

# Long term modelling of household demand and its implications for energy planning

Bruno Merven, Faaïqa Hartley and Jules Schers

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Corresponding author: [ifpri@cgiar.org](mailto:ifpri@cgiar.org)

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## Long term modelling of household demand and its implications for energy planning

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### ABSTRACT

This paper proposes an alternative method for modelling long term changes in household consumption in computable general equilibrium models. The analysis is applied to the case of South Africa and focuses on the change in income related lifestyle choices on energy demand and composition. A comparison of adjusting household consumption share (relative to static shares) reveals a shift in the economic structure to services production with a marginal increase in employment. Energy demand is found to decrease due to lower household as well as production demand with the economy becoming less energy intensive.

## 1 INTRODUCTION

Households drive energy demand both directly, through their direct consumption of energy commodities, as well as indirectly in their demand for other goods and services which use energy as an intermediary input. Not accounting for changes in production technologies and efficiencies, the long-term planning of energy supply is therefore highly dependent on expectations of household income and demand growth over time. Analytical efforts to improve the robustness of energy and mitigation planning use economic models to provide inputs to energy and climate tools on changes in energy demand. Often these economic models, however, do not endogenously account for changes in energy demand resulting from changing household expenditure patterns. In developing countries where technical progress, increasing infrastructure and improving productivity will still enable strong growth, it will matter what lifestyles households adopt as their income levels increase.

In South Africa, one of the most advanced tools for energy planning is the linked energy-economic model, SATIMGE (Arndt et al. 2016; Merven et al. 2017; 2018; 2019a; 2019b). This model combines the strengths of a detailed technical energy system optimisation model with those of a computable general equilibrium (CGE) model to provide a consistent tool for energy and mitigation planning with the impacts on economic development quantified. When describing household consumption behaviour, however, many CGE models rely on household price and income elasticities, in various forms, to predict responses of households to changing economic conditions, specifically: changing real income and changing relative prices. Whilst relevant for short to medium analysis, it is argued in this paper that this approach is not relevant for long term analysis as they often describe households as rather static income or expenditure classes for whom the composition of household consumption only changes mildly over time; are based on income elasticities that are typically estimated on changes in household consumption over short time periods; and, in many cases, are reduced to Cobb-Douglas functions as income elasticities are not available for many developing countries. An example of this is the continued demand for coal by lower household income groups over 40-year analysis periods despite rising real incomes equivalent to the middle-income group today who consume no coal.

This paper proposes an alternative methodology to modelling long-term household demands for the case of South Africa. Specifically, we include Cobb Douglas functions of household consumption for which the shares of consumption demand for goods and services adjust over time to account for changes in living standards due to changes in real incomes. This results in household consumption patterns shifting to better capture evolving living standards and the “welfare-enhancing feature of modern economic development” (Chai, 2018). The paper is structured as follows: Section 2 provides a summary of long-term household demand modelling literature; Section 3 describes the model and methodological changes in more detail; and Section 4 illustrates the implications of household expenditure pattern changes on economic growth, employment and energy demand. Section 5 concludes with a discussion of the implications of this research and the identification of further enhancements to the methodology to improve the robustness of this technique.

## 2 LITERATURE ON LONG TERM MODELLING OF HOUSEHOLD DEMAND

### 2.1 Introduction to the literature study

A large part of economics is about cost-benefit analysis of policy. Climate policy and other questions about man’s use of the environment and about resource management push existing methods and tools for cost-benefit analysis to a frontier, because they require *ex ante* evaluation of policies and other responses (or lack thereof) to environmental problems to take into account long time horizons. In the

case of climate and energy policy, economic evaluation of such far time horizons cannot be avoided. Furthermore, the solutions for many environmental problems require strong technical and/or behavioural change, for which there are often no past precedents – at least none that will work in the same way.

New or alternative technologies might not be cheaper than existing polluting technology, or they might not be developed or constructed *in time*, meaning with the foresight to avoid stranding polluting assets in a process of speed-up (or catch-up) of replacement of polluting capital. One can imagine this has consequences for expected and future GDP growth, which are also relevant to future pensions and returns on investments – as well as for how we save and consume today. Furthermore, there might be consequences for inequality, and a proper evaluation of distributional impacts will be necessary too.

Given the potentially big changes that can be expected in welfare, technology, preferences and relative prices at the time scale of multiple decades, the composition of household demand might change much more than can be expected based on econometrically calibrated price and income elasticities. To correctly represent household demand it is important to understand what distributional impacts of policies and other changes (technology, lifestyle) could be. Household demand is also an important determinant for the composition of the economy (globally about 50% according to Chai (2018)). Lastly, households also determine a significant part of national energy use.

To correctly capture household demand and its rigidities is therefore very important for macro-economic projections. However, as this section proposes, conventional representations of household demand in CGE models are insufficient to capture changes in household demand in the long term, leave alone for disaggregated households. This section first elaborates on the arguments about whether existing approaches can deal with long term changes in household demand (2.2) and then introduces our approach of modelling household demand through “income bands” (2.3).

## 2.2 A criticism of the use of income elasticities for long term prospective modelling of household demand

Typically, CGE models use income and price elasticities to describe household demand. For instance, in their classical book about applied CGE modelling for developing countries, Dervis et al (1982) propose the use of a Linear Expansion Systems (LES)<sup>1</sup> for the description of household consumption behaviour. CGE models tend to keep the income and price elasticities of such consumption functions constant over the projection period of their scenarios, but such constant income and price elasticities are most likely too static to describe the evolutions that can be found in consumption behaviour over longer time horizons (Lahiri et al, 2000), for which big changes can take place in welfare, as well as technically and socially (Chai, 2018).

Also, Engel budget share curves are found to be non-linear for many categories of goods and services in both the UK (Barigozzi and Moneta, 2016) and South Africa, for which Bagilet (2017) finds quadratic Engel budget share curves for many product categories. Barigozzi and Moneta (2016) find three functional forms underlying most Engel curves for all types of consumed goods and services in the UK, with one of the three of a quadratic nature and another one of a logarithmic nature. These (independent) functional forms reflect different types of products: necessities, luxury goods or services, and unity (income) elasticity goods. Typically, the necessity component of a products characteristics shows saturation effects, something also identified in other literature (Chai, 2018). For

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<sup>1</sup> Linear Expansion Systems use income and own price elasticities to model shares of goods and services within consumption or expenditure.

example, French households have been found to show expenditure for food decreasing with increasing income over time explained by decreasing prices (Barbier et al. 2016).

Energy is typically considered as a basic need, though certain aspects of energy use – like in the case of flight travel should be considered a luxury product. Literature finds that also the share of energy spending of income is generally found to be lower for deciles with higher incomes. The latter is also found for electricity (Grottera et al., 2018), and for the UK according to Grubb (2018). Indeed, Grubb et al. (2018)’s analysis seems to show for the UK (see their Figure 14 on p.39) that in periods of high energy prices all deciles have energy expenditure shares seem to increase at a virtually similar rate. Fouquet (2014) shows that income elasticities for energy services of households in the UK have varied a lot over time, and were rather below unity in post-WWII history. Consumption of energy furthermore also shows other non-linear behaviour: For example, price elasticities can only explain changes in energy intensity per person to a limited extent because energy efficiency gains turn out to be largely irreversible (Grubb et al, xxxx).

With Engel budget share curves hardly being linear one needs to conclude that it is a mistake to assume income elasticities to be constant for long term economic projections. Indeed, both income elasticities and price elasticities have been demonstrated to vary by living standard category or by *per capita* expenditure. This is illustrated by Dervis et al. (1982) who estimated differentiated income and price elasticities for different social groups with different *per capita* expenditure groups in a developing country and by Bagilet (2017) and Burger et al (2015) who found similar results for categories of *per capita* expenditure in South Africa (see Figure 1).<sup>2</sup>

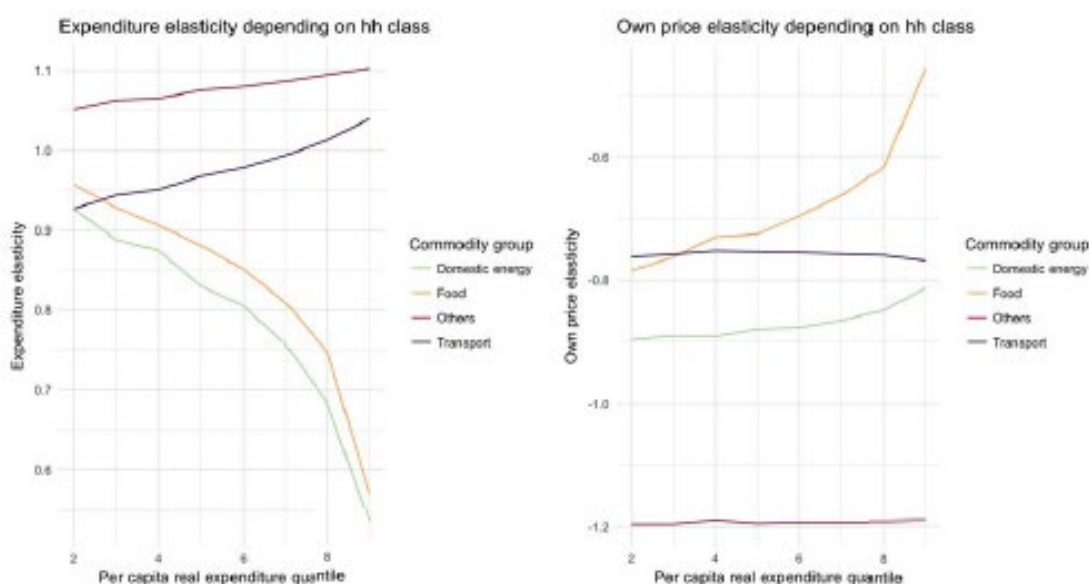


Figure 2.1 – Expenditure and own price elasticity depending on households class

**Figure 1 Expenditure (left) and own price elasticities (right) for South Africa by decile (Source: Bagilet (2017))**

<sup>2</sup> In one application Dervis et al. (1982) propose the use of different income elasticities for different socio-economic groups in a developing economy. However, modelling changes in the number of people per socio-economic group might not be common or easy for CGE models and such groups might also become wealthier while maintaining other socio-economic characteristics.

A first conclusion is therefore that using constant income elasticities proves not to be the right solution to portray household consumption patterns as it makes it too static/undynamic over longer time horizons.<sup>3</sup> Were household behaviour to be represented at a more detailed level than the aggregate household to account for inequality as well as differences in behaviour between e.g. poor, middle class and rich households this would make household descriptions more detailed, and the impact of changes in welfare and in consumption behaviour over time probably quite large.<sup>4</sup>

### 2.3 Improving the long term description of household consumption using “income bands”

Obviously, there are other aspects, besides the standard of living, that shape long term evolution in consumption budgets, besides strong changes in relative prices. Firstly, there are fundamental differences in country expenditure and consumption patterns that can be related to different geographies (Dai et al, 2012), demographic aspects like family size and age and for social or cultural differences (Chai, 2018). Differences in climate play a role for expenses on heating and cooling, and appliance ownership has been found to influence energy use (see for example Grottera et al, 2018). Technical and cultural change have already been mentioned to change consumption budgets (Chai, 2018).

However, the insight that these factors play a role has not led to a predictive or tangible aspect of change in expenditure or consumption under the influence of technical or cultural change. More detailed analysis of how household demand can change over time, and e.g. how people prioritize the “services” obtained through consumption is therefore very welcome. Obviously, to evaluate potential uptake and consumption changes under the influence of technical change our CGE model can benefit from the possibility to link it to a Bottom-Up energy systems model. However, the Bottom-Up model would also need to be constrained by household consumption budgets or priorities in other ways, which therefore need to be represented correctly for the time horizons of our modelling efforts.

This absence of the perfect multi-factorial model to predict change in household consumption does not diminish the need to improve the current representation of impacts of long-term changes in welfare on household consumption. From the above we can conclude that there are certain patterns in the evolution of household spending that are common across countries, and some maybe even over time. Research found changes in living standards to be the principle cause of changes in expenditure and consumption. Chai (2018) summarizes:

*“The best known example of this is Engel’s Law, which states that the share of household spending on food tends to decline as households grow richer. Beyond that, households consume a wider variety of goods (Jackson, 1986), more expensive types of goods and services (Bils and Klenow, 2001A), and the overall dispersion of household spending across different consumption domains tends to grow (Clements and Gao, 2012). Moreover, differences in the spending patterns of affluent households rise (Chai et al., 2015). While low- and middle-class households tend to spend in a relatively similar manner, spending patterns among affluent households differ considerably, likely due to the greater discretionary power these households enjoy in terms of spending. All in all, income effects are typically found to have a much stronger impact*

<sup>3</sup> The same is true for price elasticities, that are also found not to be constant with the standard of living (Burger et al 2015, Bagilet, 2017).

<sup>4</sup> Even for aggregate households the changes in welfare and consumption patterns can be very big within a few decades (Lahiri et al, 2000).

on consumption patterns than price effects (Brown and Deaton, 1972; Lavoie, 1994; Clements et al., 2006).” (Source: Chai, 2018)

Barigozzi and Moneta (2016)’s analysis of British household consumption from 1977 to 2006 supports the idea of making the priority different product categories receive in household consumption depend on a household’ living standard. They find that products represent different degrees of three fundamental product types: necessities, luxury goods or services, and products of unity (income) elasticity. Inter-country comparisons for France and Brazil (Grottera et al, 2018; Barbier et al, 2016) and South African data (Bagilet, 2017; Burger et al, 2015, Mhlongo and Daniels (2013)) also show the mentioned evolution of consumption patterns with changes in living standard or in per capita income (see Clements et al., 2006).

In South Africa, despite poverty and inequality remaining high, household well-being has improved since 2008 as can be observed in both increased household consumption expenditure as well as improved asset ownership (Nthatisi and Wittenberg, 2019). The pattern of household consumption shows a clear correlation to the level of income earned: Figure 2 presents the share of per capita expenditure by commodity group and decile for the case of South Africa in 2008 and 2012 (see also Mhlongo and Daniels (2013)). Spending patterns of lower expenditure deciles in 2012 shifted to looking more like those of higher expenditure declines in 2008. For example, as reported by Mhlongo and Daniels (2013), households in South Africa were spending proportionally less on food in 2008 compared to 2012 even though food remained the most important expenditure item. In their comparison to 2010 data, they found that food shares were larger than in 2008 as income levels were lower highlighting the importance of income changes in consumption patterns.

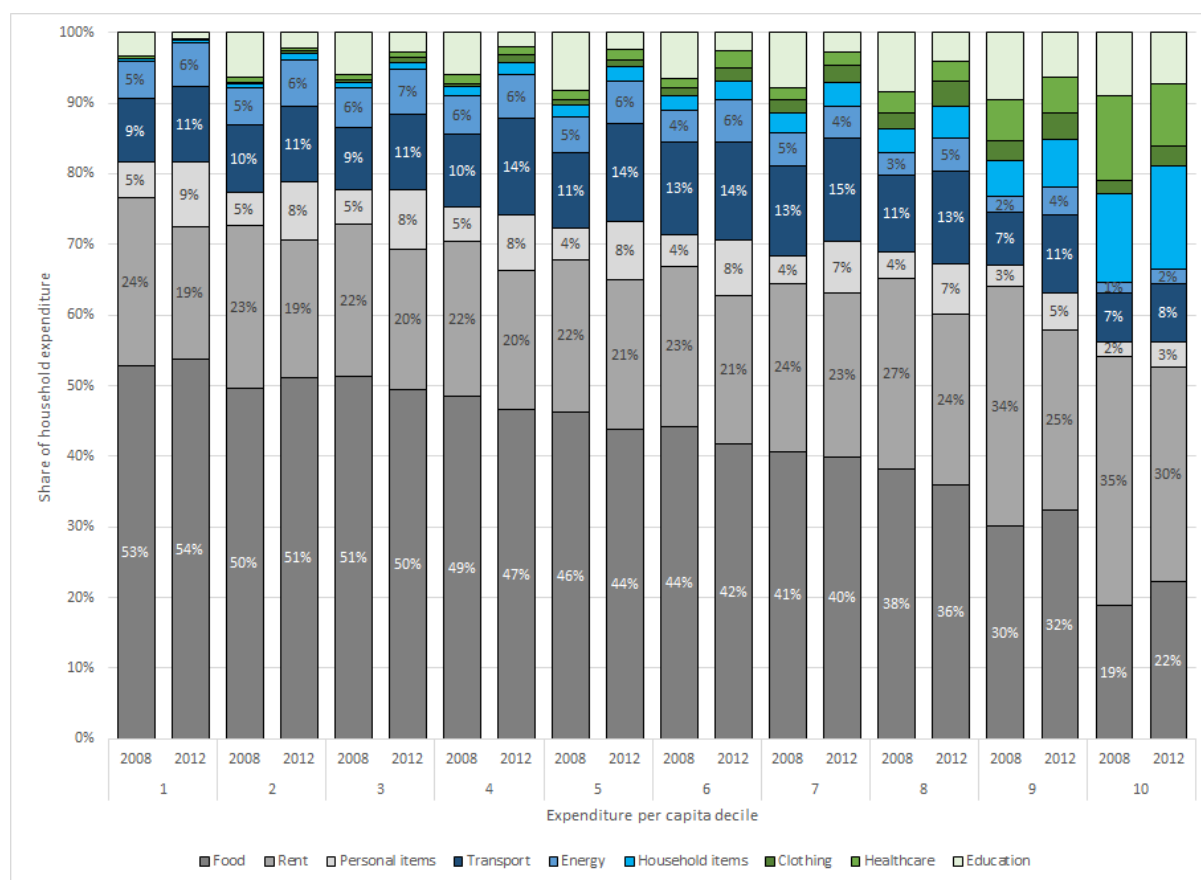
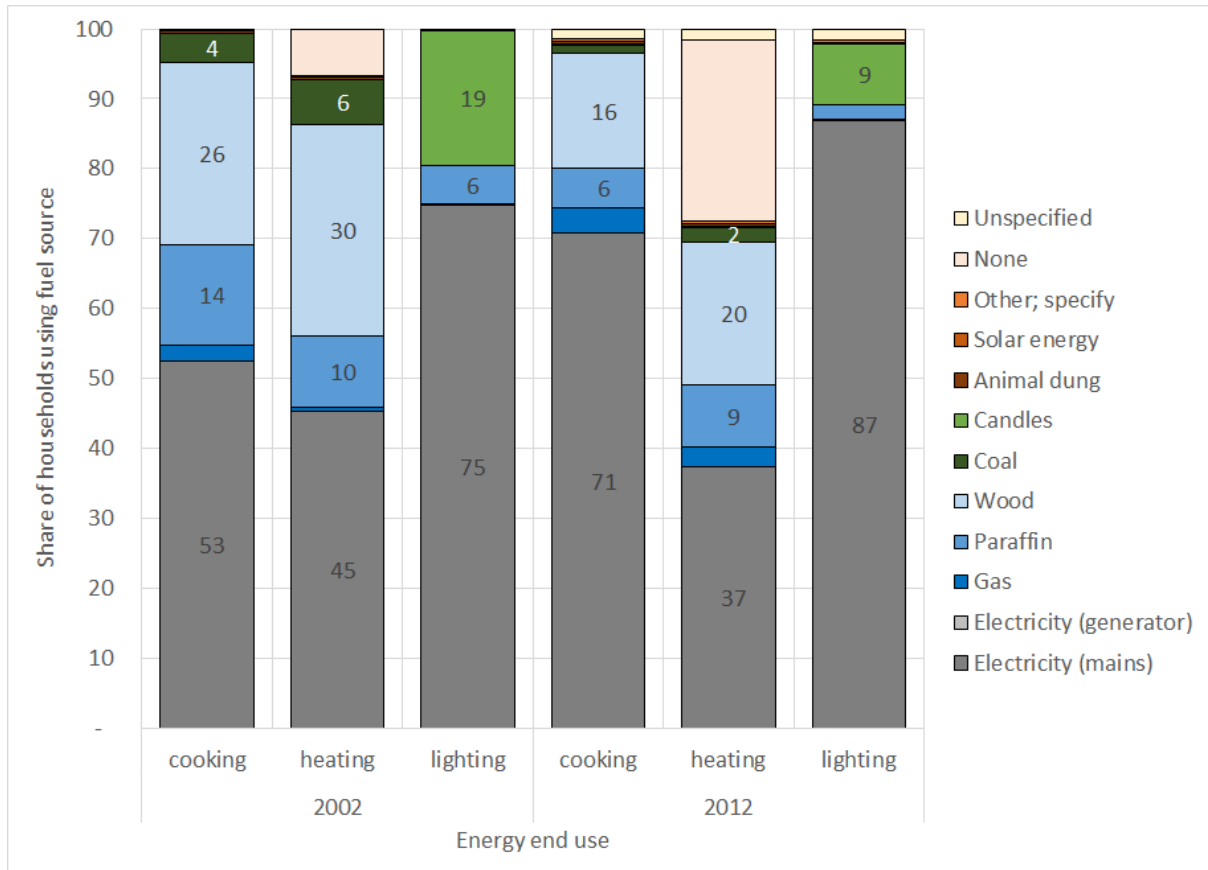


Figure 2 Expenditure by commodity group in 2008 and 2012



**Source: Own calculation using NIDS data as reported by Mhlongo and Daniels (2013)**

Also the share of energy expenditure in total South African household expenditure has changed over the past decade with more households having access to energy options such as electricity - the household electrification rate (access to electricity mains) in South Africa increased from 77% in 2002 to 85% in 2013. As the share of energy expenditure has changed over time, so too has the composition of fuels used. Figure 3 graphically presents the share of households using different fuels to meet three key energy end uses (namely cooking, heating and lighting). As illustrated, between 2002 and 2012 there has been a decrease in the number of households using coal for cooking and heating purposes with the shares of electricity and gas increasing in its stead.



**Figure 3 Composition of fuel use to meet energy end use demands of cooking, heating and lighting**  
**Source: Own calculation using General Household Survey data, StatsSA**

The existence of such patterns makes it interesting to explore what we brand as “income bands” as an approach to describe household behaviour. While it is not unusual to estimate Engel curves, only a few examples are known to the authors of the use of Engel curves to model household consumption behaviour within CGE models, e.g. for Brazil (Grottera et al, 2020) and China (Dai et al, 2012). Their examples show that Engel curves can be very useful to represent lifestyle changes or geography-related lifestyles in a CGE model.

Typically, Engel budget share curves calculate a budget share,  $w$ , of household  $i$  for product  $j$  as a function  $F_j(\cdot)$  of *per capita* income/expenditure or household living standard  $X_i$ , i.e.:

$$w_{i,j} = F_j(X_i)$$

Instead, in our model we choose a more discrete approach to calculating new consumption profiles in which we calibrate a set of consumption profiles by level of *per capita* consumption – which we call “income bands” - known through our hybrid SAM, and we obtain future consumption by making linear combinations of the income bands that are closest to a household category’s *per capita* consumption budget. This procedure is explained in detail in section 4.3 below.

### 3 MODELLING AND CALIBRATION OF HOUSEHOLD INCOME BANDS IN THE SOUTH AFRICAN GENERAL EQUILIBRIUM MODEL

#### 3.1 The South African CGE model - SAGE

The SAGE model is a dynamic recursive CGE model for South Africa. The model, developed by UNU-WIDER for use by the South African National Treasury, is based on the generic static and dynamic CGE models described in Lofgren et al. (2002) and Diao and Thurlow (2012). While used independently for an array of policy analysis, the energy SAGE (or eSAGE) model is also used in the linked energy-economic model, SATIMGE, at the University of Cape Town to enable more robust energy policy analysis with macroeconomic impact assessments (see Arndt et al. 2016, and Merven et al. 2017; 2018; 2019a; 2019b).

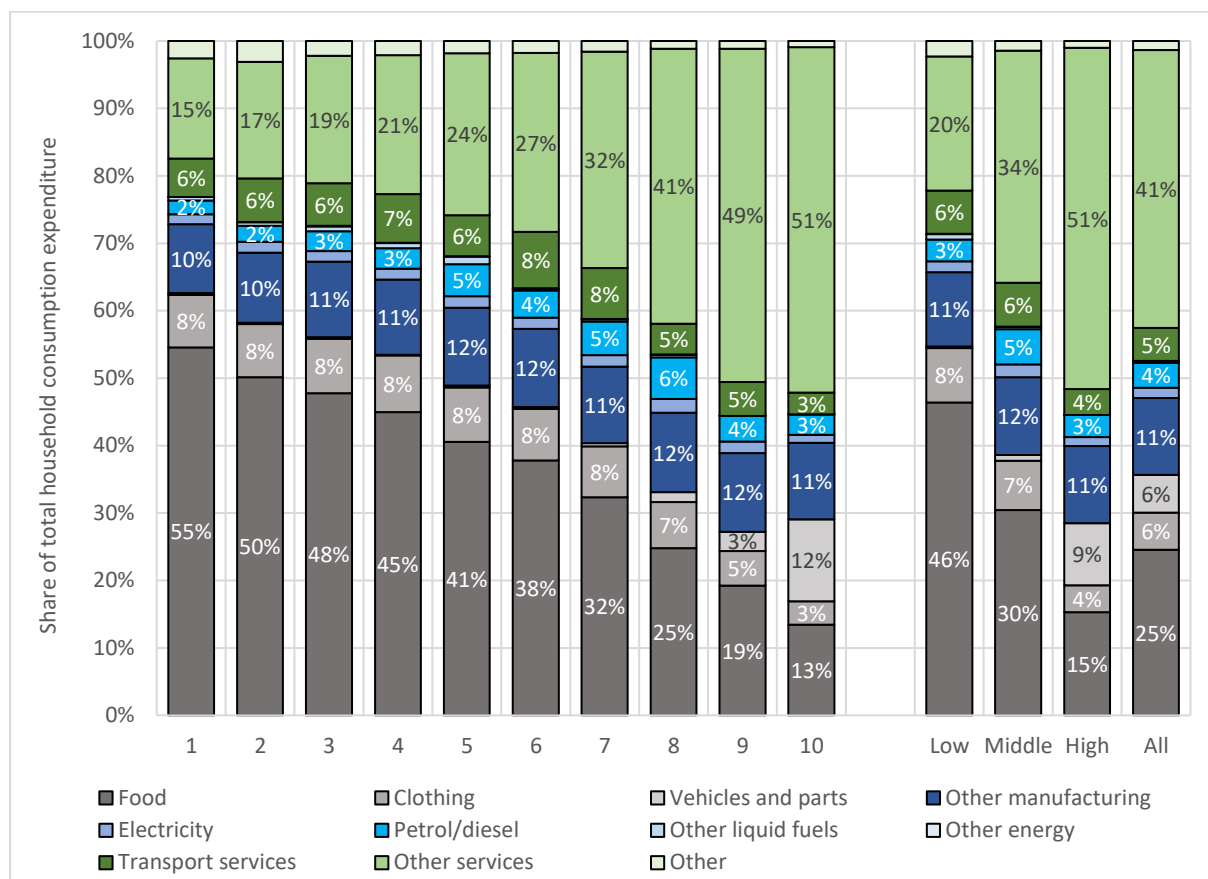
SAGE is calibrated to the 2012 social accounting matrix (SAM) for South Africa (see van Seventer et al., 2016). For alignment with the energy model in SATIMGE, the 2012 SAM is hybridised with energy data for the country such that the physical volumes of energy consumption are included in the model. The 2012 SAM consists of 51 activities and 54 commodities. It includes 4 categories of labour which distinguishes between skill level (determined by education). To further highlight the differences between the energy and non-energy sectors capital is disaggregated between energy and non-energy capital. Households are divided into deciles with the top decile split into 5 groups to capture the large differences in income. However, for this exercise, only the household decile groups will be used. Household income and consumption patterns in the base year are determined by national household survey data, specifically the 2008/9 Living Conditions Survey.

Household consumption covers marketed commodities, purchased at market prices that include commodity taxes and transaction costs. Household consumption evolved according to LES demand functions, derived from the maximization of a Stone-Geary utility function subject to a household budget constraint and allows for the identification of supernumerary household income that ensures a minimum level of consumption. Given prices and incomes, these demand functions define households’ real consumption of each commodity in the ‘within period’ of the CGE model solve (Lofgren et al., 2002; Thurlow, 2004). In the case of South Africa, the Frisch elasticity is set to -1 due to a lack of information. As a result, final household demand for each commodity is assumed to be a fixed share of aggregate institutional spending. Therefore, expenditure shares for each commodity are fixed and do not adjust in response to changes in relative prices. This specification also does not allow household consumption patterns to adjust to changes in household incomes. While suited to short- and medium-term analysis, as substitution possibilities are likely to be limited, such an approach is not suitable for longer term analysis as discussed in Section 2.2.

#### 3.2 Household consumption expenditure in the base year

Figure 4 presents household consumption spending in the base year by decile and household group. As expected, basic goods and services comprise a large share of low-income household consumption with the share decreasing as household’s income rise. Food is the largest expenditure item of

households in the Low group, which comprise expenditure deciles 1 to 5. The share of food decreases as household income increases with the High group (deciles 9 and 10) spending only 15% of its total consumption expenditure on food. The Low household group also consumes more transport services (primarily public transport) than the High household group which uses private transport as illustrated by the larger share of expenditure on vehicles and parts. Households in the High group spend most of their consumption expenditure on services, which account for more than half of consumption expenditure.

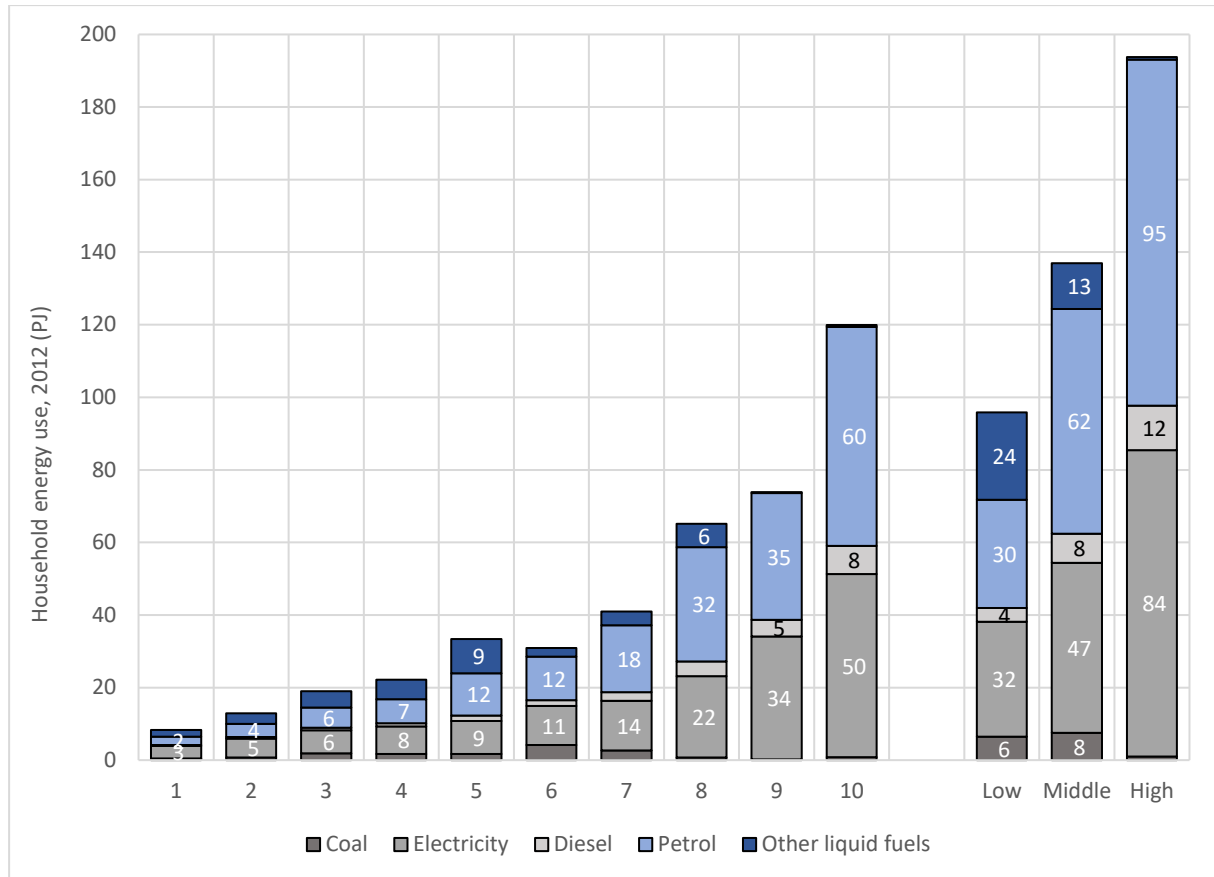


**Figure 4 Base year household consumption shares**

Source: 2012 SAM

Note: Other services include trade, hotel and accommodation, communication, financial and business, government and other personal and community services including health care and education

High household energy consumption goods, as reflected in Figure 3, seem smaller than that of Middle and Low household groups. This is, however, due to the larger levels of income earned by the High household group. When looking at household energy consumption volumes (see Figure 5), the High household group consumes 1.4 and 2 times more petajoules (PJ) than the Middle and Low household groups respectively. High household energy consumption is comprised primarily of petrol and electricity which make up more than 90% of their total energy consumption. This is different from the Low household group, which also experiences large shares of other liquid fuel consumption (primarily paraffin) and who also consumes coal. These trends suggest that accounting for behavioural changes linked to increasing income levels, would alter the composition of energy demand in South Africa and hence the supply responses.



**Figure 5 Base year household energy consumption**

Source: eSAGE

### 3.3 Methodological changes to eSAGE

In the BudSharAdj, scenarios, the budget shares  $s_{h,c}(t)$  for each household decile group  $h$  for each commodity  $c$ , are modified over time  $t$ , given projected real income  $y_h(t)$  and the base year budget shares  $s_{h,c}(t_0)$ , which is used as a template for budget shares, by simple linear interpolation. This is done in four steps as presented below. Prior to these changes the eSAGE household consumption function is transformed from an LES to Cobb Douglas. As a result household consumption shares are fixed.

1. Calculate “income distances”
2. Identify “closest neighbours” (lower and upper)
3. Calculate “weightings” based on distance to “closest neighbours”
4. Calculate new shares based on calculated “weightings”

#### **Step 1: Calculate “income distances”**

“Income distance”,  $d_{h,h'}(t)$  is calculated for each income group  $h$  as the difference between the group’s real income level  $y_h(t)$  at time  $t$  and the income levels of all the 10 decile groups in the base year  $t_0$ .

$$d_{h,h'}(t) = y_h(t) - y_{h'}(t_0).$$

#### **Step 2: Identify closest neighbours**

The closest *lower* neighbour  $hl$  and its distance from  $y_h(t)$  is calculated as

$$d_{h,hl}(t) = \min \{d_{h,h'}(t), \forall d_{h,h'}(t) \geq 0\},$$

The closest *upper* neighbour  $hu$  and its distance from  $y_h(t)$  is calculated as

$$d_{h,hu}(t) = -1 \times \min \{d_{h,h'}(t), \forall d_{h,h'}(t) < 0\}.$$

#### **Step 3: Calculate “weightings” based on distance to “closest neighbours”**

The budget shares weighting  $w_{h,hl}(t)$  could be calculated in different ways as a function of the distance. In this paper we adopt a simple linear approach, where:

$$w_{h,hl}(t) = \frac{d_{h,hu}(t)}{d_{h,hl}(t) + d_{h,hu}(t)},$$

and

$$w_{h,hu}(t) = 1 - w_{h,hl}(t).$$

#### **Step 4: Calculate new shares based on calculated “weightings”**

The new budget shares  $s_{h,c}(t)$  for each household decile group  $h$  for each commodity  $c$  is then simply calculated as follows:

$$s_{h,c}(t) = w_{h,hl}(t) \cdot s_{hl,c}(t_0) + w_{h,hu}(t) \cdot s_{hu,c}(t_0), \forall y_h(t) < y_{10}(t_0).$$

If the income for group  $h$  is greater or equal to the highest income decile income level, which here is the 10<sup>th</sup> income decile, then this group will only have a closest *lower* neighbour, and no *upper* neighbour, and will take on the budget shares of the highest income decile group,

$$s_{h,c}(t) = s_{10,c}(t_0), \forall y_h(t) \geq y_{10}(t_0).$$

However, one could potentially improve things by including the budget shares of higher income groups as “templates” for the “distance” and “weighting” calculations. This is left for future work.

## 4 IMPACT OF NEW APPROACH

This section assesses the impact of the new approach to modelling household consumption in the CGE model. We compare two scenarios to quantify the impact of altering household consumption patterns over time. The scenarios are one in which the budget shares remain fixed over time (i.e. Reference) and the second in which they are adjusted to account for changes in real income (i.e. BudShrAdj).

The model is run from 2012 to 2050 and scenario 'Reference' is treated as the reference case to which results from the BudShrAdj scenario is compared. The growth rate in the Reference scenario is targeted to meet actual growth between 2012 and 2017, whilst growth between 2018 and 2050 are based on a combination of projections from the 2018 Medium-Term Policy Statement (National Treasury, 2018), October 2018 World Economic Outlook (IMF, 2018) and the Department of Energy's planning average annual growth rate of ~3.0% to 2050.

Exogenous assumptions are the same in the Reference and BudShrAdj scenarios. The supply of labour is assumed to increase in line with population growth (~0.89%, UNEP 2016), although upward sloping labour supply curves are assumed for all skill categories, given the long-term nature of the analysis, which means that increases in wages resulting from higher labour demand increases the labour force participation rate. Government spending and foreign savings increase by 3% per annum, although the increase in foreign savings decreases over time as debt is repaid. Total factor productivity is adjusted in the Reference scenario to reach the real GDP growth forecasts discussed above.

The macroeconomic closures included are aligned to the stylized facts for South Africa: investment is driven by the total level of savings in the economy although investment and government expenditure as shares in total absorption are fixed (balanced savings-investment closure); government savings are flexible and no fiscal rule is imposed; the exchange rate is flexible with the level of foreign savings (in foreign currency) rising by an exogenous growth rate which decreases over time as South Africa repays its foreign debt. Existing capital is assumed to be fully employed and activity specific. A least cost optimal energy pathway from the South African Times model is included. The latter provides information on energy production and investment; and electricity prices.

### 4.1 Changes in household consumption expenditure shares

Figure 6 presents the consumption expenditure shares for all households in 2050 for the BudAdjShr scenario. Under the Reference scenario, household consumption shares remain fixed to the 2012 values. Real average annual household income increases by 2.8% in both the Reference and BudAdjShr scenarios between 2012 and 2050. The pattern of total household consumption expenditure shifts over time with households spending smaller shares of their budgets on basic goods such as food, clothing and transport services, primarily public transport. The largest decline in consumption share is for food, which includes both agriculture and processed foods.

Consumption shares of manufactured items and other services increases over time. In the case of manufactured items, the increase is driven by large ticket items such as increased vehicle purchases. The consumption shares of select manufactured goods such as chemicals, paper, and electrical machinery declines. All service sub-categories experience an increase in share of consumption with business, financial and other services (which include education and healthcare) experiencing the largest share increases. For certain goods and services, a humped shape pattern is observed in the change in commodity consumption share. A clear example of this is energy, where the share of expenditure increases to 2025 but thereafter declines. A similar pattern is also experienced in manufactured sub-categories such as furniture.

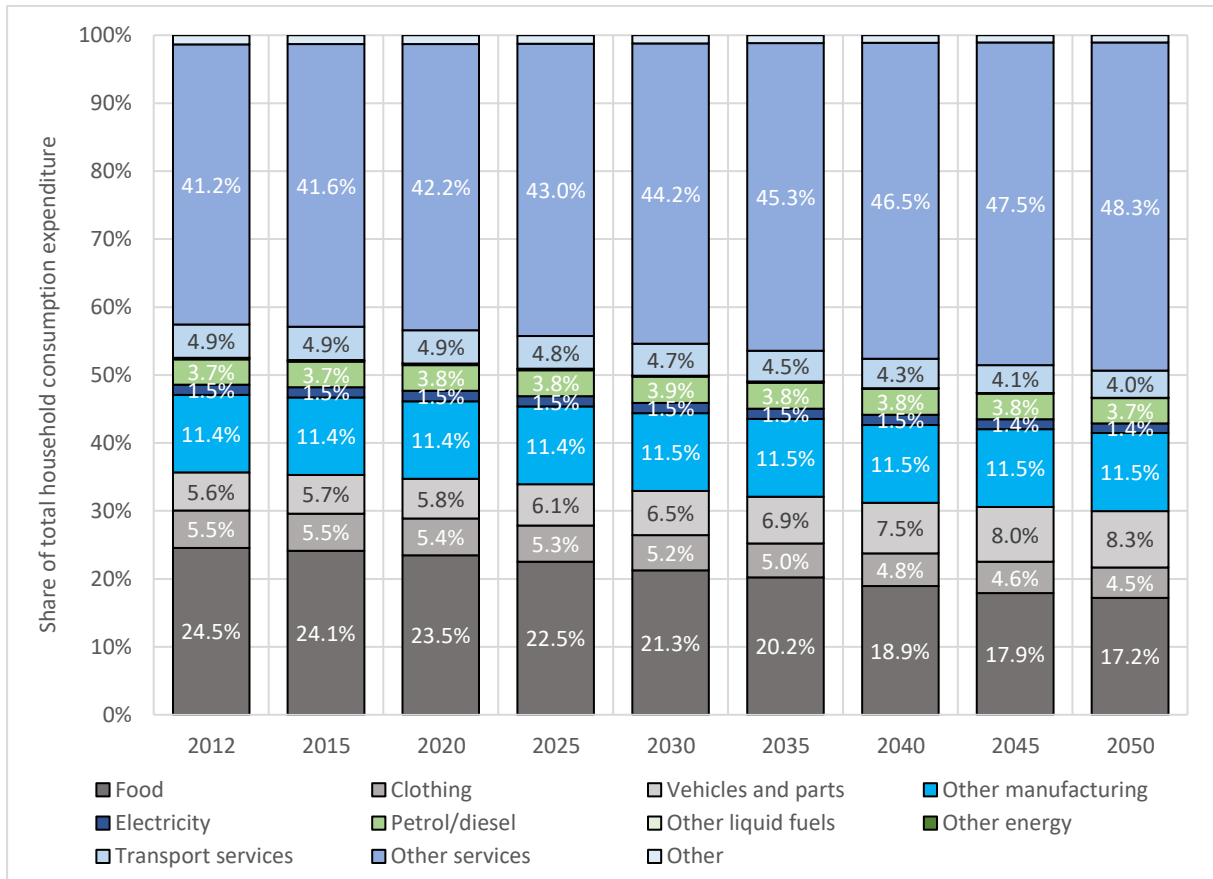
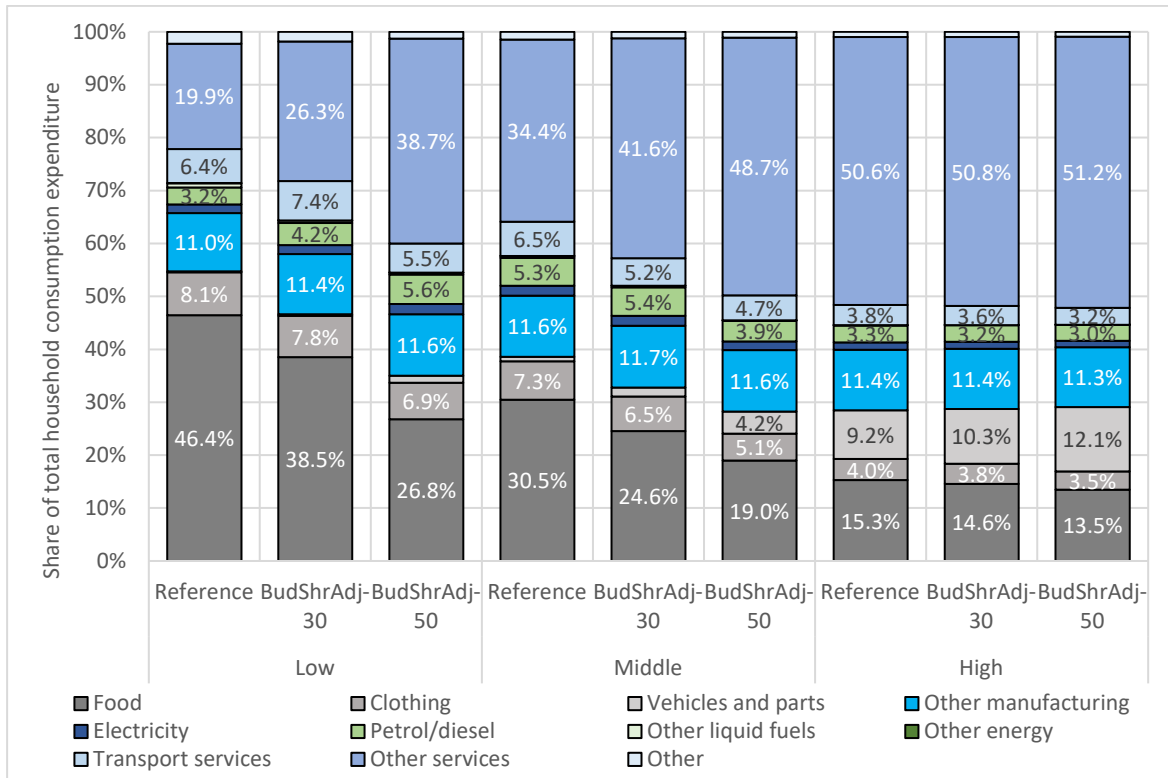


Figure 6 Household consumption shares - all households, 2012-2050

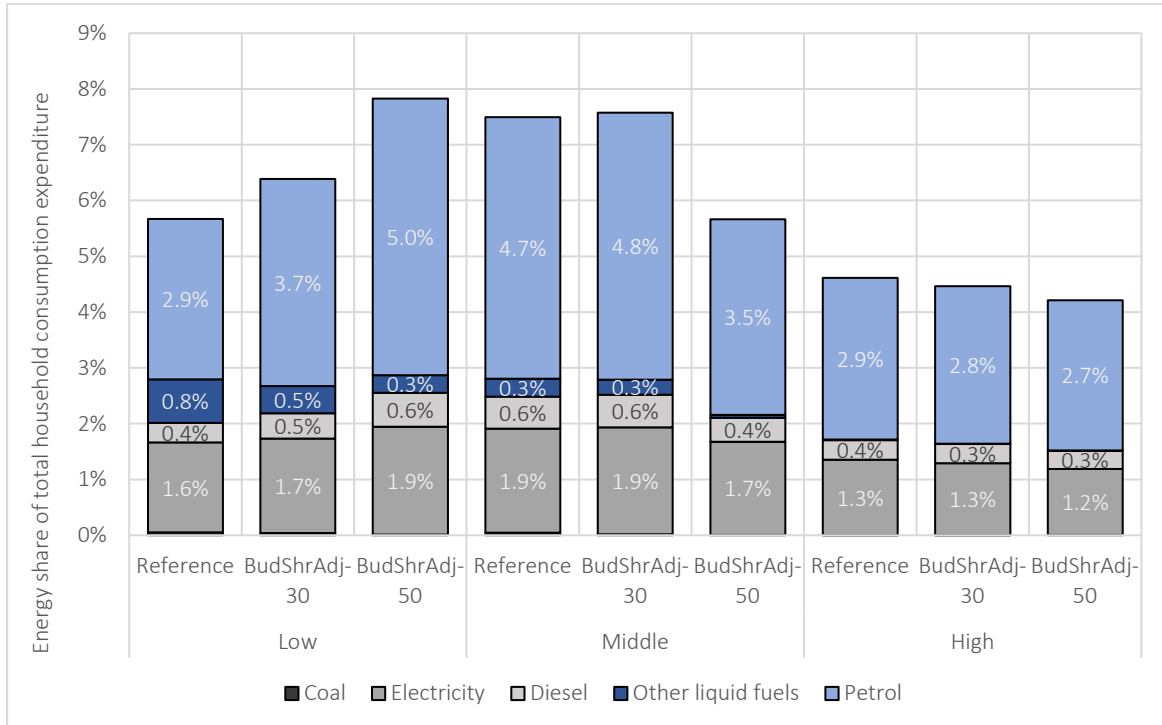
Source: eSAGE results

Figure 7 illustrates the change in consumption patterns for three groups of households. The figure presents 2012 consumption shares for each household in the Reference scenario which is also the 2030 and 2050 consumption shares as they do not adjust over time. Consumption shares in 2030 and 2050 are presented for the BudShrAdj scenario. Low, Middle and High household groups are classified as income deciles 1 to 5; 6 to 8; and 9 to 10 respectively.

As seen in the overall household trend in Figure 6, the share consumption of basic commodities (i.e. food and clothing) declines across all household groups. Unlike Middle and High household groups, however, the Low group experiences an increase in energy consumption shares over the full period. The increase is driven by rising shares of petrol, diesel and electricity which replaces the use of fuels like coal and paraffin (see Figure 8). The increased use of other commodities such as motor vehicles and machinery also contributes to the rise in the household group’s energy share. The share of transport services in the Low household group increases to 2030 but thereafter declines as households on the upper end of the group (namely deciles 3 to 5) switch to using more private transport. The Middle household group experiences a marginal increase in their energy consumption share in 2030, due to increased petrol and diesel use, but this decreases to 2050. The use of other liquid fuels, which comprise largely of paraffin, decreases significantly in the Low and Middle household groups. Similarly coal consumption, although a small share of consumption expenditure, declines reaching almost zero by 2050.



**Figure 7 Household consumption shares, 2030 and 2050**  
Source: eSAGE results



**Figure 8 Household energy consumption shares, 2030 and 2050**  
Source: eSAGE results



## 4.2 Impacts on sector production and gross value added

The shift in household consumption between commodities has implications for production as household consumption accounts for nearly half of final demand in South Africa (StatsSA, 2012). Table 1 below shows the change in the level of real GDP and employment in the BudShrAdj scenario relative to the Reference case in which household budget shares do not change.

Sectors' producing commodities which decrease as a share of household consumption budgets experience a decrease in real GDP relative to the Reference scenario. This is seen by the decrease in food, other agriculture, clothing, energy and transport real GDP levels relative to the Reference case. The largest decline is in the food and other agriculture production sectors. Crop and livestock production declines by 12.8% relative to the Reference scenario while processed food production decreases by 13.1%. While the level of food production is lower in the BudShrAdj scenario, the sector still experiences growth in real GDP and employment of 2.4% and 2.2% per annum respectively, although this is 0.8 and 0.9 percentage points lower than in the Reference scenario. Lower production levels lead to job losses in the respective sectors.

In turn, sector's producing commodities with rising shares experience an expansion in production. These are primarily in the Manufacturing and Services sectors. As expected, given the changes in budget share, the motor vehicle and financial services sectors experiences the largest increase in real GDP within the Manufacturing and Other services sectors. Employment within these sectors also increase.

On aggregate, the level of total real GDP is slightly higher in the BudShrAdj scenario by 2050 with corresponding higher employment levels. In terms of average annual growth, total real GDP grows at 2.77% over the period – 0.01 percentage points higher than in the Reference scenario with an extra 3,000 jobs created. Jobs are created for secondary and tertiary educated workers (i.e. Grade 10 and more) whilst job losses are experienced by low skilled works with primary and middle school levels of education (i.e. less than Grade 10).

**Table 1 Change in real GDP and employment level by sector, 2030 and 2050**

Sector	2030		2050	
	Change in level of			
	GDP (%)	Employment ('000s)	GDP (%)	Employment ('000s)
Food	-10.3	-235	-25.0	-898
Clothing	-3.0	-11	-10.6	-72
Vehicles and parts	4.3	6	12.8	35
Other manufacturing	-0.2	5	-0.1	25
Electricity	-0.4	0	-1.4	-2
Petroleum	0.0	0	0.0	0
Other energy	0.0	0	-0.1	0
Transport services	-1.4	-9	-6.1	-82
Other services	1.2	224	3.6	931
Other	0.2	13	1.9	67
Total GDP	0.0	-7	0.3	3

**Source: eSAGE results**

Figure 9 below presents the change in the structure of GDP between the Reference and BudShrAdj scenarios. The shares of Manufacturing and Services sectors increases between the scenarios while

that of Food and Energy decreases. The decline in the share of Energy's share of GDP suggests that the energy intensity of the economy is lower in the BudShrAdj scenario relative to the Reference scenario.

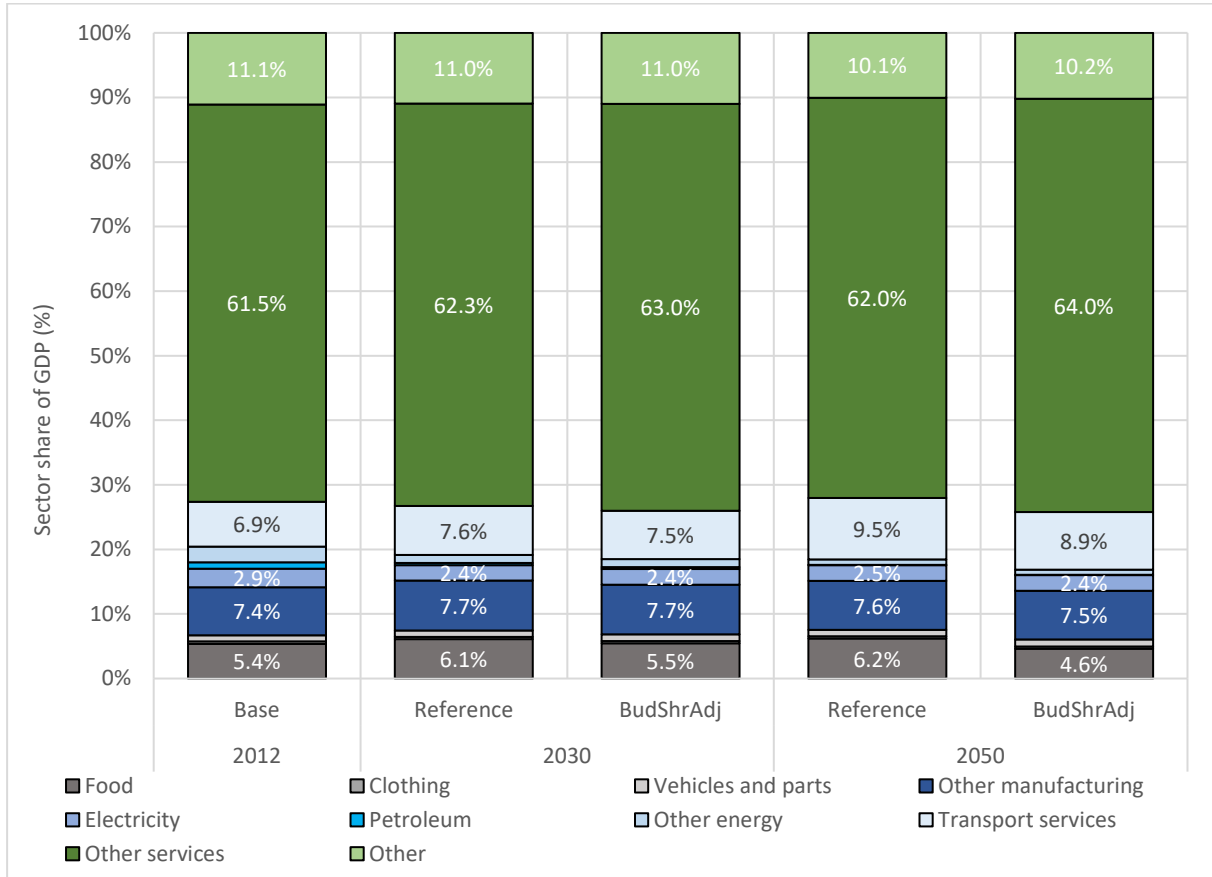
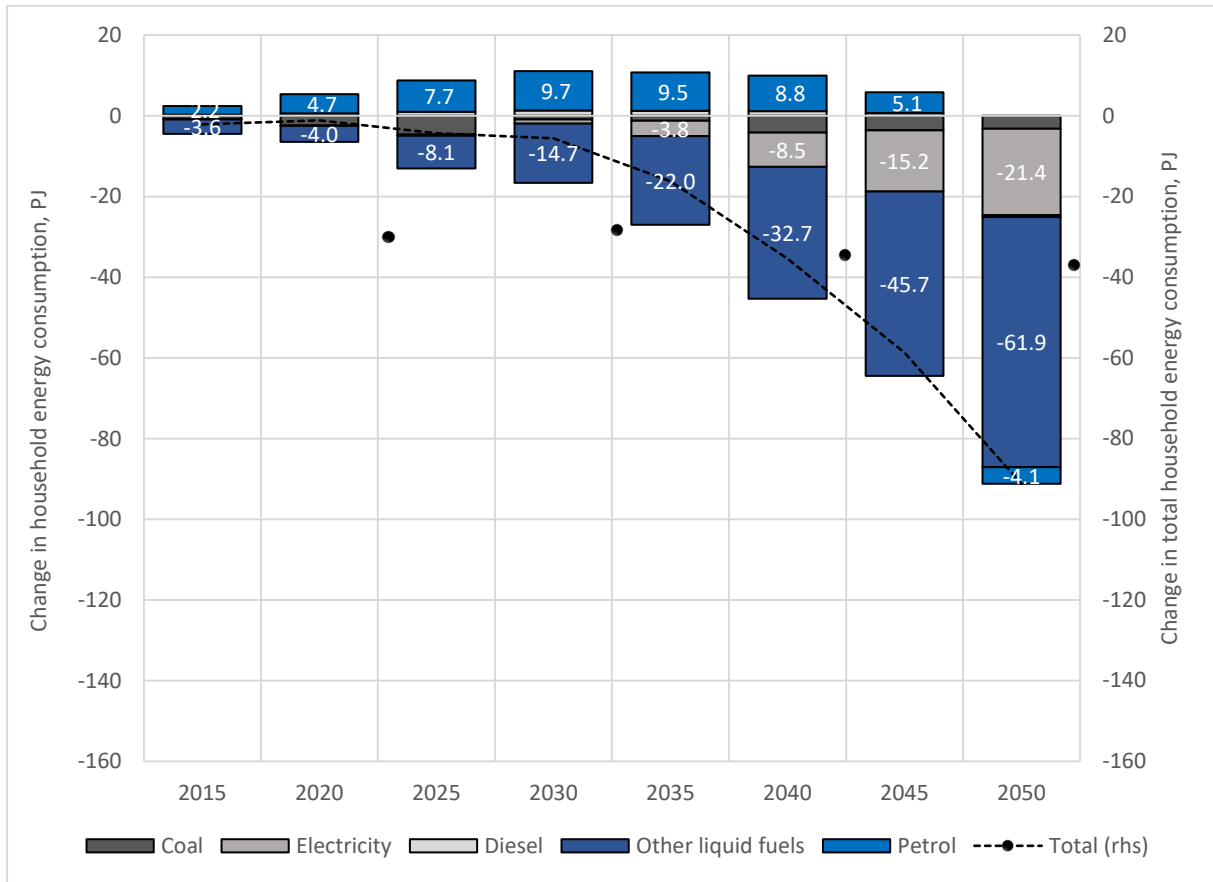


Figure 9 Real sector GDP as a share of total real GDP, 2012-2050

Source: eSAGE results

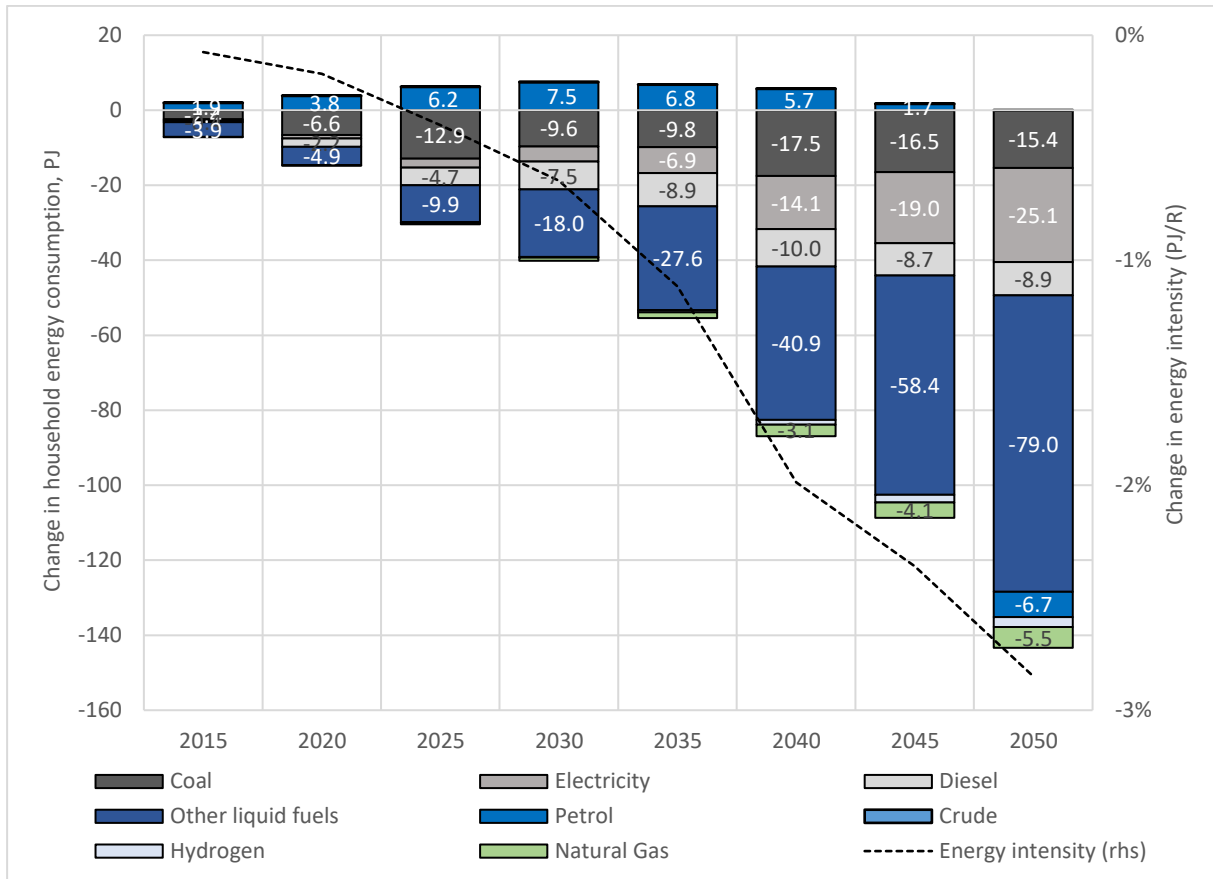
### 4.3 Implications for planning: the case of energy

Changing household consumption patterns has important implications for infrastructure planning, particularly for energy capacity, as it not only changes households' demand for goods and services but also that of the production sector. Figure 10 presents the difference in total household energy demand between the BudShrAdj and Reference scenarios. The decline in consumption share allocation to energy in the BudShrAdj scenario results in a decline in total energy purchased by households. Relative to the Reference scenario, residential energy demand is 91PJ lower in the BudShrAdj scenario. The decline in demand occurs across all energy groups, although the largest decline is for other liquid fuels, which for households is mainly paraffin, followed by electricity. The demand for petrol is higher than in the Reference scenario over the period due to the increase in private transport use.



**Figure 10 Difference in household energy consumption (relative to Reference) by fuel, PJ**  
**Source: eSAGE results**

Figure 11 presents the change in total energy use in the economy and energy intensity of real GDP (PJ/R) relative to the Reference scenario. As presented above, changing household consumption baskets affect sector production and the structure of the economy. This in turn has implications for intermediate goods and services demanded. In the case of energy, the change in sector structure in the economy results in a decline in energy demanded. Total energy demanded is 143 PJ lower by 2050 in the BudShrAdj scenario – 52 PJ more than the decline in residential demand. The largest contributors to the decline in total demand is less consumption of other liquid fuels, electricity and coal. The energy intensity of real GDP also declines as a result of the changes in household consumption patterns, falling by 2.8% relative to the Reference case value.



**Figure 11 Difference in total energy consumption and energy intensity (relative to Reference)**  
**Source: eSAGE results**

The decline in energy demand demonstrated here has implications for energy planning as the level of capacity needed for supply to meet demand may not be as large as assumed in the modelling done here. Furthermore, the composition of energy needed also changes. This also has implications for the flow of investment funds between energy and non-energy sectors and hence the ability of non-energy sectors to expand and contribute to economic growth. While this falls outside the scope of this paper, a further assessment of the changes in demand in the linked energy-economic model, SATIMGE, is needed.

## 5 DISCUSSION AND FURTHER WORK

This paper presents an alternative and arguably better approach to modelling long term household consumption in the eSAGE model. The paper finds that adjusting shares over time to reflect lifestyle changes based on income groups affects both direct and indirect demands for goods and services. Indirect demand is affected by the change in the production structure of the economy. When accounting for income related lifestyle changes, the South African economy becomes more services orientated. This has implications for employment (particularly by skill level), energy demand, the energy intensity of GDP and by extension (potentially) emissions.

Energy demand is found to be lower when changing budget shares are considered. Furthermore, the composition of energy demanded is also found to change with coal and paraffin consumption declining. As mentioned, this may have implications for the level of energy investment needed in the country as well as the price paid for this energy. If less energy investment is needed, this frees up investment funds for use elsewhere in the economy which may have a positive impact on economic growth and employment. This however needs to be assessed in the linked energy-economic model, SATIMGE.

This paper presents a first attempt at accounting for long term consumption behaviour in CGE models. As such the scope of changes made to the model has been narrow. Further work is needed to extend the changes in consumption shares to changes in expenditure shares which include spending on items such as savings, remittances and taxes. The approach presented in this paper also uses the calibration year as the reference point for adjusting shares. One may find that instead a dynamic approach is needed in which the household share profile from the previous year or an average of several years is needed to properly capture changes in household lifestyles. This remains an area of future research.

Cobb Douglas utility functions are criticized for being static (in terms of expenditure shares) but also because they fail to take into account the behavioural response to price changes. The approach taken here suffers from the same criticism. Considering ways to account for behavioural responses to price changes is needed.

Lastly, the paper focuses on household consumption expenditure only and does not account for the similar adjustments that may take place on the income side. Changes in education levels and incomes or wealth, will affect where households source their income. In South Africa, one would suspect that over time lower income households become more educated and/or skilled with members from these households becoming increasingly employed in higher skilled jobs which offer higher wages. This would also affect the need for social welfare assistance which would have implications for other government spending or tax policy. Similarly, middle income households may become owners of capital allowing for increased diversification of income streams. Accounting for these changes may result in more rapid shifts in the economic structure.

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## About the authors

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Bruno Merven leads the Energy Systems Research Group at the University of Cape Town. Faaiga Hartley is a researcher within the group and Jules Schers is a visiting researcher from Expertise France. All are involved in the development and maintenance of the Group's energy, economic and linked energy-economic model.

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE  
A world free of hunger and malnutrition  
1201 Eye Street, NW | Washington, DC 20005-3915 USA  
T: +1.202.862.5600 | F: +1.202.862.5606  
Email: [ifpri@cgiar.org](mailto:ifpri@cgiar.org) | [www.ifpri.org](http://www.ifpri.org)

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