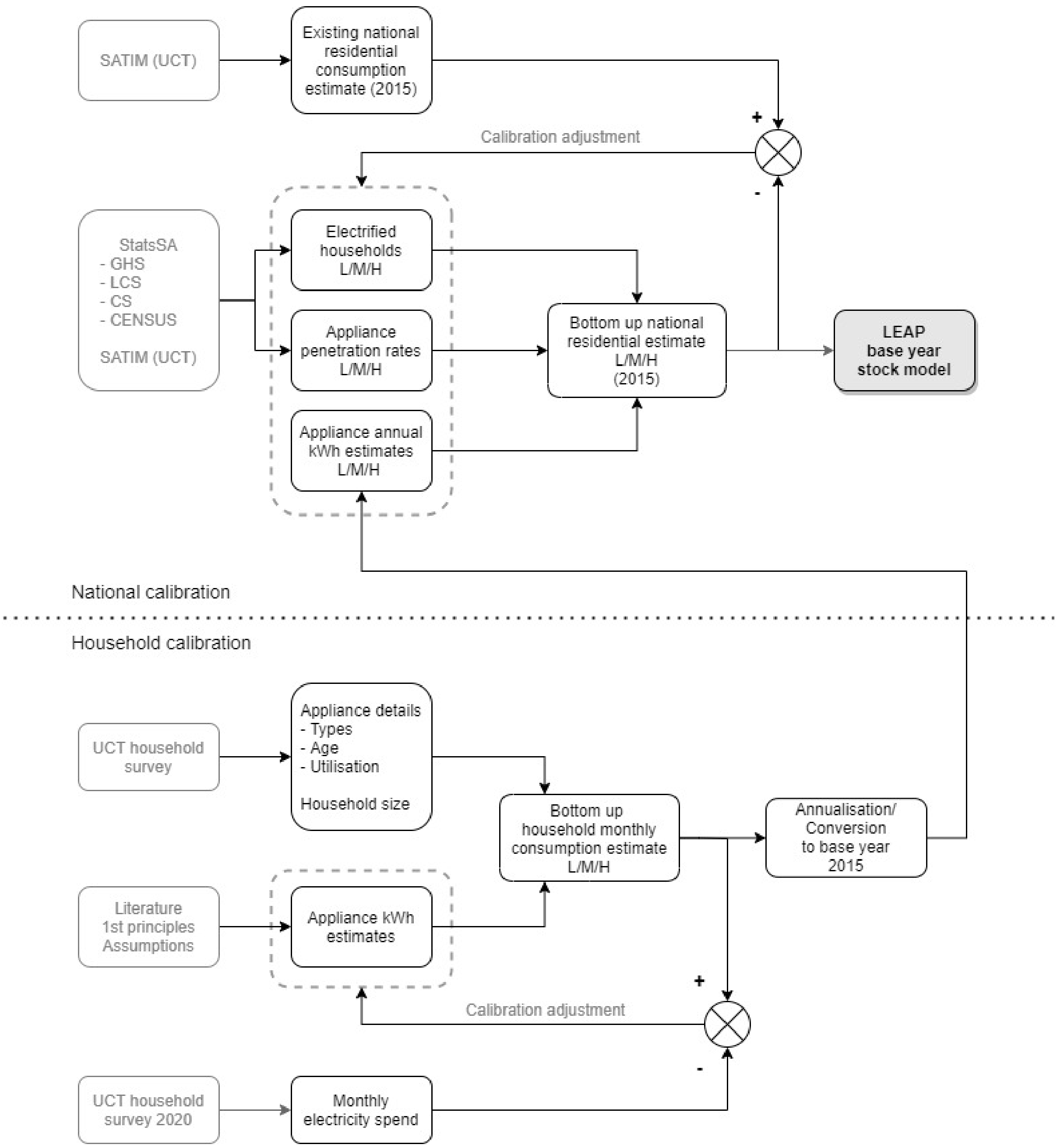


*Figure 5-3: Overview of two step data calibration process*

### 5.2.1. Characterization of end use and appliance electricity consumption

The estimates of end use and appliance electricity consumption, used in the LEAP model, were developed by drawing on a literature survey of empirical data, the REC 2020 survey and a review of data available through StatsSA national surveys and AMPS.

An extensive literature survey was undertaken[6], which included a review of international studies, studies focused specifically on South Africa, as well as all the South African national standards related to appliance performance levels implemented through MEPS regulation and the S&L programme. In some cases, consumption estimates were derived from first principles, but with usage and electrical demand assumptions informed by the literature. Where possible, kWh estimates were corroborated between multiple sources or against derivations from first principles.

The review was used to develop an estimate of annual kWh consumption for energy services and appliance types as a function of various key independent variables. Although, in reality, the electricity consumption of appliances is affected by multiple factors, appliance consumption has only been characterized here by the independent variables deemed to be the most significant, and for which data is most readily available. For example, each refrigerator configuration type is characterized as a function of appliance age, but not by door-opening cycles or temperature setpoint. Assumptions are made for the two latter variables in the standardized performance testing regime.

The independent variables selected typically differ from one appliance to the next. For example, kettle consumption is a function of the number of boil cycles, but is not clearly correlated to household occupancy. On the other hand, stove top (hob) consumption is a function of household occupancy and income category, but not of appliance age. As a final example, washing machine consumption is characterized as a function of appliance age and utilization.

In most cases, in order to obtain a final effective annual electricity (kWh) consumption estimates for energy services and appliances, various assumptions were necessary. For example, an average washing machine capacity (kg) and an average volume (ℓ) for each cold compartment in each category of refrigerator. In some cases, assumptions are implicitly included as stipulations within the standardized testing regimes. For example, the washing machine test standard assumes certain load sizes and cycle temperatures.

The results of the review are presented in tables of step-wise intervals, showing consumption as a function of key variables considered. In cases where appliance utilization patterns and age have an important influence on consumption, the stepwise intervals were mapped to match the options available to respondents in the REC 2020 survey. In the REC 2020 survey the age category intervals available were broadly informed by the dates at which the MEPS regulations were introduced. Three selected examples of appliance annual electricity (kWh) consumption estimates are provided in Table 5-7 to Table 5-9 in Section 5.4.

### 5.2.2. Estimation of individual household electricity consumption

The consumption of each appliance type, described in the previous section, were applied to each household response obtained from REC 2020. This provided an estimated annual consumption per household calculated according to income group, appliance ownership, age and utilization patterns according to the survey responses. The annual household kWh consumption estimate is calculated according to the below equation.

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[6] References used for specific appliances are listed in Section **Error! Reference source not found.** which details the assumptions used for deriving all appliance energy intensities. A full list of references is provided in Section 9.

$$h_m = \sum_{i=1}^{21} a_{i,j,k,l,o}$$

Where h = estimated total annual consumption of household m (kWh)
m = survey household number
a = estimated annual appliance consumption (kWh)
i = appliance type (21 appliance categories in total, including "Other")
j = household income category
k = appliance age
l = appliance utilization
o = household occupancy

### 5.2.3. Conversion of monetary spend to kWh consumption

The survey included a voluntary question asking respondents to share their average monthly monetary spend (R) on electricity. The reported spending on electricity was converted to kWhs and used to calibrate the kWh estimates derived for each household based on their reported appliance ownership and utilization patterns.

However, the conversion of Rands spent to kWh consumed is subject to significant uncertainties. Even if the Rands spent provided by respondents represents a true average, some of these values will be provided with VAT and some without. Also, service charges are applicable only to some municipalities and are sometimes included in the tariff and sometime charged separately, as part of general municipal billing. A further uncertainty is introduced by the component of free basic electricity (FBE) as this is allocated differently from one municipality to the next. Finally, it was found that some respondents provided estimated average consumption in units of electricity purchased, not in Rands. These areas of uncertainty mean that Rand estimates can, at best, provide a *range* of monthly kWh values within which the predicted monthly consumption should fall.

### 5.2.4. Calibration of appliance electricity consumption at household level

As shown in the lower half of Figure 5-3, the predicted kWh consumption of each household (based on appliance ownership and utilization patterns) was compared to the kWh range of values derived from the reported monthly amount spent on electricity in Rands. This comparison provided the basis for the refinement of the appliance kWh consumption values derived from the households reported appliance ownership and utilisation. This calibration at household level represented the household appliance stock during 2020 as this was the year of the survey.

The calibration of household consumption was a manual process that sought to minimize the expression of the equation below, primarily by adjusting independent variables in which known uncertainties exist. For example, informed assumptions were originally made about daily average hot water volume consumed per person for each income category. Similarly, an average geyser setpoint temperature is also assumed. These both form useful adjustment levers as small changes to either volume or setpoint temperature have relatively large impacts.

$$\min \sum_{m=1}^{n} \left[h_m - \frac{1}{12} e_m\right]$$

Where
- h = estimated total annual consumption of household m (kWh)
- e = Rand-derived estimated monthly consumption of household m (kWh)
- m = survey household number
- n = total survey respondents that supplied kWh Rand estimate

### 5.2.5. Conversion to 2015 appliance stock and stock kWh consumption

The LEAP model is used to determine the savings brought about by the S&L programme during the period 2015-2020 and thus required a base year of 2015. The 2020 stock estimates were adjusted to represent the stock that *would have been in place* in 2015. This was achieved by adjusting the (calibrated) performance of each appliance to what it would have been in 2015. For example, if in 2020 an item was "6-10 years old", it was treated as though in 2015 it was "1-5 years old" and the likely kWh consumption relevant to that period was applied, and so on.

### 5.2.6. Characterization of aggregate appliance electricity consumption (2015 stock)

An aggregate 2015 consumption $\bar{a}_{i,j}$ per appliance type and income category was determined according to the equation below.

$$\bar{a}_{i,j} = \frac{1}{n_i} \sum_{m=1}^{n_i} a_{i,j,k,l,o}$$

Where
- ā = aggregated annual consumption per appliance type (kWh)
- m = survey household number
- n = total respondents per income group that own appliance i
- i = appliance type (21 appliance categories in total, including "Other")
- j = household income category
- k = appliance age
- l = appliance utilization
- o = household occupancy

### 5.2.7. Uncertainties in aggregated consumption data

The household appliance consumption data estimates were inherently susceptible to various uncertainties, some of which are briefly discussed below.

Where REC 2020 respondents were required to select an appliance age, answers were restricted to intervals, such as "1-2 years old" or "3-5 years old", etc. Similarly, appliance usage is described by a choice of interval such as "2-3 times a week" or "4-6 times a week", and so forth. It could be that the *true* answers of respondents were heavily skewed towards one extreme of an interval. For example, when people answered "4-6 times per week", the bulk of these responses may have been far closer to "4" than to "6". This uncertainty is handled by assuming that the true answers of respondents across the entire survey are uniformly distributed between the start and end values of each interval.

Although, ideally, the survey responses of appliance usage and Rand spend should represent long term averages, it is very unlikely that this is the case. In most cases, these are probably quite seasonal, and respondent answers are very likely to be biased by recent memory. For example, if just before taking the survey, someone paid a utility bill or purchased a month's worth of electricity, that amount paid will likely impact the answer given, although that amount may be somewhat seasonally dependent.

Another aspect to consider is that survey was held in 2020 during which much of the population may have been living in quite unusual circumstances, such as being locked down in their homes due to COVID-19. Appliance utilization patterns may have changed during this time and this may also have affected responses. As discussed previously, in practice the use of respondent Rand spend to determine household electricity consumption provides at best a range of possible kWh values.

### 5.2.8. National calibration method

The calibration of the bottom-up household electricity consumption estimates to the national level estimates of residential electricity consumption in the base year (2015), is not simply an open loop extrapolation exercise, but rather a process of iteratively matching the cumulative bottom-up estimates to a national total consumption target. What is *not* precisely known, and therefore could not be included in the national calibration, is the contribution of each income group to the national total.

Figure 5-3 shows the input variables used to extrapolate the household estimates to an estimated total end use consumption in three income groups at the national level. The equation below provides the calculation. In this calibration step, adjustments were made to those variables which are likely to have the greatest uncertainty.

$$\min\left[e_n - \sum_{j}^{3}\sum_{i}^{21} n_j \times p_{i,j} \times \bar{a}_{i,j}\right]$$

Where $e_n$ = SATIM estimated national residential consumption (kWh)
i = appliance type (21 appliance categories in total, including "Other")
j = household income category (3 categories Low, Middle, High)
n = number of electrified households per income category
p = appliance type penetration rate per income category (levels of ownership)
ā = aggregated annual consumption per appliance type (kWh)

### 5.2.9. Appliance ownership estimates

There are several surveys published by Statistics South Africa (Stats SA), which can be used to estimate appliance ownership across income groups. In addition, the Community Survey can be used to estimate appliance ownership at the national scale for certain appliances. The surveys listed in Table 5-2 were used, along with the REC 2020 survey, to estimate appliance ownership levels for the three income groups in the LEAP model. Table 5-2 contains an overview of the surveys used, in addition to the REC 2020 survey, to estimate the percentage of households owning appliances in each of the income bands.

*Table 5-2: The surveys used to estimate appliance ownership*

| Survey | Source | Income representation | Appliances extracted | Use in this study |
|---|---|---|---|---|
| General Household Survey (GHS) 2017 and 2018, | www.datafirst.uct.ac.za DOI: https://doi.org/10.25828/9tmn-fz97 (Stats SA 2019a, 2020) | Discrete | Stove, microwave, fridge, freezer, TV, washing machine, dish washer, tumble dryer, air conditioner, swimming pool, geyser | Income was inflated to an equivalent 2020 value and used to group households in the sample into the low, middle and high income groups represented in the model. |
| Living Conditions Survey (LCS) 2014-2015 | www.datafirst.uct.ac.za DOI: https://doi.org/10.25828/9229-xz60 (Stats SA 2017b) | Continuous | Stove, microwave, fridge, freezer, TV, washing machine, dish washer, tumble dryer, geyser | Income was inflated to an equivalent 2020 value and used to group households in the sample into the low, middle and high income groups represented in the model. |
| Eighty20 All Media Products Survey AMPS (2015) | www.dataportal.eighty20.co.za (South African Audience Research Foundation (SAARF, 2015) | Discrete income bands | Stove, oven, microwave, fridge, freezer, TV, washing machine, dish washer, air conditioner, geyser | The income band categories were inflated to equivalent income categories and household income bands were assigned to the low, medium and high income group based on the income band match. |
| Community Survey 2016 | Superweb.Statssa.gov.za (Stats SA, 2016) | None | Stove/oven, microwave, fridge/freezer, TV, washing machine, air conditioner, geyser | Used to provide overall, nationally representative, appliance ownership estimate. |
| Census 2011 | Superweb.Statssa.gov.za (Stats SA, 2012) | Discrete income bands | | Used to estimate household income bands shares |

CPI inflators drawn from Stats SA (Stats SA, 2021) were used to adjust the income reported in the surveys to the equivalent 2020 income bands of less than R5,000, R5,000 – R20,000 and R20,000 and above. The inflators and equivalent income categories in the surveys are shown in Table 5-3.

*Table 5-3: Adjustments for income*

| Nominal Rands | 2011 Census | GHS 2017 | GHS 2018 | LCS 2014/15 | AMPS 2015 |
|---|---|---|---|---|---|
| **Low** | < R38,200 | < R4,478 | < R4,682 | < R4,008 | < R2,499 |
| **Middle** | R38,201 to R153,800 | R4,479 to R17,910 | R4,683 to R18,728 | R4,009 to R16,030 | R2,500 to R19,999 |
| **High** | > R153,800 | > R17,911 | > R18,729 | > R16,031 | > R 20,000 |
| **Variable** | NA | totmhinc | totmhinc | income | NA |
| **Inflator** | 0.625 | 0.896 | 0.936 | 0.802 | 0.802 |

### 5.2.10. Stock estimates

Base year stock estimates for each income group were derived using the percentage of households owning appliances of each type, the mean number of appliances of each type owned by households and the number of households in each income group.

$$Stock_j = \sum_{j=1}^{3} number\ of\ households_j * \%\ appliance\ ownership_{j,i} * number\ of\ appliances\ per\ household\ _{i,j}$$

Where *j* represents income bands (low, middle and high)
*i* represents the appliance type.

## 5.3. Key drivers

### 5.3.1. Population and household assumptions

The population and household estimates draw on Stats SA surveys and population estimates as well as the United Nations World Population Prospects series. The source for population data between 2015 and 2019 is Stats SA midyear population estimates (Stats SA 2019b), from 2025 onwards the mid-range estimate of population growth from the United Nations (UN) is used (UN 2019). The population estimate for 2015 is therefore 55.3 million growing to 71.37 million in 2040. Figure 5-4 shows the population estimate used in the LEAP model as well as the UN lower and upper 85 and 95 percentile estimates for population growth in South Africa.

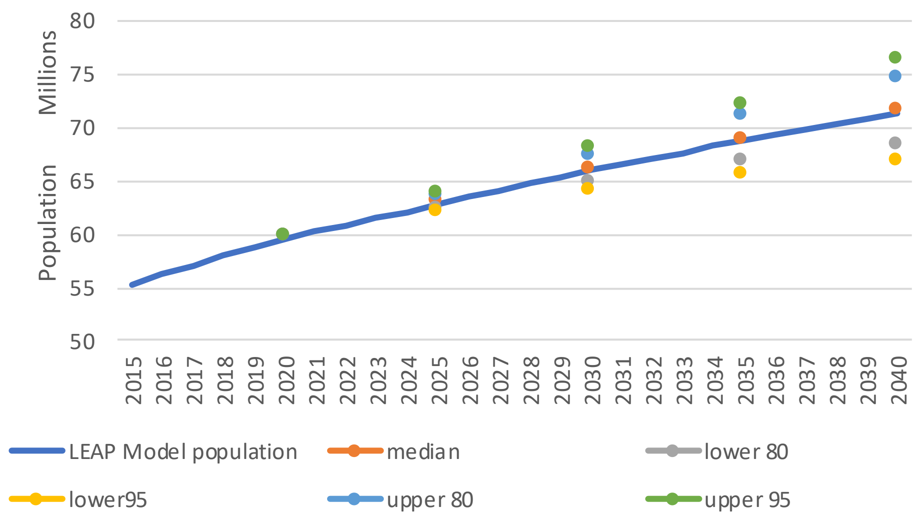


*Figure 5-4: Population estimates (Source UN and Stats SA)*

Household estimates are available for 2011 and 2016 from the StatsSA Census and Community Survey respectively. In 2011 the Census (Stats SA 2011) estimated the number of households to be 14.4 million, by 2016 this had increased to 16.9 million. In 2015 the number of households is assumed to be 16.5 million with an average household size of 3.35. Household size is assumed to drop to 2.7 by 2040, and the number of households in this year is therefore 26.4 million. Figure 5-5 shows the estimated growth in the number of households between 2011 and 2040.

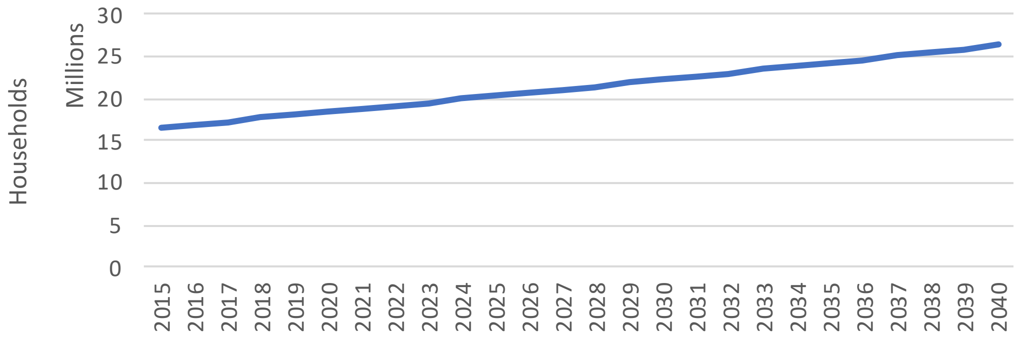


*Figure 5-5: Estimated number of households (2015 – 2040)*

## 5.3.2. Electrification

Electrification continues to increase in South Africa, and this is reflected in the LEAP model. Electrified households include all households that have access to electricity regardless of the type of connection. The estimate for the number of electrified households in 2015 is taken from Integrated National Electrification Programme (INEP) estimates. It is assumed that electrification reaches 95.6 percent by 2040. Figure 5-6 shows the assumed number of electrified households as well as the number of unelectrified households between 2015 and 2040.

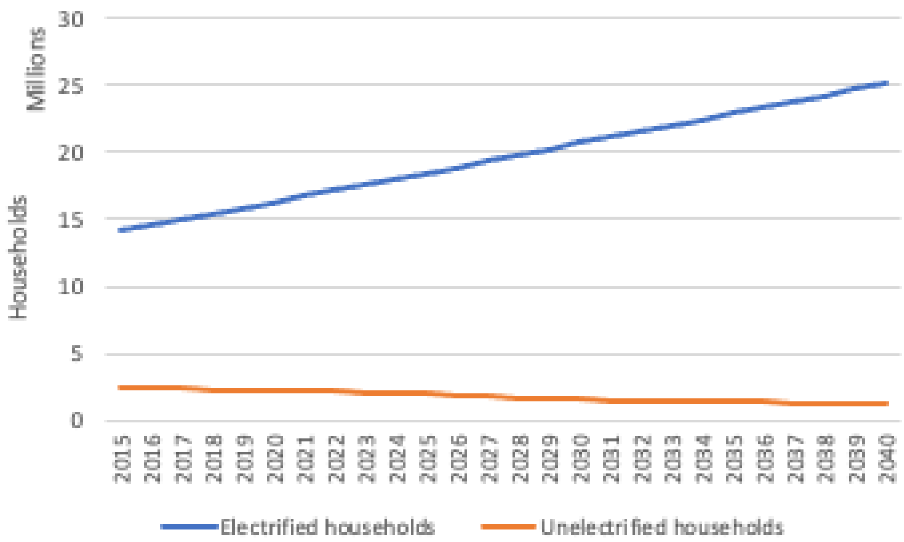


*Figure 5-6: Estimated number of electrified households (2015 – 2040)*

### 5.3.3. Household income

Three household income groups are used in the model. The composition of household income groups is shown in Figure 5-7. The assumptions for income shares are taken from outputs of the SATIM-eSAGE model (ESRG, 2020). A steady decline in the number of low income households is anticipated, although a large number of households still remain in the low income group in 2040. As electricity use increases dramatically with rising income, a different GDP growth can have a large influence on the model results as it would imply a different ratio of household income groups at the end of the period and a corresponding increase or decrease in appliance ownership and consumption levels within the model.

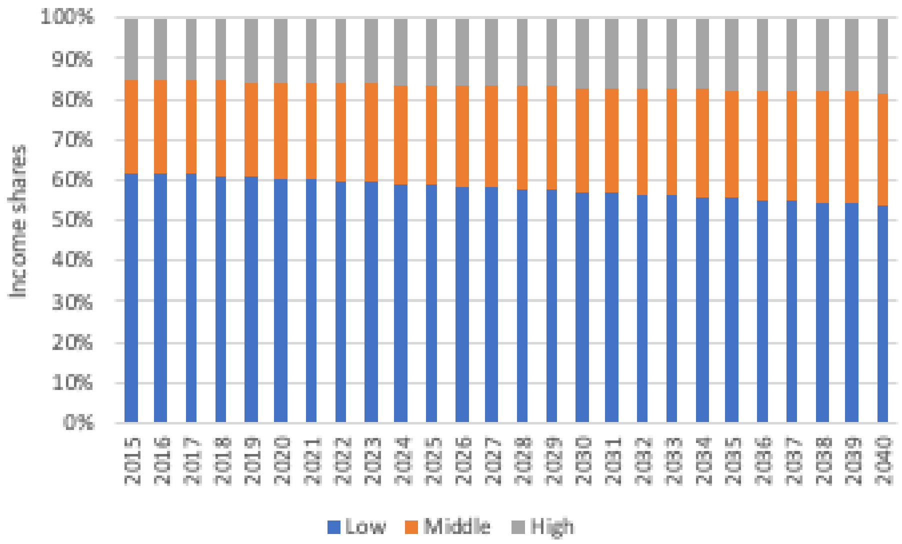


*Figure 5-7: Composition of household income shares (2015-2040)*

Figure 5-8 shows the growth in households across the three income groups represented in the SA LEAP model.

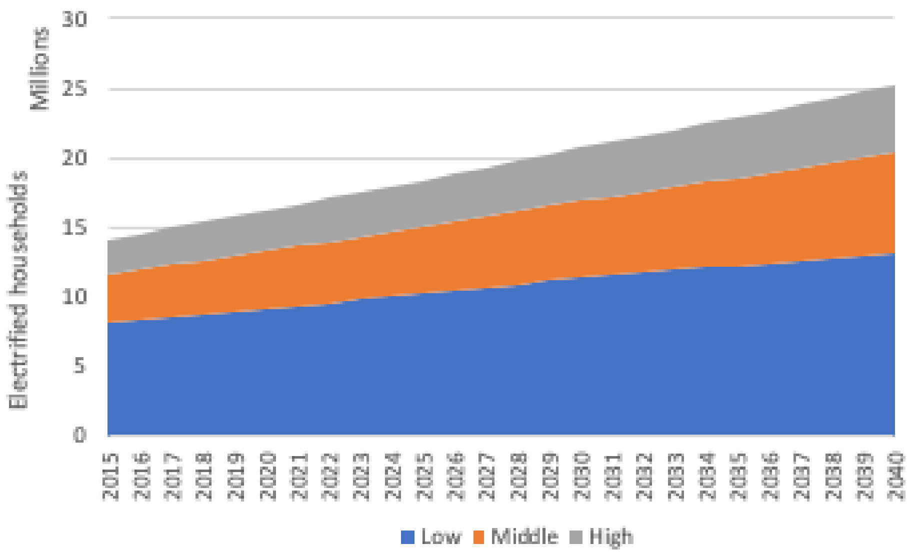


*Figure 5-8: Households in the low, middle and high income groups (2015-2040)*

### 5.3.4. Appliance ownership

Table 5-4 shows the appliance ownership percentages extracted from the GHS 2017 and 2018, LCS 2014-15, AMPS 2015 and REC 2020 surveys for the low, middle and high income groups. It also shows the overall appliance ownership recorded in the Stats SA 2017 General Household Survey (GHS) and 2016 Community Survey. Electric stove and oven ownership were not recorded separately in the GHS surveys and Table 5-4 shows the responses households gave in response to questions about the ownership of either a stove or an oven. The final two columns in the table show the appliance ownership shares used in the LEAP model, and the overall appliance ownership in the LEAP model resulting from these shares and the share of households in each income group.

Several households reported owning more than one appliance in the REC 2020 survey. The ownership of more than one appliance was incorporated into the LEAP model, based on the household responses to multiple appliance ownership for TVs, fridges, freezers in the REC 2020 survey. Table 5-5 provides the assumptions applied to second appliance ownership in the LEAP model. Both primary and secondary ownership assumptions are used to calibrate the base year stock of each appliance type.

*Table 5-4: Appliance ownership shares in National surveys, the REC 2020 survey, and the SA LEAP model*

| | By Income Group | | | | | Overall | | By income group | Overall |
|---|---|---|---|---|---|---|---|---|---|
| | GHS 2017 | GHS 2018 | LCS 2014-2015 | AMPS 2015 | REC 2020 | GHS 2017 | Community Survey 2016 | SA LEAP | SA LEAP |
| **Washing machine** | | | | | | | | | |
| Low | 21.2% | 20.9% | 14.3% | 15.2% | 51.7% | 34% | 41% | 24% | 41% |
| Middle | 41.4% | 39.1% | 35.6% | 43.3% | 76.4% | | | 46% | |
| High | 79.2% | 60.3% | 71.0% | 93.3% | 90.6% | | | 88% | |
| **Dish washing machine** | | | | | | | | | |
| Low | 1.7% | 1.5% | 0.7% | 0.2% | 5.3% | 5% | NA | 1.7% | 6% |
| Middle | 3.9% | 3.1% | 2.1% | 1.2% | 10.0% | | | 3.9% | |
| High | 22.4% | 14.5% | 16.8% | 15.4% | 25.6% | | | 22.4% | |
| **Tumble dryer** | | | | | | | | | |
| Low | 2.8% | 2.5% | 0.8% | | 10.6% | 7% | NA | 2.8% | 8% |
| Middle | 6.0% | 5.2% | 2.6% | | 18.4% | | | 6.0% | |
| High | 28.2% | 18.9% | 18.7% | | 26.6% | | | 28.2% | |
| **Air conditioner (Excluding fans)** | | | | | | | | | |
| Low | 1.1% | 1.0% | | 0.3% | 5.8% | 4% | 7% | 1.3% | 6% |
| Middle | 3.2% | 2.9% | | 1.8% | 11.1% | | | 3.8% | |
| High | 21.9% | 14.4% | | 20.6% | 22.6% | | | 25.8% | |
| **Swimming pool** | | | | | | | | | |
| Low | 0.8% | 0.8% | | | 3.7% | 3% (swimming pool) | NA | 0.8% | 4% |
| Middle | 1.6% | 1.4% | | | 5.0% | | | 1.6% | |
| High | 15.5% | 9.8% | | | 16.8% | | | 15.5% | |
| **Television** | | | | | | | | | |
| Low | 80.9% | 79.9% | 69.1% | 74.4% | 84% | 86% | 89% | 80.9% | 87% |
| Middle | 92.4% | 91.6% | 86.3% | 92.2% | 93% | | | 92.4% | |
| High | 97.8% | 89.9% | 93.5% | 98.5% | 95% | | | 97.8% | |

| | By Income Group | | | | | Overall | | By income group | Overall |
|---|---|---|---|---|---|---|---|---|---|
| | GHS 2017 | GHS 2018 | LCS 2014-2015 | AMPS 2015 | REC 2020 | GHS 2017 | Community Survey 2016 | SA LEAP | SA LEAP |
| **Fridge** | | | | | | | | | |
| Low | 73.1% | 73.9% | 55.3% | 71.2% | 94.2% | | | 76.4% | |
| Middle | 88.1% | 87.0% | 77.0% | 88.6% | 98.7% | 80% | | 92.1% | 84% |
| High | 97.4% | 88.9% | 91.5% | 97.9% | 99.8% | | | 97.9% | |
| **Deep freeze** | | | | | | | 88% | | |
| Low | 16.4% | 15.5% | 15.5% | 6.2% | 21.1% | | | 16.4% | |
| Middle | 22.6% | 21.1% | 22.1% | 16.3% | 34.6% | 22% | | 22.6% | 23% |
| High | 47.4% | 34.9% | 42.0% | 47.6% | 44.7% | | | 47.4% | |
| **Electric stove** | | | | | | | | | |
| Low | 90.2%[1] | 90.2%[1] | 78.1%[2] | 49% | 30% | | | 48.6% | |
| Middle | 95.9%[1] | 95.9%[1] | 87.9%[2] | 31% | 13% | 93% | 91% | 31.0% | 38% |
| High | 99.2%[1] | 96.4%[1] | 89.9%[2] | 11% | 3% | | | 11.0% | |
| **Electric Oven** | | | | | | | | | |
| Low | | | | 40% | 66% | | | 39.7% | |
| Middle | | | | 69% | 84% | | | 68.5% | 57% |
| High | | | | 97% | 94% | | | 96.6% | |
| **Microwave oven** | | | | | | | | | |
| Low | 46.5% | 45.6% | 27.9% | 34.6% | 69.9% | | | 46.5% | |
| Middle | 69.7% | 67.7% | 54.5% | 66.6% | 89.5% | 59% | 58% | 69.7% | 61% |
| High | 94.3% | 80.0% | 84.7% | 96.9% | 94.7% | | | 94.3% | |
| **Geyser providing hot running water** | | | | | | | | | |
| Low | 9.4% | 8.8% | 4.8% | 21.6% | 34.2% | | | 0.0% | |
| Middle | 25.1% | 24.2% | 17.2% | 54.4% | 65.8% | 22% | 27% | 39.8% | 27% |
| High | 76.8% | 55.8% | 56.0% | 94.3% | 87.5% | | | 94.3% | |

Notes:

1) Ownership of stoves and ovens are not reflected separately in this survey, these responses represent households that indicated that they owned an electric stove (Q821).

2) Ownership of stoves and ovens are not reflected separately in this survey, these responses represent households that indicated that they owned or were able to access a stove (Q69108).

*Table 5-5: Ownership of more than one appliance*

| Income group | TVs | Fridge | Freezer | Geyser |
|---|---|---|---|---|
| Low | 9.7% | 15.4% | 0.8% | 0% |
| Middle | 17.0% | 22.4% | 2.1% | 0% |
| High | 23.7% | 32.6% | 3.0% | 10% |

### 5.3.5. Base year stock and sales

The estimates of the total stock of appliances in the base year in the LEAP model, as well as the base year appliance sales and the assumed growth of sales until 2040 are provided in Table 5-6.

*Table 5-6: 2015 Stock and sales estimates and sales growth to 2040*

| Appliance type | Mean lifespan[1] | Income group | Total stock 20152 | Sales 2015[3] | Sales growth[4] |
|---|---|---|---|---|---|
| Oven | 14 | Low | 3,213,116 | 311,192 | 0.1% to 2020, 0.5% to 2025, 2% to 2040 |
| | | Middle | 2,405,886 | 233,012 | 2% to 2025, 2.5% to2030, 3% to 2040 |
| | | High | 2,418,117 | 234,196 | 1% to 2020, 2% to2030, 3% to 2040 |
| Fridge or combined Fridge/Freezer | 14 | Low | 7,436,048 | 179,295 | 3% to 2020, 2% to2030, 1.5% to 2040 |
| | | Middle | 4,020,910 | 560,673 | 1% to 2020, 2% to2025, 3% to 2040 |
| | | High | 3,265,444 | 455,332 | 1% to 2020, 2% to2030, 3% to 2040 |
| Deep Freezer | 17 | Low | 1,392,771 | 117,283 | 0.5% to 2020, 1% to 2040 |
| | | Middle | 864,670 | 72,813 | 2% to 2030, 3% to 2040 |
| | | High | 1,260,017 | 106,104 | 2% to 2040 |
| Dish washing machine | 11 | Low | 134,382 | 14,852 | 1% to 2020, 2% to2030, 1% to 2040 |
| | | Middle | 137,890 | 15,240 | 2% to 2018, 2.5% to2025, 3% to 2040 |
| | | High | 560,134 | 61,908 | 2% to 2025, 3% to 2040 |
| Washing Machine | 15 | Low | 1,910,517 | 188,141 | 0.1% to 2025, 0.5% to2030, 2% to 2040 |
| | | Middle | 1,618,953 | 159,429 | 1% to 2020, 2% to2030, 3% to 2040 |
| | | High | 2,206,914 | 217,330 | 1% to 2025, 2% to2030, 3% to 2040 |
| Tumble Dryer | 14 | Low | 223,091 | 22,018 | 0.1% to 2025, 1% to2030, 2% to 2040 |
| | | Middle | 211,461 | 20,871 | 1% to 2020, 2% to2030, 3% to 2040 |
| | | High | 704,491 | 69,531 | 1% to 2025, 2% to2030, 3% to 2040 |
| Hot water Geyser | 11 | Low | 0 | 0 | 0 |
| | | Middle | 1,397,263 | 153,929 | 2% to 2020, 3% to2035, 2.5% to 2040 |
| | | High | 2,596,751 | 286,071 | 1% to 2020, 2% to 2040 |
| SWH/Heat Pump | 11 | High | 111,891 | 30,000 | 1.6% to 2020, 6.7% to 2025, 7% to 2030, 5% to 2040 |
| TV | 7 | Low | 7,343,346 | 1,032,344 | 2% to 2020, 1% to 2040 |
| | | Middle | 3,842,132 | 540,136 | 3% to 2020, 2% to2030, 3% to 2040 |
| | | High | 3,041,065 | 427,520 | 2.5% to 2020, 2% to 2040 |

Notes:

1) For appliance average lifespan and survival assumptions see section 10.1.16.

2) Appliance stock it is assumed based on reported appliance ownership in Table 5-4 and Table 5-5.

3) The sum of sales across income groups matches Euromonitor data (2015) for dishwashers, tumble dryers, washing machines, ovens, microwaves, fridges and freezers. Divisions between income groups are based on appliance ownership shares, for all other appliances sales are assumed based on the total existing stock estimates, the age profile of appliance stock and the assumed survival profile of appliance stock.

4) Sales growth is calibrated to allow the total stock of appliances in each income group to grow as the number of households increases.

## 5.4. Demand assumptions

### 5.4.1. Appliance electricity consumption characteristics

This section provides examples of appliance annual kWh consumption estimates (intensities) developed from the literature review in conjunction with the REC 2020 survey. In each case energy consumption is expressed according to key independent variables specific to that appliance. Table 5-7 shows that refrigerator intensities are mainly dependent on appliance size, configuration and age. Table 5-8 shows that the intensities for dishwashers depend mainly on age and frequency of use. Finally, Table 5-9 shows that stove top electricity consumption is primarily based upon frequency of use and household size. The derivations of these intensities is described in more detail in Section 5.2.1.

*Table 5-7: Annual kWh consumption estimates for refrigerators (age & size dependent)*

| **Refrigerators (Annual kWh in 2020)** | **Appliance age** | | | | |
|---|---|---|---|---|---|
| **Size** | **1 - 2 years** | **3 - 5 years** | **6 - 10 years** | **More than 10 years old** | **Not sure** |
| Bar Fridge (Small) | 105 | 143 | 163 | 300 | 300 |
| Single Door (Medium) | 183 | 249 | 286 | 525 | 525 |
| Double door (Top Freezer) | 229 | 313 | 359 | 681 | 681 |
| Double door (Bottom Freezer) | 229 | 313 | 359 | 681 | 681 |
| Large (Multi-door) | 381 | 519 | 596 | 1131 | 1131 |

*Table 5-8: Annual kWh consumption estimates for dishwashers (age & usage dependent)*

| **Dishwashers (Annual kWh in 2020)** | **Appliance age** | | | | |
|---|---|---|---|---|---|
| **Usage** | **1 - 2 years** | **3 - 5 years** | **6 - 10 years** | **More than 10 years old** | **Not sure** |
| Twice a day or more | 594 | 717 | 784 | 1174 | 1109 |
| Once a day | 297 | 359 | 392 | 587 | 555 |
| 4 - 6 times a week | 212 | 256 | 280 | 419 | 396 |
| 2 - 3 times a week | 106 | 128 | 140 | 210 | 198 |
| Once a week or less | 42 | 51 | 56 | 84 | 79 |

*Table 5-9: Annual kWh consumption estimates for stoves (usage, occupancy & income dependent)*

| **Stove: Middle income (Annual kWh in 2020)** | **Household size** | | | | | |
|---|---|---|---|---|---|---|
| **Usage** | **1** | **2** | **3** | **4** | **5** | **6…** |
| Twice a day or more | 225 | 249 | 274 | 298 | 322 | 347 |
| Once a day | 113 | 125 | 137 | 149 | 161 | 173 |
| 4 - 6 times a week | 80 | 89 | 98 | 106 | 115 | 124 |
| 2 - 3 times a week | 40 | 45 | 49 | 53 | 58 | 62 |
| Once a week or less | 16 | 18 | 20 | 21 | 23 | 25 |

### 5.4.2. Aggregate appliance electricity consumption

The appliances characteristics described in the previous section were used, in conjunction with the REC 2020 survey, to estimate the average intensity for each appliance type in each of the three income categories. The survey results included household occupancy, income, appliance ownership and frequency of use. The same aggregation was performed for new products (new stock) that would have entered the sector from 2015 onwards.

Table 5-10 shows the energy intensities of the residential stock assumed to be in place in 2015[7]. These are the intensities applied in the LEAP model.

*Table 5-10: Aggregate appliance annual kWh consumption (2015)*

| | **2015 Average kWh Annual** | | |
|---|---|---|---|
| **Average kWh Annual** | **Income category** | | |
| **Appliance / Service** | **Low** | **Middle** | **High** |
| Lighting | 229 | 287 | 438 |
| Cooking - Oven | 224 | 249 | 272 |
| Cooking - Stove | 226 | 208 | 308 |
| Cooking - Microwave | 45 | 54 | 59 |
| Cooking - Kettle | 192 | 210 | 225 |
| Cooking - Other | 14 | 37 | 28 |
| Fridge/Freezer 1 | 487 | 499 | 543 |
| Fridge/Freezer 2 | 397 | 439 | 453 |
| Deep Freeze 1 | 564 | 552 | 569 |
| Deep Freeze 2 | 437 | 437 | 437 |
| Dishwasher | 606 | 363 | 389 |
| Washing machine | 179 | 192 | 237 |
| Tumble drier | 795 | 573 | 509 |
| Hot Water Geyser | 0 | 2804 | 3923 |
| Hot Water Geyser + SWH / HP | 0 | 0 | 1348 |
| Hot Water - Kettle | 97 | 77 | 62 |
| Space heating | 44 | 191 | 167 |
| TV | 168 | 235 | 342 |
| Pool pump | 894 | 521 | 799 |
| Aircon | 735 | 709 | 682 |
| Other | 99 | 392 | 286 |

[7] Detailed appliance performance assumptions are provided in Section **Error! Reference source not found.** (see Table 10-1).

## 5.5. Scenario development

The scenarios considered are intended to provide an estimate of the impact of energy efficiency interventions in the residential sector between 2015 and 2040. The Ex-SL scenario relates to the 2015-2020 period, whereas the Moderate MEPS, Extensive MEPS and Behavioural and SWH scenarios relate to 2020 to 2040.

The introduction of MEPS regulation has likely been a key factor driving appliance efficiency performance improvements over the past decade. However, in most cases it appears that the market itself has begun driving improvement as the current performance levels of new sales items have far outpaced the existing MEPS performance requirements. The only notable exception to this is tumble dryers.

### 5.5.1. Reference Case

The Reference case provides the baseline for the S&L impact and NEES assessments. Firstly, it includes an estimate of the actual efficiency improvements that took place as a result of the S&L programme from 2015-2020. Secondly, it provides a baseline trajectory from 2020 onwards that is used to determine savings that are likely to occur as a result of future interventions. The Reference case assumes that, from 2020 onwards, in the absence of any further policy or market intervention, retiring appliance stock is replaced with new appliances that achieve 2020 performance levels. For lighting it assumes that by 2025 the share of CFLs and LEDs is 47% and 43% respectively and that by 2030 the shares are 32% and 62% respectively. By 2040 all lighting is provided by LEDs. It is perhaps not entirely reasonable to assume that no market driven performance improvements will occur, and therefore this baseline may be slightly exaggerated, but market driven performance improvements cannot be accurately anticipated.

### 5.5.2. Ex-SL Scenario

The Ex-SL scenario represents the baseline case used to calculate S&L programme impacts for the period 2015-2020. It provides an estimated trajectory of what consumption may have been over this period in the absence of the S&L programme. It is important to note that the Ex-SL scenario includes some appliance efficiency improvements. These improvements are brought about as retired stock items are replaced over that period with new items assumed to have an intensity of what was available in 2015.

### 5.5.3. Moderate MEPS Scenario

The Moderate MEPS Scenario describes the likely growth of total residential electricity consumption under a moderate MEPS tightening of new products from 2025 onwards. The annual impact of this scenario is the difference between it and the reference scenario.

In general, the market has begun to outperform the MEPS policy as the performance of appliances available on retail floors and online mostly exceed the MEPS policy level, in some cases by a large margin. For example the MEPS requirement for new chest freezers is Level C, but most new items available are labelled A or A+.

The Moderate MEPS scenario consists of a single moderate policy shift in 2025. In cases where the market has exceeded the policy, the policy is shifted to at least match the best available on the market. For example, suppose that retail floors stock washing machines at levels A+ and A++. In this case the MEPS would be adjusted to match the better of these, A++. The purpose of this is to avoid relapse or unintended decay. In cases where the market has been sluggish, then the MEPS changes suggested are aimed at nudging the market towards better performance, typically by shifting one performance level higher than existing MEPS.

Note that the SANS standard for dishwashers would require an amendment to include performance above level A and would need to align with the amended EU performance classifications. For lighting it assumes that by 2025 the share of CFLs and LEDs is 24% and 71% respectively and that by 2030 the shares of CFLs and LEDs are 9.2% and 89% respective. By 2040 all lighting is provided by LEDs. This trajectory is similar to that in the business as usual case described by Walsh et al. (2019). The changes implemented in this scenario are listed in Table 5-11.

*Table 5-11: Existing and proposed appliance performance for Moderate MEPS Scenario*

| | MEPS | | |
|---|---|---|---|
| **Appliance** | **Existing** | **Proposed 2025** | **Notes** |
| Fridges & Fridge/Freezer | B | A++ | |
| Deep Freeze | C | A+ | |
| Dishwasher | A | A++ | SANS 50242 requires amendment |
| Oven (Small) | A | A+ | |
| Oven (Medium) | A | A+ | |
| Oven (Large) | B | A | |
| Washing machine | A | A++ | |
| Tumble Drier | D | C | |
| Air conditioner | B | A+ | |
| Geyser | B | B | |
| Lighting | N/A | Penetrations<br>2025: LED: 71%; CFL: 24%<br>Other: 6%<br>2030: LED: 89%; CFL: 9.2%<br>Other: 1.8% | |

## 5.5.4. Extensive MEPS Scenario

The Extensive MEPS scenario aims to actively implement S&L policy interventions over the period 2021 – 2040 in two phases. The years in which the policy changes are implemented are flexible, but for the sake of this assessment are selected to be 2025 and 2030. The first policy intervention (2025) aims, in all cases, to beat what the market has already achieved. The second policy intervention (2030), aims to further improve these new 2025 performance levels wherever there is still space to do so. In some cases no further S&L improvements are possible as the performance ceiling would have been reached. For example, if fridges moved to "A+++" in 2025, no further move would be possible in 2030. This is not to say the range of MEPS performance levels could not be expanded to accommodate new technologies, but such expansions are not included here.

Note that as with the previous scenario, the SANS standard for dishwashers would require an amendment to include performance above level A and would need to align with the amended EU performance classifications. For lighting, the same penetrations of CFLs and other lamps are assumed as in the Moderate MEPS scenario (see Table 5-12).

The Extensive MEPS scenario also expands the basket of technologies included in the current MEPS regulation. Firstly, vacuum cleaners are included to align with current EU legislation and secondly televisions are included for electricity consumption when switched on and not just for standby use, as is currently the case. The suggested changes for this scenario are listed in Table 5-12.

*Table 5-12: Existing and proposed appliance performance for Extensive MEPS Scenario*

| Appliance | MEPS | | | Notes |
|---|---|---|---|---|
| | **Existing** | **Proposed 2025** | **Proposed 2030** | |
| Fridges & Fridge/Freezer | B | A+++ | A+++ | No change |
| Deep Freeze | C | A++ | A+++ | |
| Dishwasher | A | A+++ | A+++ | SANS 50242 requires amendment |
| Oven (Small) | A | A++ | A+++ | |
| Oven (Medium) | A | A++ | A+++ | |
| Oven (Large) | B | A+ | A++ | |
| Washing machine | A | A+++ | A+++ | No change |
| Tumble Drier | D | B | A | |
| Air conditioner | B | A++ | A++ | No change |
| Geyser | B | B | B | No change |
| Lighting | | Penetrations<br>LED: 71%; CFL: 24%<br>Other: 6% | Penetrations<br>LED: 89%; CFL: 9.2%<br>Other: 1.8% | |
| Television | N/A | N/A | Current EU BAT | |
| Vacuum cleaner | N/A | N/A | Current EU BAT | |

### 5.5.5. Behavioural Scenario

This scenario is intended purely to quantify the potential impacts of selected consumer behavioural changes. The interventions considered are firstly those in which the likely impacts have been quantified, and secondly those which are low cost and considered to have a plausible chance of broad, sustained uptake. Hence the results are conservative as the interventions form a small subset of all the possible behavioural interventions. The scenario provides a preliminary comparison of the magnitudes of savings that could be expected from a few realistic behavioural interventions versus the technical intervention scenarios (Moderate MEPS, Extensive MEPS).

It is important to note that these modelled impacts are *additive* with either the Moderate or Extensive MEPS scenarios as the behavioural interventions are independent of appliance performance. Catalysts for these changes may be things such as focused information and awareness campaigns or educational programmes. In this scenario, the savings are introduced gradually at 5% per annum for a 20 year period, starting in 2021. The interventions selected are described below.

*Kettle overfilling*

Kettle overfilling and reheating appears to be quite prolific and offers an easy savings opportunity across all income groups. The data from a study of electric kettle energy consumption suggests that a potential 14% savings may be achieved purely by not overfilling or reheating (Murray et al., 2016: 235). In this scenario, this saving has been applied to kettle usage for tea, coffee and cooking, it has not been applied to kettle use for bathing, cleaning and washing. In the latter cases it is assumed that all the water heated is used (i.e. that no overfilling occurs).

*Increased use of pot lids*

The use of well-fitting pot lids has a significant impact on stove top electricity use (Oberascher, Stamminger & Pakula, 2011: 206). In the Reference case it has been assumed that stove top cooking without pot lids occurs in roughly 50% of low income households. In the Behaviour based scenario, this has been reduced to 25%. This leads to a reduction in stove top electricity use, in low income households, of about 20%.

*Geyser "standing" losses*

Geyser "standing" losses may be reduced by only energising the geyser element shortly before the hot water is required. This avoids the thermal standing losses associated with a hot water cylinder being heated more or less permanently and storing a full charge of hot water for long periods when it is not required (throughout the night for example).

These savings can be achieved manually (or by using a timer) to switch the geyser on an hour or two prior to the hot water being needed and off at all other times. Artificial Intelligence (AI) mobile applications are also being researched to optimise electric geyser energy use depending on the unique behavioural patterns of a particular household (Nel, Booysen & Van Der Merwe, 2015: 1). This intervention does not consider savings associated with reduced hot water use and in this scenario the quantity of hot water usage per household is assumed to remain the same. In this scenario, geyser switching attains a reduction in geyser standing losses of 23% across the middle and high income groups. This effectively takes standing losses to the lower limit of Class B and the upper limit of Class A at 0.87 kWh/day.

### 5.5.6. Higher SWH and Heat Pump adoption

This scenario increases SWH and Heat Pump penetration levels in middle and high income households. It assumes that high income households adopt SWHs or Heat Pumps at a rate that is 50% higher each year than the Reference case and that 5% of geysers in middle income households are replaced by SWHs by 2040. By 2040 this results in 27% of high income households supplying water heating with SWHs compared to the Reference case where 18% of households have SWHs in 2040.

### 5.5.7. Aggregate electricity consumption of new stock

The aggregate annual kWh appliance consumptions for new stock from 2020 onwards for all scenarios are provided in Table 5-13 to Table 5-17 below. Table 5-13 provides the Reference case baseline consumption estimates for all the scenarios (except the Ex-SL Scenario). Table 5-14 provides the 2025 consumption estimates for the Moderate MEPS scenario. Table 5-15 and Table 5-16 provide the 2025 and 2030 consumption estimates for the Extensive MEPS Scenario. Table 5-17 provides the consumption estimates for the Behavioural Scenario.

*Table 5-13: Aggregate new appliance annual kWh consumption (Reference case 2020)*

| | **2020 Average kWh Annual** | | |
|---|---|---|---|
| **Average kWh Annual** | **Income category** | | |
| **Appliance / Service** | **Low** | **Middle** | **High** |
| Lighting | 225 | 282 | 431 |
| Cooking - Oven | 137 | 157 | 175 |
| Cooking - Stove | 226 | 208 | 308 |
| Cooking - Microwave | 45 | 54 | 59 |
| Cooking - Kettle | 192 | 210 | 225 |
| Cooking - Other | 14 | 37 | 28 |
| Fridge/Freezer 1 | 230 | 242 | 272 |
| Fridge/Freezer 2 | 196 | 207 | 205 |
| Deep Freeze 1 | 263 | 257 | 266 |
| Deep Freeze 2 | 198 | 198 | 198 |
| Dishwasher | 436 | 259 | 270 |
| Washing machine | 117 | 125 | 154 |
| Tumble drier | 513 | 369 | 328 |
| Hot Water Geyser | 0 | 2384 | 3567 |
| Hot Water Geyser + SWH / HP | 0 | 0 | 985 |
| Hot Water - Kettle | 97 | 77 | 62 |
| Space heating | 44 | 191 | 167 |
| TV | 168 | 235 | 342 |
| Pool pump | 894 | 521 | 799 |
| Aircon | 609 | 578 | 556 |
| Other | 99 | 392 | 286 |

*Table 5-14: Aggregate new appliance annual kWh consumption ("Moderate MEPS" Scenario 2025)*

| | **"Moderate MEPS" Average kWh Annual (2025)** | | |
|---|---|---|---|
| **Average kWh Annual** | **Income category** | | |
| **Appliance / Service** | **Low** | **Middle** | **High** |
| Lighting | 143 | 179 | 273 |
| Cooking - Oven | 137 | 157 | 175 |
| Cooking - Stove | 226 | 208 | 308 |
| Cooking - Microwave | 45 | 54 | 59 |
| Cooking - Kettle | 192 | 210 | 225 |
| Cooking - Other | 14 | 37 | 28 |
| Fridge/Freezer 1 | 227 | 240 | 271 |
| Fridge/Freezer 2 | 184 | 193 | 194 |
| Deep Freeze 1 | 229 | 224 | 232 |
| Deep Freeze 2 | 173 | 173 | 173 |
| Dishwasher | 436 | 259 | 270 |
| Washing machine | 110 | 117 | 144 |
| Tumble drier | 486 | 349 | 311 |
| Hot Water Geyser | 0 | 2384 | 3567 |
| Hot Water Geyser + SWH / HP | 0 | 0 | 985 |
| Hot Water - Kettle | 97 | 77 | 62 |
| Space heating | 44 | 191 | 167 |
| TV | 168 | 235 | 342 |
| Pool pump | 894 | 521 | 799 |
| Aircon | 609 | 578 | 556 |
| Other | 99 | 392 | 286 |

*Table 5-15: Aggregate new appliance annual kWh consumption ("Extensive MEPS" Scenario Phase 1 2025)*

| | "Extensive MEPS" Average kWh Annual (2025) | | |
|---|---|---|---|
| **Average kWh Annual** | **Income category** | | |
| **Appliance / Service** | **Low** | **Middle** | **High** |
| Lighting | 143 | 179 | 273 |
| Cooking - Oven | 104 | 119 | 134 |
| Cooking - Stove | 226 | 208 | 308 |
| Cooking - Microwave | 45 | 54 | 59 |
| Cooking - Kettle | 192 | 210 | 225 |
| Cooking - Other | 14 | 37 | 28 |
| Fridge/Freezer 1 | 184 | 194 | 218 |
| Fridge/Freezer 2 | 157 | 165 | 164 |
| Deep Freeze 1 | 168 | 165 | 170 |
| Deep Freeze 2 | 127 | 127 | 127 |
| Dishwasher | 411 | 245 | 254 |
| Washing machine | 103 | 110 | 136 |
| Tumble drier | 426 | 306 | 272 |
| Hot Water Geyser | 0 | 2384 | 3567 |
| Hot Water Geyser + SWH / HP | 0 | 0 | 985 |
| Hot Water - Kettle | 97 | 77 | 62 |
| Space heating | 44 | 191 | 167 |
| TV | 168 | 235 | 342 |
| Pool pump | 894 | 521 | 799 |
| Aircon | 591 | 562 | 540 |
| Other | 99 | 392 | 286 |

*Table 5-16: Aggregate new appliance annual kWh consumption ("Extensive MEPS" Scenario Phase 2 2030)*

| | "Extensive MEPS" Average kWh Annual (2030) | | |
|---|---|---|---|
| **Average kWh Annual** | **Income category** | | |
| **Appliance / Service** | **Low** | **Middle** | **High** |
| Lighting | 118 | 147 | 225 |
| Cooking - Oven | 79 | 90 | 100 |
| Cooking - Stove | 226 | 208 | 308 |
| Cooking - Microwave | 45 | 54 | 59 |
| Cooking - Kettle | 192 | 210 | 225 |
| Cooking - Other | 14 | 37 | 28 |
| Fridge/Freezer 1 | 184 | 194 | 218 |
| Fridge/Freezer 2 | 157 | 165 | 164 |
| Deep Freeze 1 | 135 | 132 | 136 |
| Deep Freeze 2 | 101 | 101 | 101 |
| Dishwasher | 411 | 245 | 254 |
| Washing machine | 103 | 110 | 136 |
| Tumble drier | 323 | 232 | 206 |
| Hot Water Geyser | 0 | 2384 | 3567 |
| Hot Water Geyser + SWH / HP | 0 | 0 | 985 |
| Hot Water - Kettle | 97 | 77 | 62 |
| Space heating | 44 | 191 | 167 |
| TV | 168 | 235 | 342 |
| Pool pump | 894 | 521 | 799 |
| Aircon | 591 | 562 | 540 |
| Other | 99 | 392 | 286 |

*Table 5-17: Aggregate new appliance annual kWh consumption ("Behavioural" Scenario)*

| | "Behavioural Scenario" Average kWh Annual (Gradual 2020-2040) | | |
|---|---|---|---|
| **Average kWh Annual** | **Income category** | | |
| **Appliance / Service** | **Low** | **Middle** | **High** |
| Lighting | 225 | 282 | 431 |
| Cooking - Oven | 137 | 157 | 175 |
| Cooking - Stove | 180 | 208 | 308 |
| Cooking - Microwave | 45 | 54 | 59 |
| Cooking - Kettle | 164 | 179 | 193 |
| Cooking - Other | 14 | 37 | 28 |
| Fridge/Freezer 1 | 230 | 242 | 272 |
| Fridge/Freezer 2 | 196 | 207 | 205 |
| Deep Freeze 1 | 263 | 257 | 266 |
| Deep Freeze 2 | 198 | 198 | 198 |
| Dishwasher | 436 | 259 | 270 |
| Washing machine | 117 | 125 | 154 |
| Tumble drier | 513 | 369 | 328 |
| Hot Water Geyser | 0 | 2272 | 3473 |
| Hot Water Geyser + SWH / HP | 0 | 0 | 890 |
| Hot Water - Kettle | 97 | 77 | 62 |
| Space heating | 44 | 191 | 167 |
| TV | 168 | 235 | 342 |
| Pool pump | 894 | 521 | 799 |
| Aircon | 609 | 578 | 556 |
| Other | 99 | 392 | 286 |

# 6. Model results

## 6.1. Reference case demand and stock growth

Demand growth in the reference case is influenced by appliance stock changes and the efficiency at which energy services are supplied. As population grows to 2040, and household income shifts towards a higher share of middle and high income households, appliance stock increases, increasing demand. Before 2020 some of this demand increase is mitigated by the assumed increase in efficiency of delivering energy services. The resulting demand growth, and share of electricity to energy services, are shown in Figure 6-1 and Figure 6-2. Figure 6-3 shows the stock of appliances from 2015 to 2040.

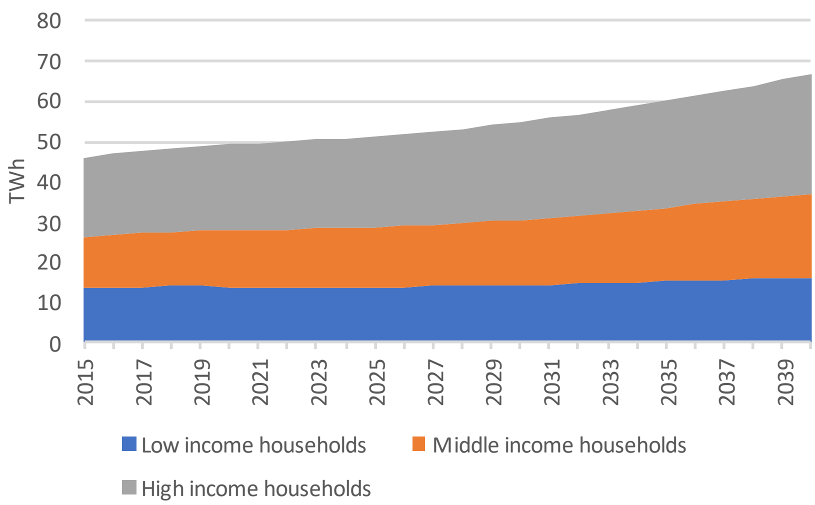


*Figure 6-1: Reference case demand growth*

Over time the percentage of total consumption needed to supply each of the energy services changes, in all income groups, in response to the assumptions around the efficiency of new appliances (see Figure 6-2). By 2040 the savings achieved, from replacing the appliance stock, are close to the maximum possible, as most of the appliance stock is replaced by new appliances over the 20 year period between 2020 to 2040. Across all income groups, refrigeration and lighting see the largest reductions in the share of electricity needed to supply energy services.

In low income households, cooking replaces refrigeration as the dominant energy consumer, the share of electricity going to refrigeration decreases by 10%, whilst that of cooking increases by 7%. Electricity use for water heating increases by 2%. The share of electricity going to televisions increases by 3%, whilst the share of electricity being used for washing decreases by 3%. Electricity used for lighting drops from 13.7% to 8.7%.

In middle income households water heating takes a larger share of electricity consumption as other appliances become more efficient, particularly fridges. Similar to high income households, the share of electricity used to supply TVs, pool pumps and air conditioning increases slightly, whilst that of dishwashers, tumble dryers and washing machines decreases slightly in response to the efficiency improvements assumed for these appliances. The share of electricity supplying refrigeration decreases by 7%, whilst that of lighting decreases by 3%.

In high income households, even though the share of water heating supplied by electric geysers decreases due to the increasing use of SWHs and there is a small improvement in geyser efficiency, water heating continues to dominate (see Table 7-1) and there is a small increase (3%) in the share of energy needed to supply water heating over the period. The share of electricity used to supply TVs, pool pumps and air conditioning increases slightly, whilst that of dishwashers, tumble dryers and washing machines decreases slightly in response to efficiency improvements. The share of electricity being used for lighting decreases by 2% whilst the share of electricity being used for refrigeration decreases by 4% over the period. Cooking sees a slight increase (1%) in the share of electricity consumed as only ovens see in increase in energy efficiency.

The share of water heating appears higher than may be expected in the high income group. It should be noted that this may be largely due to the income intervals that have been used to allocate households to income groups. The weighted average for the share of electricity used to supply hot water to middle and high income households is 42%. McNeil, Covary & Vermeulen (2015: 10) quote an Eskom study placing the SA middle income hot water share at 39%. Furthermore as high income households become more energy efficient in other areas, the share of electricity used to supply hot water increases if savings in the intensity of supplying hot water are moderate.

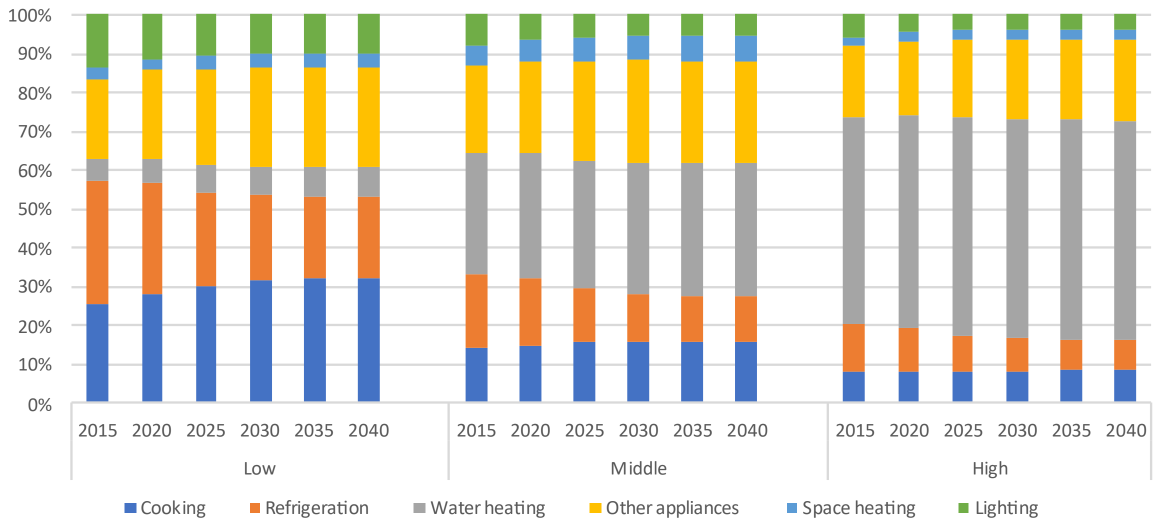


*Figure 6-2: Reference case energy service share of consumption*

The share of appliances owned by households is assumed to remain the same over the period for all energy services except water heating in high income households where the increase in SWHs reduces conventional geyser stock. The growth in the appliance stock, in response to these assumptions, is shown in Figure 6-3.

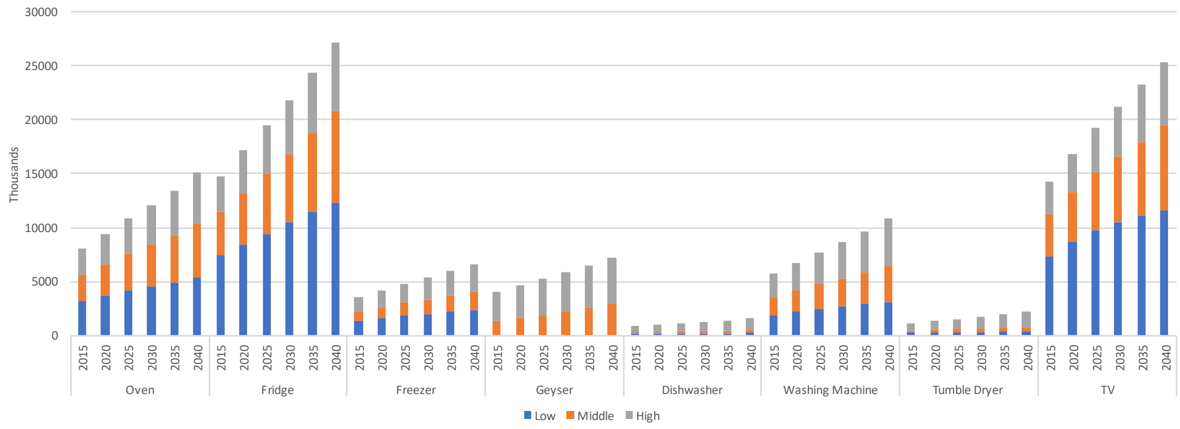


*Figure 6-3: Stock of targeted appliances and share of new appliances (2020-2040)*

## 6.2. Impacts of S&L programme 2015-2020

The estimated impact of the S&L programme is shown in Figure 6-4 and Figure 6-5. Figure 6-4 shows the savings (TWh) that are achieved in the Reference scenario compared to the Ex-SL scenario from 2015 to 2020. The highest savings are achieved in refrigeration and water heating. Savings in the low income group are dominated by refrigeration, which is expected as refrigeration consumes a large share of electricity in low income households. Similarly, water heating in high income households dominates energy consumption, and in high income households, even though efficiency gains due to lower water heating standing losses are modest, water heating efficiency gains achieve the highest savings. Figure 6-5 presents the same results as Figure 6-4 but with each appliance type shown separately, and only for 2020.

It is important to note that the Ex-SL scenario includes some appliance efficiency improvements, in other words, Figure 6-4 and Figure 6-5 do not provide an estimate of what consumption might have been with no improvements in appliance efficiency or the delivery of energy services.

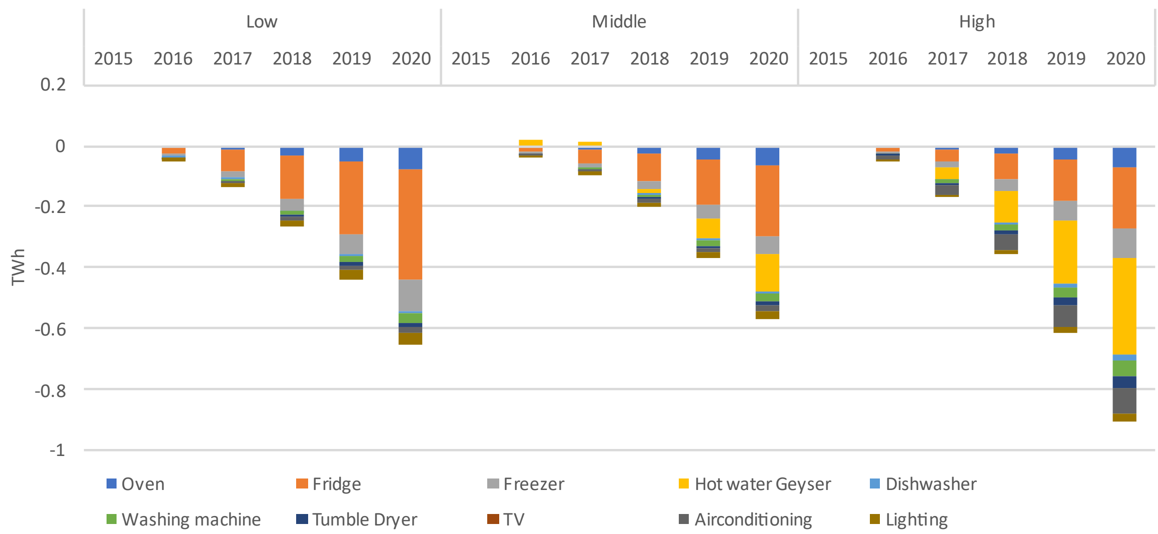


*Figure 6-4: Impact of the S&L programme 2015-2020 (TWh)*

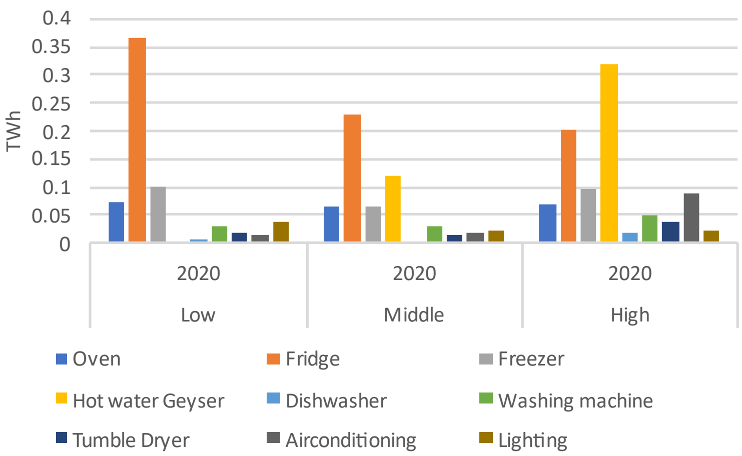


*Figure 6-5: Savings from the S&L programme 2015-2020 (Baseline is the case excluding S&L "Ex-SL")*

## 6.3. Moderate MEPS scenario: 2020 – 2040

The Moderate MEPS scenario achieves moderate savings compared to the Reference case. Table 6-1 shows the absolute savings achieved in each of the income groups as well as the percentage savings within each income group. Savings are moderate in 2040 due to the low number of appliance types that are assumed to see greater improvements in efficiency in this scenario compared to the Reference case, as well as the modest assumptions around the savings that could be achieved. In this scenario geysers, washing machines and dishwashers do not see additional efficiency improvements.

*Table 6-1: Energy savings of the Moderate MEPS case relative to the Reference case*

| TWh | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|
| Low income households | 0.30 | 0.35 | 0.35 | 0.15 |
| Middle income households | 0.18 | 0.22 | 0.23 | 0.12 |
| High income households | 0.19 | 0.24 | 0.26 | 0.15 |
| Overall | 0.66 | 0.81 | 0.84 | 0.43 |
| Percentage savings | 2025 | 2030 | 2035 | 2040 |
| Low income households | 2.11% | 2.43% | 2.29% | 0.97% |
| Middle income households | 1.17% | 1.34% | 1.27% | 0.57% |
| High income households | 0.83% | 0.99% | 0.98% | 0.52% |
| Overall | 1.28% | 1.47% | 1.40% | 0.64% |

Figure 6-6 shows the savings that could be achieved between 2020 and 2040 if the moderate MEPS scenario were to be implemented. Due to the aggressive improvements in lighting efficiency assumed in this scenario, compared to the modest assumptions of efficiency improvements in other appliances, savings in lighting dominate, in all income groups, until 2035 at which point most of the savings possible have been realized. It is important to note that, as lighting stock is replaced fairly rapidly, assumptions around the year in which lighting MEPS may be implemented can have a large impact on the year in which savings are seen.

The high incidence of refrigeration ownership in low income households, result in refrigeration savings having a larger impact in this group compared to the middle and high income groups. Refrigeration appliances, have longer lifespans than most other appliances, and therefore savings in refrigeration and freezers continue to grow until 2040 as new more efficient appliances replace older, less efficient appliances. In 2040 refrigeration provides the largest savings for low income households. Middle income households and high income households have a higher ownership of freezers and in high income households savings on freezers, which are close to 10% compared to the Reference case dominate.

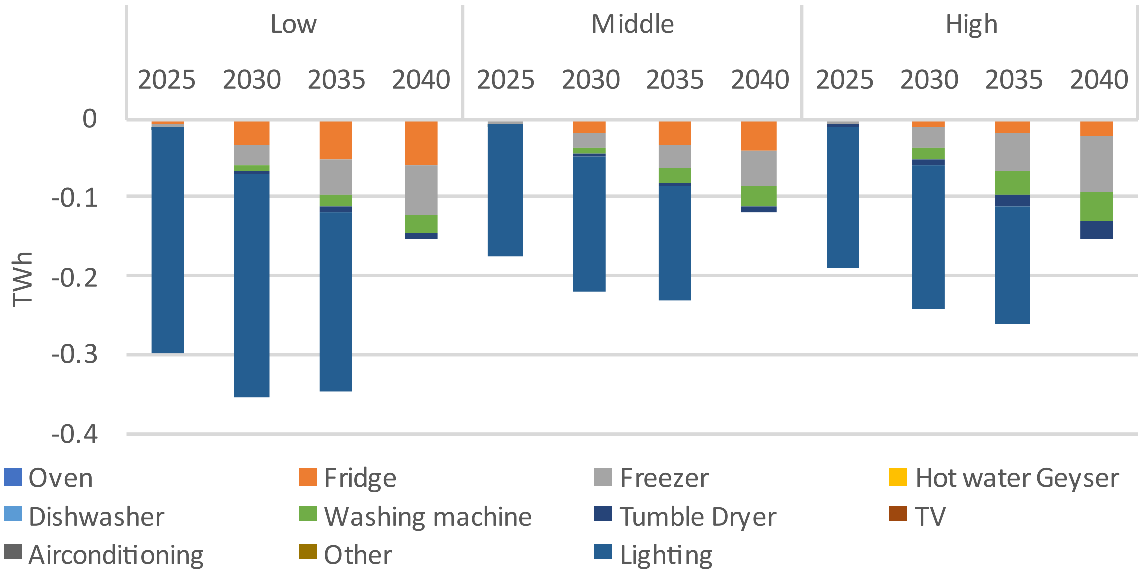


*Figure 6-6: Electricity savings achieved in the Moderate MEPS scenario*

Figure 6-7 shows the percentage of savings attributed to each energy service in the Moderate MEPS scenario relative to the consumption of that energy service in the Reference case. In other words, the lighting savings that low income households see in 2025 in Figure 6-7 are the savings that low income households saw in the Moderate MEPS scenario in 2025 divided by the total electricity used to deliver lighting in low income households in the Reference scenario in 2025. Lighting savings have a different trend compared to other savings. For appliances other than lighting, savings increase over time due to the increasing penetration of new appliances, although new appliance efficiencies are assumed to remain the same from 2025 onwards. Lighting savings decrease from 2030 onwards, as the market becomes saturated with CFLs and LEDs.

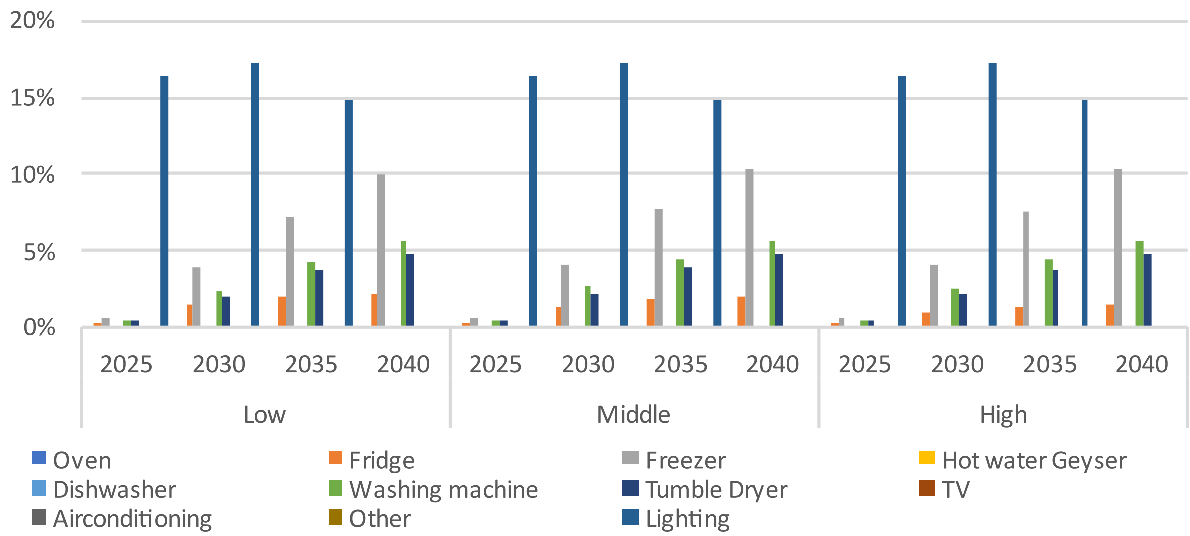


*Figure 6-7: Percentage savings relative to the Reference case in the Moderate MEPS scenario*

## 6.4. Extensive MEPS Scenario: 2020 – 2040

Savings are higher in this scenario in 2040 compared to the Moderate MEPS scenario, due to both the higher number of appliance types that are assumed to see greater improvements in efficiency as well as the more ambitious assumptions around the savings that could be achieved. Table 6-2 shows the savings likely in each of the income groups, as well as the percentage savings within each income group, that could be achieved through the Extensive MEPS measures.

In this scenario, the low income group realises similar savings to the middle and high income groups overall, as well as in terms of the percentage of savings achieved. This is once again due to the high incidence of the ownership of appliances targeted by the Extensive MEPS measures in these households and the low incidence of ownership of appliances that are not targeted by the Extensive MEPS measures. It is also due to the proportion of households that fall into the low income group. Even though lower income households own fewer appliances, the far larger number of low income households, means that a considerable number of appliances are owned by this income group.

*Table 6-2: Energy savings of the Extensive MEPS case relative to the Reference case*

| TWh | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|
| Low income households | 0.37 | 0.91 | 1.75 | 2.11 |
| Middle income households | 0.23 | 0.72 | 1.58 | 2.12 |
| High income households | 0.25 | 0.78 | 1.81 | 2.44 |
| Overall | 0.85 | 2.42 | 5.14 | 6.66 |
| **Percentage Savings** | **2025** | **2030** | **2035** | **2040** |
| Low income households | 2.6% | 6.3% | 11.6% | 13.2% |
| Middle income households | 1.5% | 4.4% | 8.6% | 10.2% |
| High income households | 1.1% | 3.2% | 6.8% | 8.3% |
| Overall | 1.6% | 4.4% | 8.5% | 10.1% |

Figure 6-8 shows the absolute savings that are likely to be achieved through the extensive MEPS scenario, whilst Figure 6-9 shows the percentage of savings in each appliance type over the 15 year period. In this scenario, households see savings in cooking (oven efficiency), refrigeration, and in a range of other appliances. Considerable savings are achieved through the improvements implemented in lighting and television efficiency and although fridge and freezer efficiency improvements are still considerable, these no longer dominate savings.

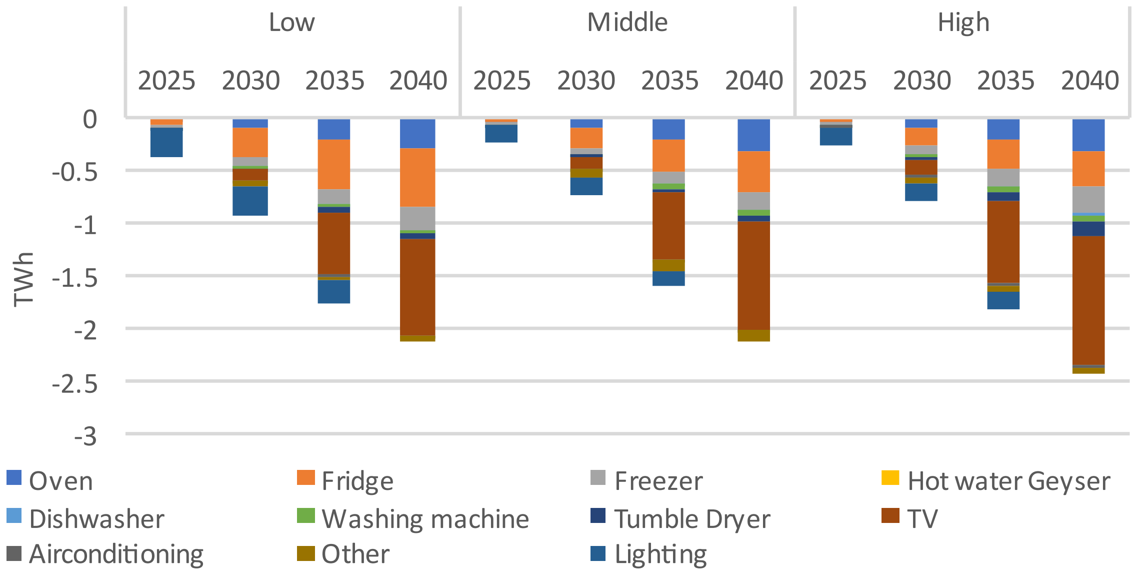


*Figure 6-8: Electricity savings achieved in the Extensive MEPS scenario*

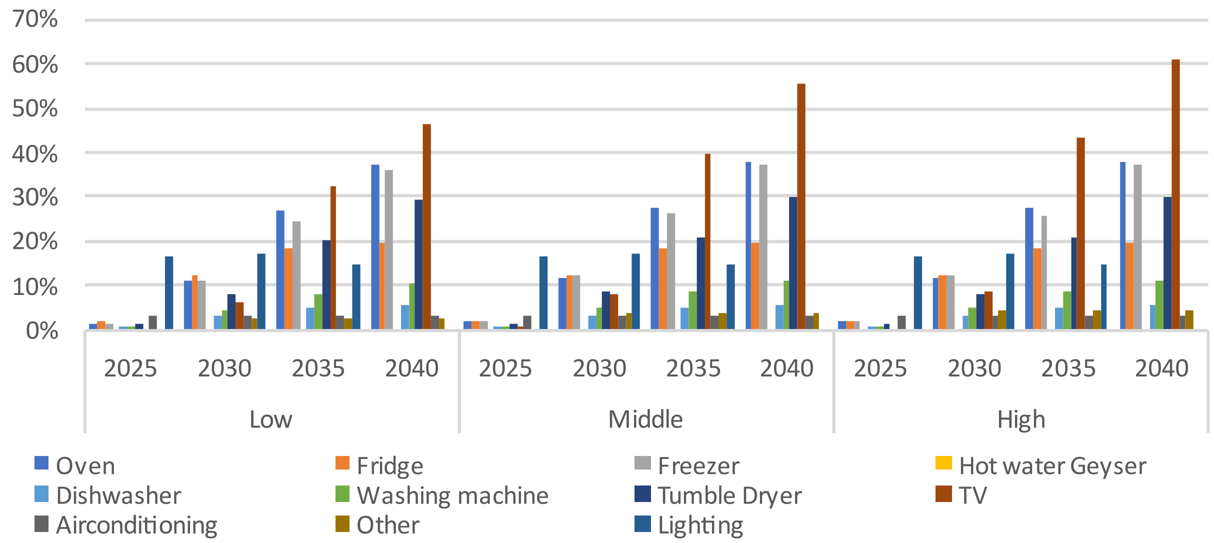


*Figure 6-9: Percentage savings relative to the Reference case in the Extensive MEPS scenario*

## 6.5. Behavioural Scenario: 2021 – 2040

In the behavioural scenario only a small range of energy services are considered, primarily water heating and low income household cooking. Table 6-3 shows the savings that are likely were these behaviour-based changes achieved. In this scenario low income households achieve the highest savings due to the estimated impacts of cooking and kettle use over the period. Overall, this scenario achieves a saving of 1.8% in 2030 compared to the 8.5% saving achieved through the Extensive MEPS scenario and a far higher saving compared to that of the Moderate MEPS scenario, which achieves less than 1.5% saving. This is partly due to the very modest assumptions of the Moderate MEPS scenario which do not extend beyond 2025, whereas the behaviour-based efficiency improvements continue to steadily grow to 2040 particularly as the share of higher income households increases and thus the overall share of energy supplying geyser water heating increases. An advantage of such behavioural interventions is the very low cost of implementation.

*Table 6-3: Energy savings of the Behaviour case relative to the Reference case*

| TWh | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|
| Low income households | 0.13 | 0.29 | 0.46 | 0.66 |
| Middle income households | 0.05 | 0.14 | 0.29 | 0.46 |
| High income households | 0.05 | 0.15 | 0.32 | 0.53 |
| Overall | 0.22 | 0.58 | 1.07 | 1.65 |
| Percentage savings | 2025 | 2030 | 2035 | 2040 |
| Low income households | 0.9% | 2.0% | 3.1% | 4.2% |
| Middle income households | 0.3% | 0.9% | 1.5% | 2.2% |
| High income households | 0.2% | 0.6% | 1.2% | 1.8% |
| Overall | 0.4% | 1.1% | 1.8% | 2.5% |

Figure 6-10 shows the electricity savings achieved between 2025 and 2040 in the behaviour-based scenario. It shows the dominance of savings in geyser hot water use in high and middle income households.

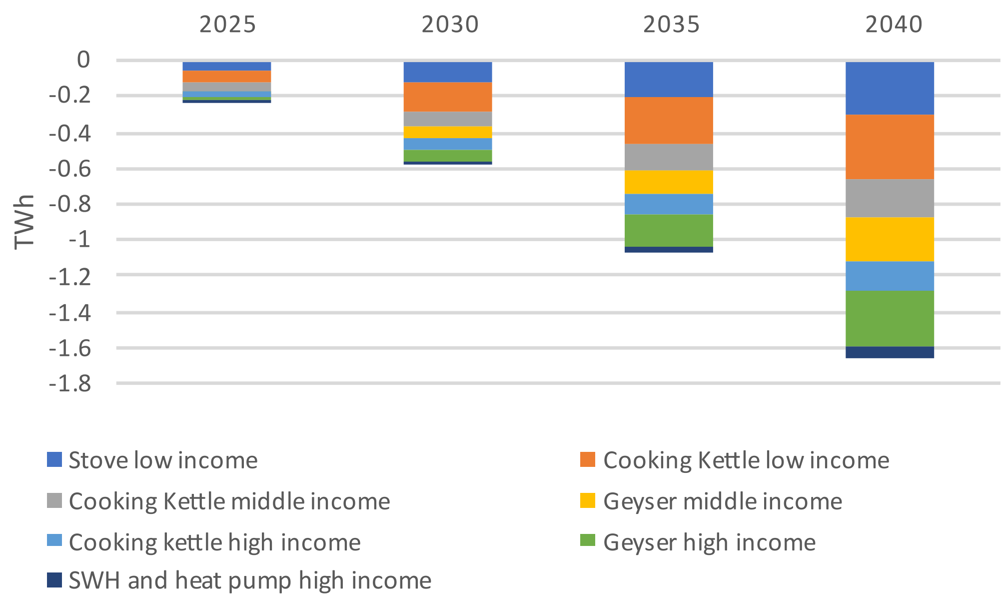


*Figure 6-10: Electricity savings achieved in the Behavioural scenario*

## 6.6. Higher SWH and Heat Pump Adoption

The increased adoption of SWH/Heat pumps in this scenario results in a savings in energy used for water heating of 3.3% and 4.5% in 2035 and 2040 respectively. Table 6-4 shows the savings achieved by the higher adoption of SWHs in which 27% percent of households in the higher income group use SWHs in 2040 compared to 18% in the Reference case, and 5% of geysers in the middle income group are replaced with SWHs. Figure 6-11 shows the savings in the SWH/Heat Pumps scenario compared to the Reference case. These savings assumptions rely on the estimates of hot water consumption attributed to middle and high income households. These estimates are subject to large variances based on assumptions such as the amount of hot water used by households and inlet water temperature.

*Table 6-4: Energy savings of the Extended SWH/Heat Pumps relative to the Reference case*

| TWh | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|
| Low income households | 0 | 0 | 0 | 0 |
| Middle income households | 0.18 | 0.58 | 1.16 | 1.71 |
| High income households | 0.31 | 0.53 | 0.84 | 1.26 |
| Overall | 0.49 | 1.11 | 2.00 | 2.97 |
| Percentage savings | 2025 | 2030 | 2035 | 2040 |
| Low income households | 0.0% | 0.0% | 0.0% | 0.0% |
| Middle income households | 1.2% | 3.6% | 6.3% | 8.2% |
| High income households | 1.4% | 2.2% | 3.1% | 4.3% |
| Overall | 0.9% | 2.0% | 3.3% | 4.5% |

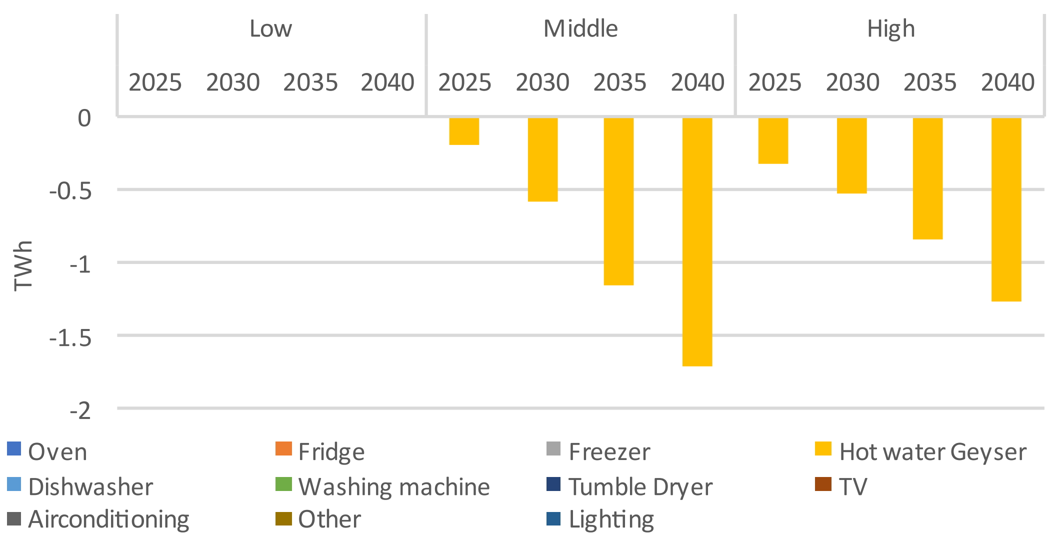


*Figure 6-11: Electricity savings achieved in Extended SWH/Heat Pumps Scenario*

# 7. Discussion & recommendations

The discussion and recommendations which follow include an assessment of the S&L programme savings (Reference case versus Ex-SL scenario), an assessment of the post-2015 NEES targets (Reference case versus Moderate and Extended MEPS scenarios) and further savings that could be achieved through faster uptake of SWHs and Heat Pumps (Reference case versus SWH/Heat Pump scenario) and small behavioural changes (Reference case versus Behavioural Scenario).

The recommendations for electrical appliances identifies and discusses five key areas of residential electricity consumption and in each case provides recommendations for further action. The key areas are electric geysers, solar water heaters, the proposed VC9008 amendments, lighting and behavioural interventions. The recommendations focus on refining the consumption estimates that are most sensitive to assumptions, accelerating the uptake of efficient technologies, revising proposed regulations and exploring the potential of non-technical interventions. Section 7.4 provides more detailed comments on electrical appliances and end uses and examines some of those cases where the details of appliance selection, utilization and maintenance are particularly important.

## 7.1. Assessment of the S&L programme

The S&L programme has achieved meaningful savings in appliance energy consumption between 2015 and 2020. Even without extending the programme, due to the long lifespans of some appliances, the programme will continue to realise savings. The estimated savings are highest in refrigeration in the low income group and in hot water heating in the high income group. This reflects the dominance of energy consumption by these two appliances in these two income groups between 2015 and 2020.

The S&L programme results in a drop in energy intensity needed to supply energy services of 4.3% in the low income group in the 2020 Reference case compared to the Ex-SL scenario in 2020. Similar reductions in energy intensity are seen in the middle and high income groups. The energy intensity of supplying energy services in middle income households drops by 3.8% and in high income households it drops by 4.2%. This amounts to an overall reduction in energy intensity of 4.1% in 2020 in the Reference case compared to the Ex-SL scenario.

## 7.2. Assessment of the Post-2015 NEES targets for appliance efficiency

This section provides an assessment of the efficiency target for residential appliances stipulated in the Post-2015 NEES. Firstly, a comparison is made, per appliance type, between the estimated 2015 performance levels and the 2030 levels envisaged for each MEPS scenario. Secondly the LEAP model is used to determine the average percentage performance improvement across all appliance types combined.

The Post-2015 NEES specifies two targets for the residential sector as follows.

- *"A 33% reduction in the average specific energy consumption of new household appliances purchased in South Africa by 2030 relative to a 2015 baseline"*
- *"A 20% Improvement in the average energy performance of the residential building stock by 2030 relative to a 2015 baseline, as measured by the energy consumption (excluding plug loads) per square meter of habitable space."* (DOE 2016: 24)

The assessment provided here relates only to the first target and it is assumed that the target implies a reduction of 33% while delivering the same level of service. At an appliance level, the anticipated energy consumption improvements are shown in Table 7-1 below for the Moderate and Extensive MEPS scenarios. The cases that meet the target are shown in bold.

*Table 7-1: Likely energy intensity %-improvements 2015-2030 under Moderate & Extensive MEPS scenarios*

| Appliance | Intensity improvement (%) | | Notes |
|---|---|---|---|
| | **Moderate MEPS** | **Extensive MEPS** | |
| Lighting | 3% | **44%** | Average lamp at specified technology shares |
| Cooking - Oven | **36%** | **63%** | |
| Cooking - Stove | 0% | 0% | |
| Cooking - Microwave | 0% | 0% | |
| Cooking - Kettle | 0% | 0% | |
| Fridge/Freezer | **52%** | **61%** | |
| Deep Freeze | **59%** | **76%** | |
| Hot Water Geyser | 9% | 9% | Shift to Class B for standing losses |
| Hot Water (SWH/Heat Pump) | 27% | 27% | |
| Dishwasher | 31% | **35%** | |
| Washing machine | **39%** | **43%** | |
| Tumble drier | **39%** | **59%** | |
| TV | 0% | **68%** | Assumed to be added to the S&L basket |
| Pool pump | 0% | 0% | |
| Aircon | 19% | 21% | |
| Space heating | 0% | 0% | |

In both the Moderate and Extensive MEPS scenarios the appliances most likely to meet or exceed a 33% efficiency improvement are those that were targeted by the S&L programme. Some appliances are likely able to meet the target easily whilst others, such as fridges and freezers, are likely to exceed it by a large margin. However, there are many appliances where no saving is anticipated such as stoves, microwave ovens, kettles, resistive space heaters and pool pumps. There are some appliances such as geysers that show some improvement but are never likely to meet a 33% reduction in energy consumption even with stringent MEPS changes. In these cases, a significant shift to a different technology would be required to meet the target.

The LEAP model is a means of assessing the target against the likely average performance of all household appliances taken together. The model results indicate that if the S&L and MEPS programmes continued in their current form, with appliance standards at the current level, they would achieve a saving of 10% in 2030 compared to the case where only moderate savings occur in the absence of these programmes. If the 2015 household baseline consumption is simply extended to 2030, the model shows a saving of 19%.

A review of the percentage change in intensity of supplying energy services to households in 2030 compared to a 2015 baseline, for the Moderate and Extensive MEPS scenarios is provided in Table 7-2.

*Table 7-2: Overall intensity %-improvements 2015-2030 under Moderate & Extensive MEPS scenarios*

| **Moderate MEPS** | | | |
|---|---|---|---|
| | **2020** | **2030** | **2040** |
| **Low** | 6.3% | 25.4% | 28.2% |
| **Middle** | 6.1% | 20.2% | 21.3% |
| **High** | 5.7% | 18.9% | 22.8% |
| **Total** | 5.2% | 19.3% | 19.8% |
| **Extensive MEPS** | | | |
| | **2020** | **2030** | **2040** |
| **Low** | 6.3% | 28.4% | 37.1% |
| **Middle** | 6.1% | 22.7% | 28.9% |
| **High** | 5.7% | 20.7% | 28.8% |
| **Total** | 5.2% | 21.7% | 27.4% |

The results indicate that without an expansion of the programme the 33% target will not be achieved. The programme expansion would require at least the changes in the Extensive MEPS Scenario, the Behavioural Scenario as well as a strong focus on key technology shifts (such as SWHs).

One thing that was clear from the REC 2020 survey data is that very few households used LEDs. This appears to be data that could inform the S&L programme lighting guide mentioned in Section 1. The REC 2020 survey and LEAP modelling indicate a large potential for rapidly improving the energy efficiency of lighting, which is seen in the large savings that are achieved in lighting in the Moderate and Extensive MEPS scenarios even when fairly conservative estimates are used. Walsh et al. (2019) indicate that, should lighting MEPS be quickly put in place, these efficiency gains in lighting could occur very quickly.

## 7.3. Key recommendations

This section identifies and discusses five key areas of residential electricity consumption and in each case provides recommendations for further action. The key areas are electric geysers, solar water heaters, the proposed VC9008 amendments, lighting and behavioural interventions. The purpose of the recommendations include refining consumption estimates, accelerating the uptake of efficient technologies, revising proposed regulations and exploring the potential of non-technical interventions.

### 7.3.1. Electric geysers

From an energy perspective, resistive water heaters are the most significant end use in South African households. The energy used by resistive water heaters is also very sensitive to small changes in assumptions such as the daily volume of hot water drawn, geyser setpoint temperature, incoming water temperature and standing losses. For a "Class D" geyser at around 65°C, each 1°C increase in setpoint temperature causes standing losses to increase by roughly 50 Wh/day (JESA 2012: 3). Similarly, in a 3-person middle or high income household, an increase in hot water consumption of 1ℓ/person/day increases electricity consumption by about 150-160 Wh/day. Although domestic hot water use is so important, it remains understudied.

Energy used for water heating was estimated by assuming an amount of hot water used per person per day by low, middle and high income households. The most significant uncertainty in calibrating geyser energy use, in this study, was estimating the volume of daily hot water use per person in households with different income levels. Only a handful of measurement-based studies have been conducted that address this question specifically in South Africa (Beute, 1993; Meyer, 2000; Donev et al., 2012). Although invaluable, these studies are outdated and refer to income groups in different ways without quoting exact income intervals.

Geyser standing losses make up a large portion of electricity use and as a fraction of a geyser's total energy use, standing losses are highest for low occupancy households. For a 1-person, high income household with a "Class D" geyser, the standing losses can account for well over one third of total geyser energy consumption. The recent introduction of VC9006 for water heaters is a major step forward towards energy conservation in water heating (DTI 2016: 2). However, the performance range of "Class B" is broad and customers still need to be educated about the benefits of geysers at the low end of Class B versus those near the high end of Class B. A move to "Class A" is well within the reach of industry if there is will to do so. Some standing loss savings are also possible through geyser switching as can be seen in the Behavioural Scenario of this study.

Inline water heaters may be a consideration as these avoid standing losses and pipe losses, although large scale uptake of these would need to a study of the diversity factor to ensure that the Eskom evening peak residential demand is not adversely affected in the context of low utility reserve margin (Beute, 1993: 109).

At the national level, there is uncertainty about the number of geysers in the country and also about the number of households that have more than one operational geyser.

*Recommendations*

Priority should be given to revising and updating the critical data required for hot water calculations, and monitoring geyser electricity use directly. At a household level, this includes daily volume of hot water consumption across well-defined income groups, water temperature at the geyser outlet, the percentage of households that possess more than one geyser and seasonal variations of incoming water temperatures. At a national level, estimates of geyser penetration need to be improved, particularly in the middle income group. Here it is important that households are able to distinguish between geysers and solar water heaters in their survey responses.

### 7.3.2. Solar water heaters (SWHs)

Quantifying SWH performance at the national level presents two major challenges. Firstly, the real performance and electrical impacts of SWHs in South Africa is not well known. Secondly, accurate data on low pressure (LP) and high pressure (HP) installation numbers at a national level is sparse. This is data that could be developed through close partnership with local government departments and the private sector. For example, there is a SWH installer (Geyserwise) that collects performance data on its installed systems. Industry association partnerships should also be explored (for example with organizations such as SESSA). Some SESSA members have expressed concern that the performance of SWH systems in practice are deteriorating faster than previously thought[8].

Prior to 2016, when Eskom was custodian of the national subsidized SWH rollout, it also built up a comprehensive database of all HP and LP installations. During this period, it also estimated the energy impacts of the programme through a measurement and verification (M&V) process. Although the M&V consisted mainly of modelled impacts (rather than wide-scale measurements), these M&V reports would nevertheless be a very useful research resource in estimating the impacts of SHWs.

[8] SESSA meeting in Cape Town in August 2013 attended by one of the authors.

*Recommendations*

Effort should be made to anonymise, compile and publicly release the database of SWH and Heat Pump installations and the verified impacts that Eskom currently holds. An accelerated rollout of HP and LP SWHs could achieve substantial benefits and should be considered. Recent estimates of SWH penetration are very sparse and need to be improved, especially for the period 2015 – 2020.

### 7.3.3. Proposed VC9008 amendments

The proposed NRCS VC9008 amendments are considered here in comparison to the SA LEAP model scenarios. The proposed regulatory amendments are roughly comparable with the Moderate MEPS Scenario. Given the likely savings of that scenario (described in Section 5.5.3), the amendments may be worth revising to levels that are more ambitious. This recommendation is purely from the perspective of likely energy savings.

Other aspects of the proposed VC9008 amendments include refrigerant types for cold appliances and also include water performance for washing machines and dishwashers. The integration of these new aspects into a performance label will require careful design or there could be a risk of consumers becoming overloaded with information.

*Recommendations*

In light of this study, an immediate revision of the proposed VC9008 amendments should be considered. This revision should be undertaken according to the findings of the Extensive MEPS Scenario shown in Sections 5.5.4 and 6.4 of this study. Thereafter these NRCS standards should be revised regularly (every three years).

### 7.3.4. Lighting

Lighting consumption is an inherently difficult end use to characterize by means of a questionnaire and the uncertainty of the bottom up approach followed in this study to estimate electricity used for lighting is unknown.

Something that is clear from the REC 2020 survey data is that very few households used LEDs in 2020. This indicates a large potential for improving the energy efficiency of lighting.

The VC9109 draft lighting regulation is to be applauded (DTI 2021). The REC 2020 survey revealed overwhelming agreement (79%) that the information provided on lamp packaging helps customers choose what they need. Only 6% disagreed and 16% were indifferent. This finding supports a move towards improved, consistent labelling to allow customers to do an impartial comparison between types, costs and manufacturers. Part of the attraction of LEDs is the lamp lifespan and although the regulation requires rated lifetime to be displayed, ongoing regulatory monitoring is required to ensure that planned obsolescence is not slowly introduced by manufacturers.

One problem with switching lighting technologies is that lighting fixtures are already in place within dwellings that were designed to provide sufficient lighting for the technology available at the time of construction (for example ceiling cut-outs and luminaires with a certain number of sockets). This 'fixed' number of lamps in the dwelling is likely to be filled, regardless of lamp efficacy. The energy use related to this problem could be addressed through the promotion of dimmers and dimmable lamps.

*Recommendations*

Adoption of VC9109 will remove less efficient lamps from the market. However, in the short term, in order to change lamp purchasing behaviour towards LEDs it is recommended that along with power

(W), luminous efficacy (lm/W) becomes a primary performance indicator on lamp packaging. This should be supported by long term, in-store information campaigns.

To reduce the uncertainty of estimating lighting energy use based on uncertain survey responses, a long-term measurement study is recommended to determine electricity used for lighting across income groups that accounts for seasonality in various geographic regions and that also determines perceptions and experiences that could slow the transition to improved technologies.

### 7.3.5. Behavioural interventions

The behavioural scenario in this study is not intended to compete with technical interventions nor to advocate for any specific actions. Rather, the purpose of the scenario is to demonstrate that a few, simple, quantifiable behavioural changes can have impacts that are at least of the same order of magnitude as technical interventions. Notably, such interventions may involve user interaction with technologies that are not part the MEPS programme. A sound long term strategy for improving residential energy efficiency in a sustainable manner will likely involve a blend of technical and behavioural interventions.

It is acknowledged that poorly implemented behavioural interventions can be worse than none at all and that rebound effects are very difficult to anticipate and quantify. However, in the context of increasing electricity prices behavioural interventions, which provide a way of improving energy efficiency at minimal cost, such as using pot lids, can help to reduce the monthly electricity expenses of low income households. Tariff increases could become a driver of behavioural change although this change should be guided by education campaigns. Implementation channels are already in place through the existing Power Alert campaign (TV and upcoming Social Media).

*Recommendations*

It is recommended that the potential for low-cost, high-impact sustainable behavioural interventions should be further investigated, not to replace, but to complement technical interventions. Implementation channels such as the existing Power Alert campaign should be exploited and expanded.

## 7.4. Further comments on selected appliances and end uses

Very often, electricity consumption is affected by subtle or unexpected factors that may depend on appliance usage habits, interpretation of advertised performance or installation quality. This section examines some of those cases where the details of appliance selection, utilization and maintenance are important.

### 7.4.1. Dishwashers

Given that dishwashers have a low penetration rate, it is obvious that most dishwashing happens by hand. A study has shown that washing dishes by hand may actually use more electricity than a dishwasher would use. However, the study also showed a very high variability in electricity use among the hand dishwashers sampled (Stamminger et al., 2003: 742). This variability was not only noted between individuals but also between nations, revealing that the attitudes towards this essential task vary greatly.

Studies such as this could lead to the conclusion that broad uptake of dishwashers will save electricity, but caution is advised here. Dishwashers are designed to accommodate a large number of place settings (typically 10-15) and the energy class stated on the machine label pertains to that design capacity. Part-load information is not provided, but the energy usage is not likely to be purely load-dependent, a dishwasher may use only slightly less energy for small loads. For most households, the dishwasher is likely to be part-loaded most of the time.

Despite the variability in washing dishes by hand, the electricity used is likely to have a greater correlation to load size and is likely to have less fixed losses. Thus, for small loads, hand dishwashing may be more energy efficient. The entire comparison between hand washing and dishwashers also assumes that hand washing uses warm or hot water, but in South Africa that may not be the case.

It must be noted that the above comments on efficiency only apply to electricity. Dishwashers may be more efficient in other aspects of operation such as use of water and time. In terms of water efficiency, dishwashers may up to five times more efficient than hand washing (Stamminger et al., 2003).

As mentioned previously, the EU has expanded the range of performance classes for dishwashers to include the classes A+ to A+++, whereas South Africa's best performing class is A. When making comparisons it should be noted that the new EU categories are based on 280 cycles annually, compared to the local categories that are based on 220 cycles annually (UNDP/DOE 2019: 71)

### 7.4.2. Kettles

Although kettles are not part of the S&L programme in SA, these are very important appliances that consume between 2-8% of household electricity and are thus worthy of mention here. The study found that there is no clear correlation or link between household occupancy and the number of times a kettle is boiled. It was also found that kettle use is more closely predicted by seasonal holidays than by weather conditions. A technology that has electricity saving potential is the vacuum kettle, or "Eco-kettle". This thermally insulated kettle keeps the water hot for longer and also allows for boiling small amounts of water. However, consumer uptake is likely to affected by high upfront cost and high noise levels (Murray et al., 2016: 234,235,241).

### 7.4.3. Cooking: General

Although, the energy used to prepare meals has been characterized to some extent in the literature, the measurements are often taken in an experimental environment and can vary from what is consumed in practice. A study found that in reality, the energy consumed to prepare the same meal by different chefs can vary as much as 100%. The same study suggested an ambitious goal for energy savings in cooking would be a 10% saving, driven by behavioral changes (Oberascher, Stamminger & Pakula, 2011: 202).

### 7.4.4. Cooking: Stove tops

Oberascher et al. (2011) reference a Vattenfall study which suggests that the greatest savings for hobs would be achieved by using less water and by using the appropriate cooking device. For example, using a rice cooker versus using a pot without a lid could achieve a saving of 77%. Savings may also be achieved by other methods such as pre-soaking prior to cooking. Although induction plates have become popular, these often consume large amounts of standby power and ultimately may consume more energy than an equivalent thermal plate. Induction plates also typically have a poor power factor (Oberascher, Stamminger & Pakula, 2011: 202)

### 7.4.5. Cooking: Ovens

The fixed losses associated with each heating cycle of a large oven volume is a source of poor performance in larger electric ovens. Oberascher, Stamminger & Pakula (2011: 202) suggest that switching to ovens with smaller volumes (mini ovens) could reduce electricity consumption by up to 27%.

### 7.4.6. Washing machines

There is a trend among new appliances in Europe to advertise superior energy performance and a favourable energy category. However, in practice these machines often do not perform accordingly. The reason is that the washing programmes used during testing are extended to many hours, but these long cycles are very rarely used in practice. Typically, shorter cycle times are chosen based on busy schedules or established household routines, but these shorter cycles do not perform as well as advertised because they require higher water temperatures. At the point of sale, consumers assume that the energy performance category applies equally to all modes of operation (Boyano, Espinosa & Villanueva, 2020: 51).

This highlights a weakness in the testing standards behind the energy labelling as the standard does not include cycle time as a performance factor. However, overloading a buyer with too much conflicting information at the point of sale may defeat the purpose of the energy label which needs to provide easily-digestable, informative and relevant performance data. One option may be introduce a programme duration limit (Boyano, Espinosa & Villanueva, 2020: 57,64). There is also evidence to suggest that the electricity consumed by washing machines may be overstated. The standard test cycles used include a total of seven washes at various loads and temperatures (5 at 60ºC and 2 at 40°C) (SABS 2016a: 160,196). Most of the electricity consumed is for water heating. However, the REC 2020 survey suggests that on average the temperature used is about 25°C. Also, the annual kWh consumption is based on 220 cycles, but the survey suggests that this is closer to 180.

There is also a trend towards larger machines in the order of 9kg capacity, although this will ultimately be limited by drum size constraints. These machines require more energy per cycle, but offer improved performance when viewed on a specific basis (kWh/kg washed). The problem with this is that consumers may not utilize that large capacity and in practice washing cycles may be mostly at part load, constrained by washing basket size, frequency of domestic help or simply old habits and routines. Importantly, a European review showed that despite machines getting larger, consumer behaviour had remained roughly constant at about 3.4kg loading per cycle (Boyano, Espinosa & Villanueva, 2020: 53). So ultimately, larger machines may not result in fewer annual washing cycles, nor exploit the improved specific energy consumption, and consumers need to be made aware of this. The reason for manufacturers to be increasing machine size is also not apparent, because the sizes of homes in Europe are shrinking (Boyano, Espinosa & Villanueva, 2020: 53). A potential avenue of energy saving could also be by a broad shift to lower temperature cycles brought about by improvements in cold water detergent technology.

### 7.4.7. Geysers

Since hot water usage forms such a large proportion of residential electricity consumption, even relatively small savings at the household level can yield a large impact for the sector. Household hot water needs to be viewed as a system, rather than simply viewing the geyser as an appliance in isolation. The parts of the system consist of the number of geysers, thermostat setting, installation area and orientation, insulation materials, water pipes, safety valves and very importantly, characteristic usage patterns (Beute, 1993: 103).

Hot water pipes should be lagged with insulation and pipe length should be as short as possible. Standing losses increase with higher temperature settings so the temperature should be set as low as possible while avoiding the risk of Legionnaires' disease (60°C) (SABS 2013a: 28). Geyser systems should also be maintained such that hot water is not lost through valves.

Short, low volume usage events should be avoided as each of these requires the water pipes to be heated up and this energy is normally lost through radiation to the surroundings. Small volumes of hot water can be heated in a kettle to avoid the fixed losses associated with the hot water pipes.

Having more than one geyser per household should be avoided as the increased effective surface area increase the standing losses (Beute, 1993: 107). Standing losses due to radiation are a problem and the potential savings have been addressed in the LEAP model under the behavioural scenario which includes intelligent geyser switching.

Many of the same system-related arguments above also apply to solar water heaters where collectors, pipes, valves, thermostats, pumps and timers form a system that needs to be properly installed and maintained.

### 7.4.8. Tumble dryers

There are three broad categories of tumble dryers, namely “Vented”, “Condensing” and “Heat Pump”, although this naming convention is not consistent. The first two are the more conventional types and are named by the water removal mechanism, but the third is named after the source of heat. Thus it is possible to purchase a new unit which is both “Heat Pump” and “Condensing”. Vented driers are the least energy efficient and heat pump driers are the most efficient. It is possible that Class B machines may be achieved by vented or condensing units, but a shift to Class A performance is only possible with heat pump dryers. Widespread uptake of heat pump dryers may be inhibited by the cost of this technology. As with washing machines, the trend is towards larger and larger capacity devices (Siderius, 2013: 766,767).

## 7.5. Project lessons learned and further recommendations

### 7.5.1. Municipal data

At the household level, electricity consumption is estimated as a function of income, household size, appliance ownership, age and utilization patterns. For accurate bottom up calibration of household consumption it is imperative that real kWh household consumption is known. Ideally, future surveys should be rolled out in close partnership with municipalities, or ESKOM, that provide access to monthly kWh data.

### 7.5.2. Solar PV data

The growing levels of home solar PV penetration are an important factor in determining household level electricity consumption. PV energy production is often unknown, as it is produced on the user side of the electricity meter. This is especially true in non-feed-in systems. An industry association that may provide a fruitful partnership is the Association for Renewable Energy Practitioners (AREP). This association appears to maintain a reliable database of installations nationwide that could prove very valuable in refining the national residential electricity model.

## 7.6. Eskom Residential DSM programme (Power Alert)

The objective of the Eskom “Power Alert” campaign is to achieve a reduction in residential demand when there is an increasing strain on the national electricity supply in South Africa. This is done by superimposing a notional electrical meter onto the TV screen on selected channels that provides a real-time awareness to the public of the instantaneous strain on the national grid. These broadcasts appeals for a voluntary market participation to reduce household demand by switching off various electrical loads. Although the Power Alert initiative does not fall within the scope of this study, there is a case for overlap and the following comment is provided.

Power Alert interventions involve both energy conservation as well as demand reduction. Conservation interventions involve switching off non-essential appliances such as lighting and demand reduction interventions involve switching off large loads such as geysers. Some interventions, such as geyser switching, may involve “comeback loads”. This means that the overall energy required by a particular device is not reduced, but rather consumed at a different time of the day. This is voluntary load-shifting and serves to smooth the daily peaks in the demand curve of the residential sector, but does not reduce the overall energy consumed. Unlike purely demand-focused interventions, energy efficiency interventions can serve to reduce both energy consumption *and* time-based demand.

In principle however the Power Alert campaign is a reactive modification of consumer behaviour and may benefit from a strategic shift in focus away from reactive market participation and towards pro-active end user behaviour changes that also have financial benefits for the consumer in the long term. Currently, the campaign appears only to appeal to consumers to play their part in averting load-shedding, without any other real benefits, other than maintaining a stable power supply.

A prime example of synergy could be in the area of geyser switching, where messaging could be altered to ensure that geysers *remain* off when not required to reduce overnight and daytime standing losses. Given that so many people are working from home in the context of COVID-19, effective geyser switching could even be achieved without the need for timers or AI mobile applications. Much other energy saving advice could be offered during prime time viewing that would potentially reduce household consumption over the long term.

As consumers begin to self-generate SSEG electricity (such as home solar PV), there may be a natural trend towards more efficient utilisation of that electricity at the time of day it is produced, instead of curtailing the power production or feeding it into the local grid at an unfavourable rate. This may lead to a shift away from consumption during the evening peak.

# 8. Conclusion

This project has made two important contributions to assessing the impact of energy efficiency interventions and possible future savings in the residential sector in South Africa. These are the development and rollout of a household survey to assess energy consumption at the level of energy services and the development and population of a residential sector LEAP model with households represented in three income groups. A further contribution is the methodology developed to calibrate an energy service based LEAP model using the REC 2020 survey responses.

The LEAP model has been applied to assess the impact of the Standards and Labelling programme in South Africa from 2015 to 2020 and the possible level of savings that could be realized through further energy efficiency gains between 2020 and 2040. These further gains were presented in both a Moderate and an Extensive MEPS scenario. In addition, the literature review highlighted the potentially large savings that could be realized through behavioural change, and a third scenario which mimics behavioural change in water heating and cooking was modelled.

The S&L and MEPS programmes have improved the energy efficiency of targeted appliances. The model results show that the S&L programme has likely achieved an overall reduction of electricity use of around 3.5% in 2020 compared to a case where no S&L programme had been implemented but some appliance efficiency improvements have still taken place through natural replacement. These savings increase to 11% in 2030. The savings occur mainly in fridges, which have a high ownership share in all household groups and are a relatively large energy consumer.

Beyond 2020, further modest improvements in the energy efficiency of the appliances in the S&L programme achieves a saving in electricity use of only 0.5%, however extending the basket of appliances that see savings, and increasing the savings assumptions to closer to those that could be achieved based on technology best practice, could result in a further savings of 7% by 2030 compared to those already being seen by the sector through the current S&L programme. These savings increase to 13% by 2040.

Behavioural awareness campaigns could result in further savings. Importantly these savings are additional to those that could be achieved through the S&L and MEPS programmes. Focusing only on water heating, without reducing hot water consumption, savings could be as high as 3% by 2030, increasing to 8% in 2040. These hot water efficiency gains and savings are achieved primarily through geysers and kettles. SWHs continue to replace conventional geysers, however it is worth noting that whilst an increase in hot water supplied by SWHs reduces these savings slightly, a large number of households in the model (80% of high income households) still have conventional geysers in 2040. A focus on SWH use could result in further significant savings in water heating.

The disaggregation of the model into three income groups, and several energy services and appliances, provides valuable insight into the savings possible and allows the assumptions and results to be further interrogated. The income group disaggregation, for example, allows increases in appliance ownership and electricity consumption that occur as incomes rise to be endogenously modelled. It was also assumed that appliance energy efficiency improvements would benefit mainly higher income households, however the results show that low income households can also realise significant benefits. The disaggregation by income group does however add complexity to the calibration and population of the LEAP model and increases the uncertainty in several areas. For example, assumptions around appliance stock, efficiency and sales must be made for each of the income groups in the model, and whilst there is empirical evidence to base these assumptions on, there is room for improvement. Repeating the REC 2020 survey on a regular basis (ideally annually), as well as working with municipalities and ESKOM to match household survey responses to actual electricity use will increase the level of confidence and reduce the uncertainty in the disaggregation of electricity used between household appliances and energy services. Similarly, focusing on keeping regular records of appliance sales and the age of appliance stocks will reduce the uncertainty in populating the age and survival profiles within the LEAP model.

The online RECS 2020 survey, whilst providing valuable information for the model calibration and assessments, was lengthy and may have induced respondent fatigue. It is proposed that future surveys are shorter and targeted at specific technology ownership and usage patterns. The high income group is well represented in the REC 2020 sample, both in terms of the number of households that responded and in terms of the profile of appliance ownership which is similar to that of national surveys in this group. Subsequent surveys could therefore initially target lower and middle income groups, where the REC 2020 respondents appear to be understating income or overstating appliance ownership levels. Ideally these surveys should include a door-to-door component. Amongst the energy services, a focus on water heating and lighting would add significantly to the reliability of energy service calibration, as well as to ensuring that South Africa is able to meet its efficiency targets.

Whilst this report has presented an improved understanding of electricity use and savings possible within the residential sector of South Africa, it is seen as a beginning rather than an end point. Both the model and underlying data would benefit from regular updates, particularly once the 2021 Census results have been released.

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# 10. Appendix

## 10.1. Assumptions

This section provides assumptions and references used in deriving appliance consumption.

### 10.1.1.Performance categories allocated to appliance ages (REC 2020 survey)

Table 10-1 below shows the S&L performance categories allocated to the REC 2020 survey responses to appliance age. These allocation resulted in predicted monthly household kWh consumption used for the household calibration described in Section 5.2.4.

*Table 10-1: Performance categories allocated to appliance ages for the REC 2020 survey*

| Appliance | 1 - 2 years | 3 - 5 years | 6 - 10 years | More than 10 years old |
|---|---|---|---|---|
| Refrigerator | A++ | A+ | A/A+ | B/C/D |
| Deep freeze (Chest freezer) | A/A+ | B | C/D | D |
| Dishwasher | A++ | A | B | C/D/E/F/G |
| Oven (Small) | A+ | A | B/C | D |
| Oven (Medium) | A+ | A | B/C | D |
| Oven (Large) | A | B | C | D |
| Washing machine | A+/A++ | A | B/C | D |
| Tumble dryer | D | D+ | D++ | D++ |
| Air conditioner | A+ | B | C | D |

*Note: " / " indicates average*

### 10.1.2.Refrigeration

*Table 10-2: Refrigeration assumptions and references used for kWh estimates*

| Description | | Compartment volumes (l) Main | Freezer | Other factors applied |
|---|---|---|---|---|
| **Fridge** | Bar Fridge (Small) | 38 | 4 | Frost free;<br>Subtropical;<br>Not built-in;<br>15l chill compartment in multi-door units; |
| | Single Door (Medium) | 176 | 21 | |
| | Double door (Top Freezer) Small | 101 | 41 | |
| | Double door (Top Freezer) Large | 241 | 99 | |
| | Double door (Bottom Freezer) Small | 101 | 41 | |
| | Double door (Bottom Freezer) Large | 241 | 99 | |
| | Large (Multi-door) Small | 242 | 99 | |
| | Large (Multi-door) Large | 423 | 172 | |
| **Chest freezer** | Top door Small (<200l) | NA | 142 | |
| | Top door Medium (200l - 350l) | NA | 241 | |
| | Top door Large (>350l) | NA | 426 | |
| | Upright | NA | 489 | |

*Table 10-3: Reference devices and literature used in refrigeration*

| Description | Reference devices (web search) | Key references |
|---|---|---|
| **Fridge** | Hisense H60RS, Hisense H230RBL<br>KIC KTF 518/1 ME, Samsung RT62K7110SL<br>Defy 192 DAC 319, Bosch KGN76AI30Z<br>SMEG FQ60XP1, SAMSUNG RS65R5691B4 | (Dutt, 1993; van Gass, 1993; South African Bureau of Standards, 2008; Siderius, 2013; Covary & du Preez, 2015; Gotz et al., 2016; Kevin Lane Oxford LTD, Urban-Econ & Energy Efficient Strategies, 2019) |
| **Chest freezer** | Defy CF210HC , Defy CF300HC,<br>Defy DMF 456, Defy DMF 454,<br>Hisense 139, H240CF, KCG 570/1 WH | |

## 10.1.3.Dishwasher

*Table 10-4: Dishwasher sizes and market shares for dishwasher kWh estimates*

| Machine size (Place settings) | Final weighting (based on market share) | Key references |
|---|---|---|
| 4, 8, 10 (Averaged) | 19% | (South African Bureau of Standards, 2010a; Kevin Lane Oxford LTD, Urban-Econ & Energy Efficient Strategies, 2019) |
| 12, 15 (Averaged) | 81% | |

Average household dishwashing by hand assumed to be 249 kWh annually for middle and high income households and half of that for low income households due to assumed far greater degree of cold water washing.

## 10.1.4.Oven

*Table 10-5: Oven sizes for kWh estimates*

| Oven description | Cavity size (l) | Key references |
|---|---|---|
| Small | 23.5 | (South African Bureau of Standards, 2015; Kevin Lane Oxford LTD, Urban-Econ & Energy Efficient Strategies, 2019) |
| Medium | 50.0 | |
| Large | 77.5 | |

## 10.1.5.Microwave oven

*Table 10-6: Microwave oven assumed unit power and daily time used for various qualitative utilisation descriptors*

| 800W Microwave oven | |
|---|---|
| **Utilisation descriptor** | **Assumed time used per day (min)** |
| Heating up food and re-heating food | 10 |
| Defrosting food | 10 |
| Cooking meals from raw | 45 |
| Heating up drinks like tea & coffee | 5 |
| A bit of everything | 10 |

### 10.1.6. Electric stove top (Hob)

*Table 10-7: Stove top cooking assumptions used for kWh estimates*

| Income group | No of pots on the stove top per meal | Cooking efficiency assigned | Total meal size prepared | Key references |
|---|---|---|---|---|
| **Low** | 1 | Average of Unideal pot without lid and Ideal pot with lid | Proportional to household size | (Oberascher, Stamminger & Pakula, 2011) |
| **Middle** | 2 | Ideal pot with lid | Proportional to household size | |
| **High** | 3 | Average efficiency of Ideal pot with lid and Pressure cooker | Proportional to household size | |

### 10.1.7. Hot water

*Table 10-8: Hot water assumptions used for kWh estimates*

| Income group | Average volume consumed per day (l) | Delivery temperature (°C) | Notes | Key references |
|---|---|---|---|---|
| **Low** | 15.5 | 100 | Assumed final temperature 35 degrees after mixing with cold water. Assume 2.4 kettles boiled per person per day. | (Beute, 1993; Meyer, 2000; Cengel & Boles, 2008; Donev et al., 2012; South African Bureau of Standards, 2013b,a; McNeil, Covary & Vermeulen, 2015) |
| **Middle** | 30 | 60 | Geyser setpoint shown. Temperature lower at POD | |
| **High** | 55 | 60 | Geyser setpoint shown. Temperature lower at POD | |

*Table 10-9: Other hot water assumptions*

| Geyser standing losses "Class B" (kWh/day) | Geyser standing losses "Class D" (kWh/day) | Savings of SWHs over conventional geysers (kWh/person/year) | Annual national average incoming water temperature (°C) |
|---|---|---|---|
| 1.13 | 2.14 | 894 | 17 |

### 10.1.8. Washing machine

*Table 10-10: Washing machine capacity*

| Machine capacity (kg) | Weighting according to market share | Key references |
|---|---|---|
| Average of 5 – 7 | 62% | (Dutt, 1993; Covary, T;Du Preez, K;Gotz, 2015a; South African Bureau of Standards, 2016a; Boyano, Espinosa & Villanueva, 2020) |
| Average of 7.5 – 8 | 24% | |
| Average of 9, 10, 11 | 14% | |

### 10.1.9. Tumble dryer

*Table 10-11: Tumble dryer assumptions used for kWh estimates*

| Average machine capacity (kg) | Partial load factor | Key references |
|---|---|---|
| 7 | 0.627 | (South African Bureau of Standards, 2010b; Siderius, 2013; Covary, T;Du Preez, K;Gotz, 2015b) |

### 10.1.10. Air conditioner

*Table 10-12: Assumed air conditioner unit power and daily time used for qualitative utilisation descriptors*

| 5.5 kW (Average split unit) | | |
|---|---|---|
| **Utilisation descriptor** | **Assumed time used annual (h)** | **Key references** |
| Used only in summer for cooling (> 10h/week) | 192 | (South African Bureau of Standards, 2016b) |
| Used only in summer for cooling (≤ 10h/week) | 360 | |
| Used in summer for cooling and in winter for heating | 720 | |

### 10.1.11. Television

*Table 10-13: Television assumptions used for kWh estimates*

| Television type | $P_{ON}$ (W) | $P_{STANDBY}$ (W) | Notes | Key references |
|---|---|---|---|---|
| Television CRT | 55 | 0.62 | Mix of old technologies. Standby power assumed. | (South African Bureau of Standards, 2010c; Guan, Berrill & Brown, 2011; Siderius, 2013; European Commission, 2019; Kevin Lane Oxford LTD, Urban-Econ & Energy Efficient Strategies, 2019) |
| Television flat screen ≤ 50 inch | 94 | 0.62 | 75% HD; 25% QLED 4K | |
| Television flat screen > 50 inch | 199 | 0.62 | QLED 4K | |
| Television flat screen > 50 inch | 520 | 0.62 | QLED 8K; Assumed in 2020 that 10% of new devices is 8K. Assumption increased to 50% by 2030. | |

### 10.1.12. Lighting

*Table 10-14: Inside lighting assumptions for power and penetration rates for different technologies*

| Lamp Type | Power per lamp (W) | Penetrations | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 |
| **Other** | 56.3 | 20% | 19% | 8% | 4% | 2% | 1% |
| **CFL** | 15.0 | 76% | 67% | 31% | 15% | 8% | 4% |
| **LED** | 10.6 | 4% | 13% | 61% | 81% | 91% | 96% |

*Table 10-15: Lighting assumptions for time on and number of lamps on per income group*

| | Number of lamps on | Time lamps on (h) |
|---|---|---|
| **Low** | 4.4 | 6 |
| **Middle** | 5.8 | |
| **High** | 8.6 | |

## 10.1.13. Kitchen plug loads (with time estimates)

*Table 10-16: Assumptions used for kitchen plug load kWh estimates*

| Appliance | Power (W) | Time per use | Uses per week | Notes | Key references |
|---|---|---|---|---|---|
| Toaster | 1,233 | 2.5 min | 2 | | (Oberascher, Stamminger & Pakula, 2011) |
| Coffee machine | 1,036 | 5 min | 4 | | |
| Slow cooker | 371 | 8 h | 1 | | |
| Air fryer | 1,635 | 15 min | 1 | | |
| Induction stove | 2,000 | 30 min | 4 | Standby load 25 W for 166 hours per week | |
| Food processor | 890 | 1 min | 2 | | |
| Blender or juicer | 890 | 1 min | 2 | | |
| Coffee grinder | 198 | 20 s | 2 | | |

## 10.1.14. Other plug loads: general

*Table 10-17: Assumptions used for other plug load kWh estimates*

| Appliance | Power (W) | $t_{ON}$ Annual (h) | Notes | Key references |
|---|---|---|---|---|
| Pool pump | 925 | See note | 0.75 – 1,100 W. Usage informed by REC 2020 survey. | |
| Borehole or wellpoint | 925 | See note | Usage informed by REC 2020 survey. | |
| Clothes iron | 1,800 | See note | Usage informed by REC 2020 survey. Usage capped at 10h per week. 80% of stock assumed to be steam irons. | (Sheinbaum, Martínez & Rodríguez, 1996; Blom, Itard & Meijer, 2011) |
| Vacuum cleaner | 1,900 | 104 | 2h per week. Time assumed to remain constant with decreased power for Scenario B in 2030. | (Sataloff, Johns & Kost, 2013) |
| Hair iron or hairdryer | 1,950 | 26 | 10min, 3 times per week | |
| Dehumidifier | 229 | 320 | 5 days per week, 4h per day for 4 months of the year. | |
| Fan | 55 | See note | Usage hours and number of fans per household informed by REC 2020 survey. | |

### 10.1.15. Other plug loads: media & entertainment

*Table 10-18: Assumptions used for other plug load kWh estimates*

| Appliance | $P_{ON}$ (W) | $P_{STANDBY}$ (W) | $t_{ON}$ Annual (h) | $t_{STANDBY}$ Annual (h) | Usage notes | Notes |
|---|---|---|---|---|---|---|
| Laptop computer | 396 | 1 | 365 | 8,395 | | Standby power estimated |
| Desktop computer | 400 | 1 | 365 | 8,395 | 1h per day | Standby power estimated |
| Tablet / iPad | 99 | 0.1 | 548 | 8,213 | | Standby power estimated. Charge fully every two days. Full charge takes 3h. |
| Wifi router | 9 | 1 | 8,760 | 0 | | Standby power estimated |
| Cell phones | 99 | 0.1 | 365 | 8,395 | | |
| Gaming console | 395 | 1 | 365 | 8,395 | 1h per day | XBOX 360 |
| PVR or DSTV decoder | 24 | 3 | 365 | 8,395 | 1h per day | $P_{ON}$ = 12V @ 2A |
| DVD Player | 9 | 1 | 104 | 8,656 | 2h per week | Standy power estimated |
| Home theatre system | 339 | 1 | 365 | 8,395 | 1h per day | Standby power estimated |
| Audio system or Bluetooth speakers | 90 | 1 | 365 | 8,395 | 1h per day | Bose Soundtouch 20 |

### 10.1.16. Appliance Weibull parameters, survival profiles and average lifespans

*Table 10-19: Assumptions for appliance Weibull parameters and stock age profiles*

| | Weibull parameters | | | Stock age profile (years) | | | |
|---|---|---|---|---|---|---|---|
| Appliance | Alpha | Beta | Gamma | 1-2 | 3-5 | 6-10 | > 10 |
| Cooking - Oven | 15.5 | 4.0 | 0.0 | 18% | 25% | 32% | 25% |
| Fridge/Freezer | 10.0 | 2.6 | 0.0 | 26% | 32% | 33% | 9% |
| Deep Freeze | 19.0 | 2.5 | -0.5 | 14% | 19% | 26% | 41% |
| Hot Water Geyser | 12.0 | 5.0 | 0.0 | 22% | 30% | 37% | 11% |
| Hot Water (SWH/Heat Pump) | 12.0 | 5.0 | 0.0 | 22% | 30% | 37% | 11% |
| Dishwasher | 12.0 | 5.0 | 0.0 | 24% | 32% | 35% | 9% |
| Washing machine | 19.7 | 3.5 | -3.0 | 16% | 21% | 29% | 34% |
| Tumble drier | 19.7 | 3.5 | -3.0 | 24% | 32% | 35% | 9% |
| TV | 10.1 | 3.0 | 0.0 | 22% | 30% | 39% | 9% |

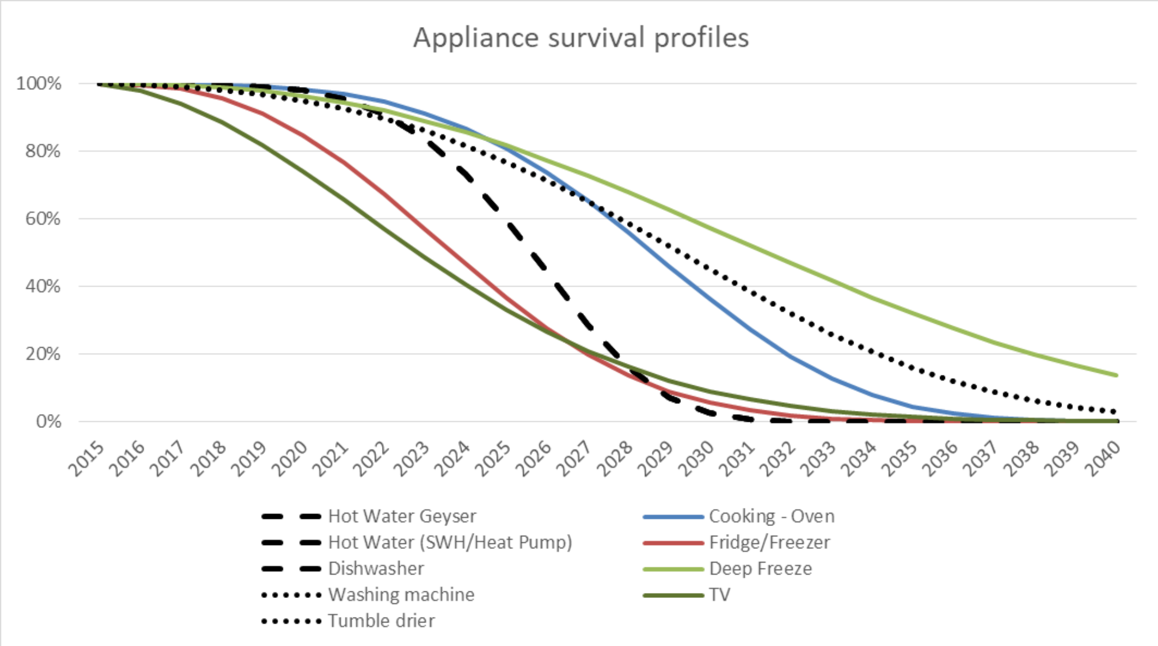


*Figure 10-1: Assumed appliance survival profiles (graphs indicate % of appliances that survive as a function of time)*

*Table 10-20: Assumed average appliance lifetimes*

| Appliance | Average lifetime | Key references |
|---|---|---|
| Cooking - Oven | 14 | (Siderius, 2013; Covary, T;Du Preez, K;Gotz, 2015a; Willis, 2015; Moore et al., 2017; de la Rue du Can et al., 2020) |
| Fridge/Freezer | 14 | |
| Deep Freeze | 17 | |
| Hot Water Geyser | 11 | |
| Hot Water (SWH/Heat Pump) | 13 | |
| Dishwasher | 11 | |
| Washing machine | 15 | |
| Tumble drier | 14 | |
| TV | 7 | |